S3: Fundamentals of Touch Technologies and Applications

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June 3, 2012

PDF File Download: *www.walkermobile.com/SID_2012_Short_Course_S3.pdf*

Agenda…1

❖ **Course structure**

Topic	Allocation	
Introduction		11%
Main Content		84%
Capacitive – 1	28%	
Resistive – 2	12%	
Acoustic – 3	13%	
Optical – 4	28%	
Embedded – 5	13%	
Other – 6	6%	
Wrap-Up		5%
TOTAL	**100%**	**100%**

➔ **6** core touch technologies with **19** flavors and a total of **40** variations

Agenda…2

- **Admin** [4]
- **Introduction** [6]
- **Multi-Touch** [10]
- **Capacitive** [41]
  - Projected Capacitive (P-Cap) [27]
  - ITO Replacement Materials [8]
  - Surface Capacitive [6]
- **Resistive** [18]
  - Analog Resistive [7]
  - Analog Multi-Touch Resistive [11]

[ ] = Number of content slides in each section

Agenda…3

- **Acoustic** [19]
  - Surface Acoustic Wave (SAW) [9]
  - Acoustic Pulse Recognition (APR by Elo TouchSystems) [5]
  - Dispersive Signal Technology (DST by 3M Touch Systems) [5]
- **Optical** [42]
  - Traditional Infrared [10]
  - “High-Finger-Count” Multi-Touch Infrared [6]
  - Waveguide Infrared (DVT by RPO) [5]
  - Camera-Based [10]
  - Planar Scatter Detection (PSD) [4]
  - Vision-Based [7]

[ ] = Number of content slides in each section

Agenda…4

- **Embedded** [20]
  - In-Cell Light Sensing
  - In-Cell Pressed Capacitive
  - In-Cell Self-Capacitive
  - In-Cell Voltage-Sensing
  - On-Cell P-Cap
  - Hybrid On-Cell/In-Cell P-Cap
  - On-Cell Analog Resistive
- **Other** [9]
  - Force-Sensing [5]
  - Electromagnetic Resonance (EMR) Pen Digitizer [4]
- **Comparing Touch Technologies** [4]
- **Conclusions** [5]

[ ] = Number of content slides in each section

Introduction

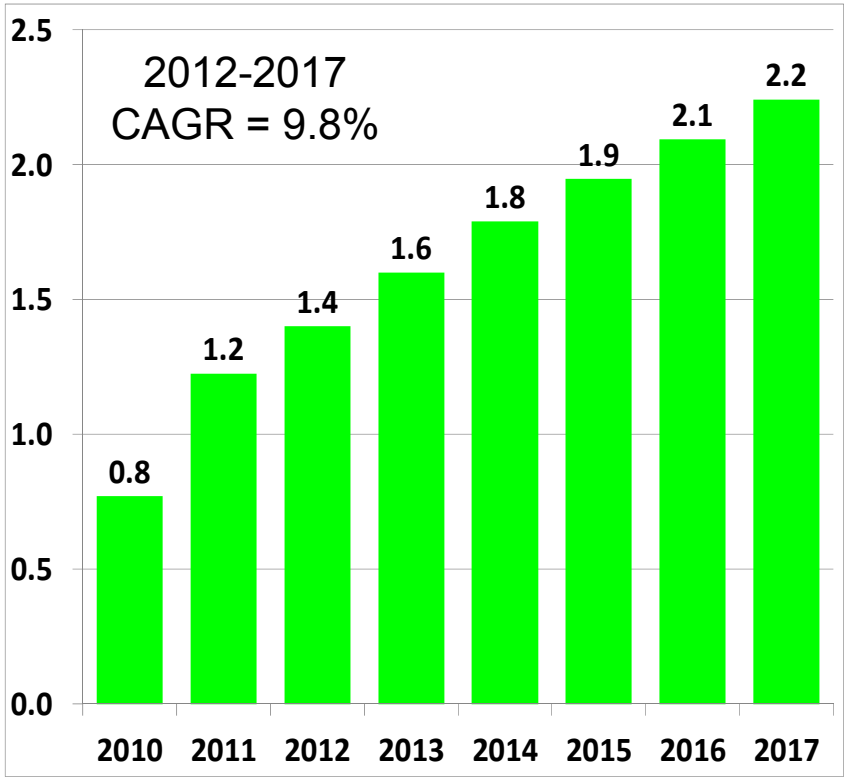
Source: Elo TouchSystems

Two Basic Categories of Touch

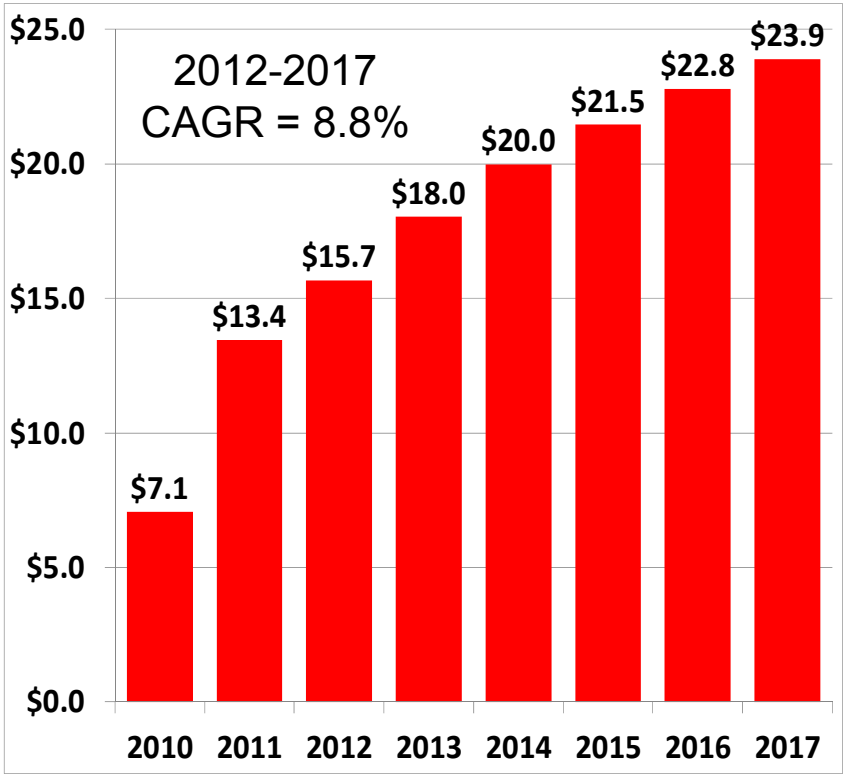
- **Opaque touch**
  - Dominated by the controller chip suppliers
    - Atmel, Cypress, Synaptics, etc.
    - One technology (projected capacitive)
    - Sensor is typically developed by the device OEM
  - Notebook touchpads are the highest-revenue application
    - Synaptics, Alps and Elan have the majority of the market
    - Sensors are all two-layer projected capacitive
  - *There is no further discussion of opaque touch in this course*
- **Transparent touch on top of a display**
  - Dominated by the touch module manufacturers (150+ worldwide)
  - 6 fundamental technologies with 20+ variations

Overall Touchscreen Market 2010-2017

Units (Billions)



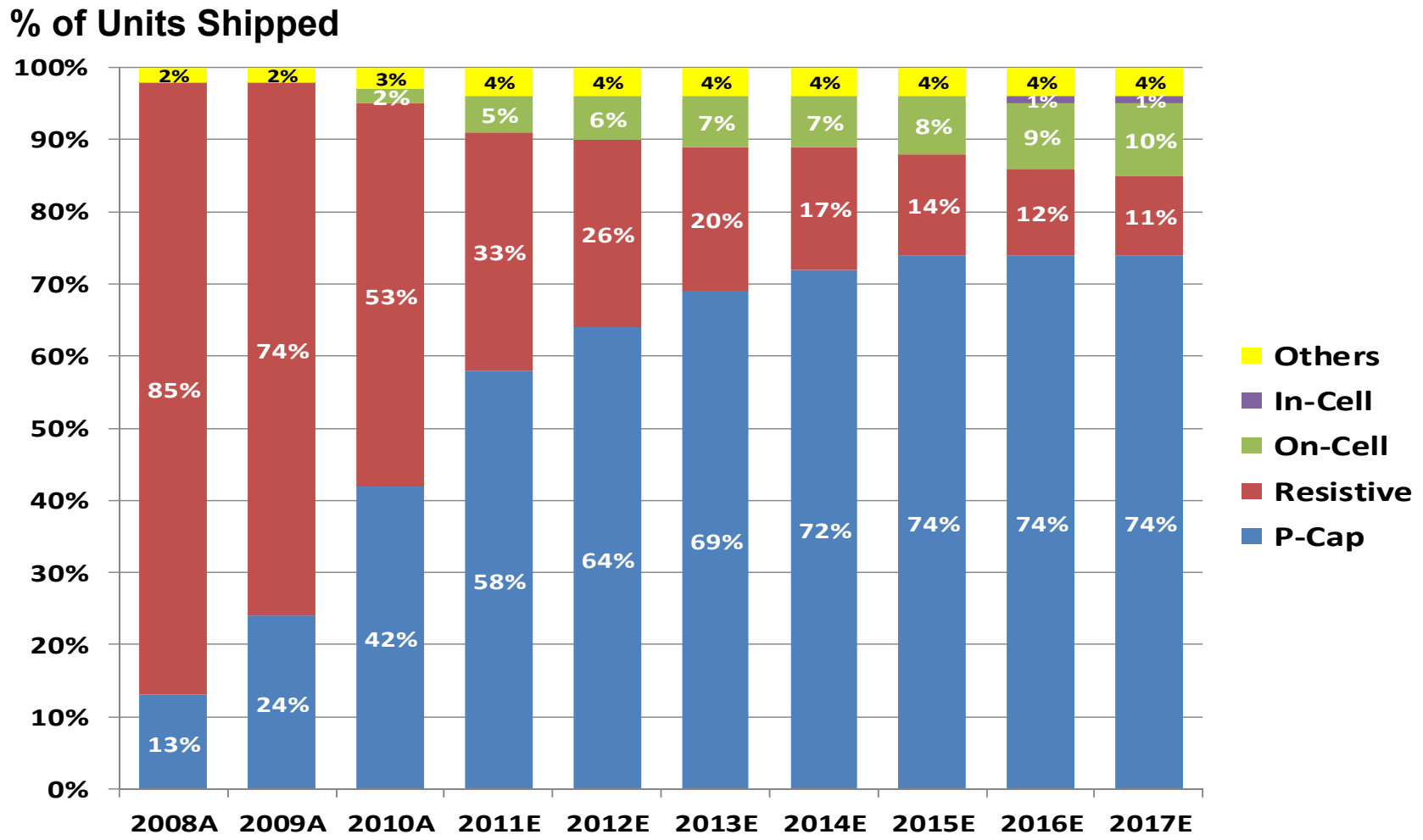
Revenue ($Billions)



Source: DisplaySearch "Touch-Panel Market Analysis 2011Annual Report" (May 2011)

Touch in 2007 was 308M units & $1.3B…

Touchscreen Market 2008-2017 by Technology (Units)



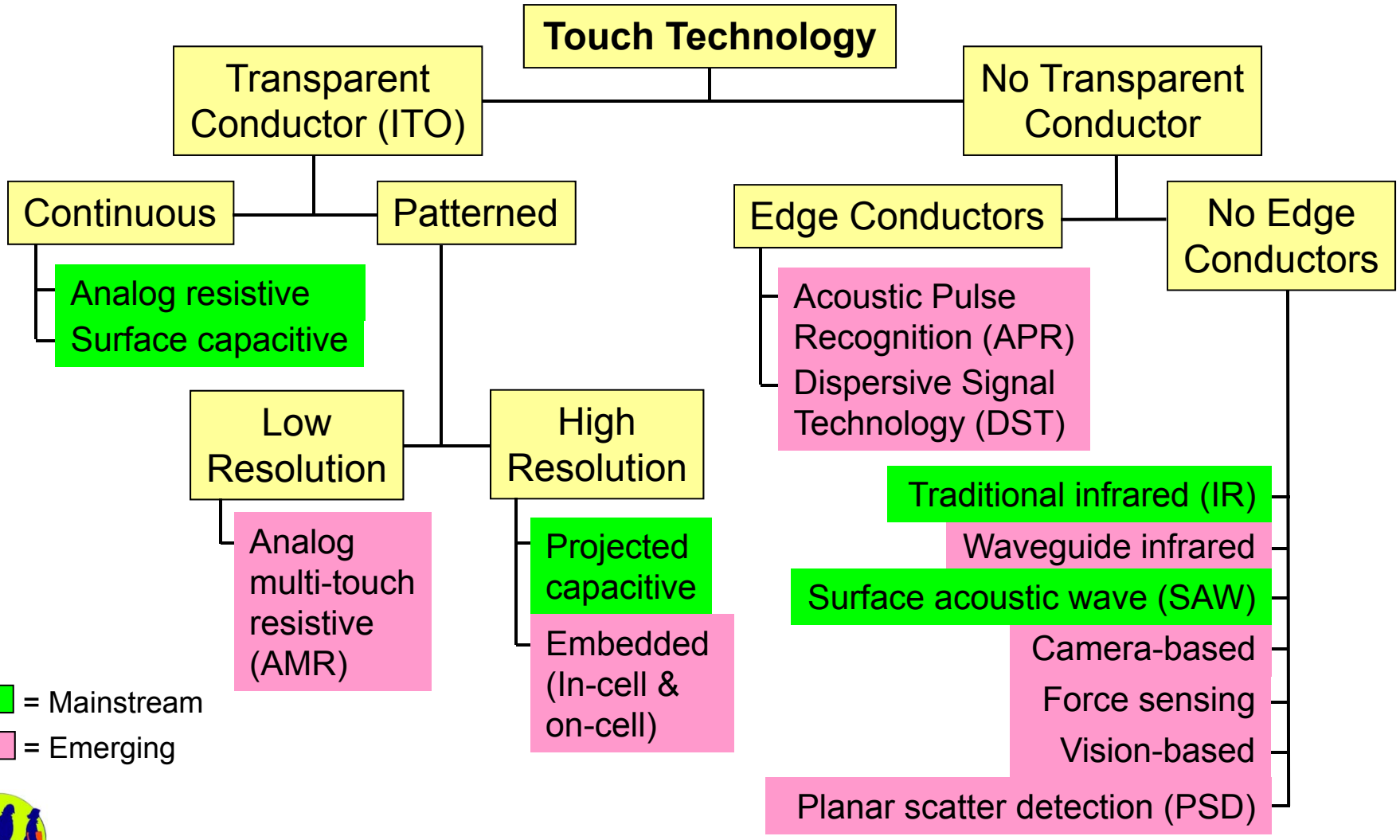
Source: Guoxin Securities, TPK, and DisplaySearch (February, 2012)

Touch Technologies by Size & Application

Touch Technology	Mobile (2" – 17")	Stationary Commercial (10" – 30")	Stationary Consumer (10" – 30")	Large-Format (>30")
Projected Capacitive (P-Cap) (ITO)	M	E	E	
Projected Capacitive (P-Cap) (wires on film)		L		L
Surface Capacitive		M		
Analog Resistive	M	M	L	
Analog Multi-Touch Resistive (AMR)	E		E▼	
Surface Acoustic Wave (SAW)		M	E▼	L
Acoustic Pulse Recognition (APR from **Elo**)	E	L		L
Dispersive Signal Technology (DST from **3M**)				L
Traditional Infrared (IR)		M	E	M
"High Finger-Count" Multi-Touch Infrared				E
Waveguide Infrared (from **RPO**)				
Camera-Based Optical			M	M
Planar Scatter Detection (PSD from **FlatFrog**)				E
Vision-Based				E
Embedded (in-cell & on-cell)	E			E
Force Sensing		E		
Electromagnetic Resonance (EMR)	M			

M = Mainstream **L** = Low-volume **E** = Emerging

Touch Technologies by Materials & Process



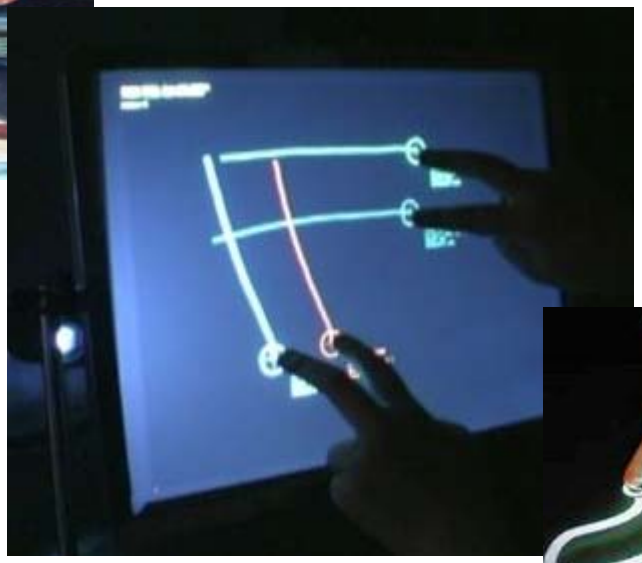
Touch Is An Indirect Measurement

One Reason Why There Are So Many Technologies…

Touch Technology	What's Being Measured
Resistive (all forms) & Embedded (voltage-sensing)	Voltage
Surface capacitive	Current
Surface acoustic wave	Ultrasonic wave amplitude
Projected capacitive, Embedded (capacitive)	Change in capacitance
Camera-based & Infrared (all forms), Planar scatter detection	Absence or reduction of light
Embedded (light-sensing)	Presence of light
Vision-based	Change in image
Acoustic Pulse Recognition & Dispersive Signal Technology	Bending waves
Force sensing	Force

The ideal method of sensing touch has yet to be invented!

Multi-Touch

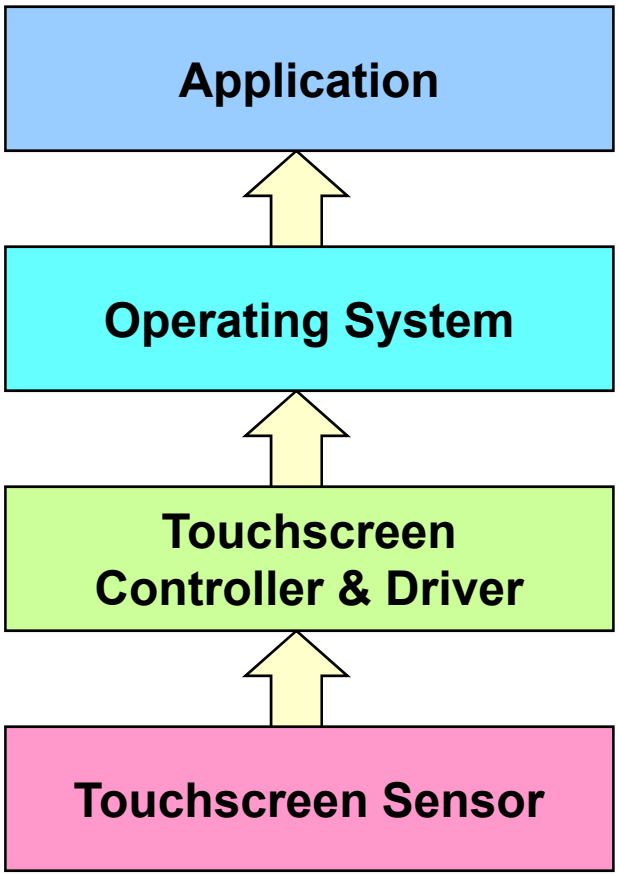


Sources: Engadget, Do Device and Good Times & Happy Days

Multi-Touch

- ***Multi-touch*** is defined as the ability to recognize two or more simultaneous touch points
- 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 (10/09) & Windows 8 (~10/12) both support multi-touch throughout the OS and is structured to support an "unlimited" number (~100) of simultaneous touch points
- Android, iOS and Linux currently support ~5 touches

Multi-Touch Architecture



Capable of decoding multiple streams of moving points and taking actions in response

Capable of forwarding multiple streams of moving points (and acting on a defined subset of them)

Capable of delivering sets of simultaneous points to the OS

Capable of sensing multiple simultaneous points

Multi-Touch Technologies

Touch Technology	Multi-Touch Capable? (#)	Win-7 Logo Capable?	Win-8 Logo Capable?	Commercial MT Product Example
Projected Capacitive	Yes (unlimited*)	Yes	Yes	***Apple iPad***
Embedded (On-cell p-cap)	Yes (unlimited*)	Yes	Yes	***Samsung OLED Phones***
Vision-Based	Yes (unlimited*)	Yes	Yes	***Microsoft Surface***
"High Finger-Count" Multi-Touch Infrared	Yes (20-40)	Yes	Yes	***PQ Labs G3***
Planar Scatter Detection	Yes (20-40)	Yes	Yes	***FlatFrog MT-3200***
Analog Multi-Touch Resistive (Stantum)	Yes (10)	Yes	Yes	***None***
Camera-Based	Yes (5)	Yes	Yes	***HP TouchSmart***
Embedded (In-cell)	Yes (unlimited*)	Yes	Depends	***Samsung ST700 Camera***
Analog Multi-Touch Resistive (AMR)	Yes (10)	Yes	Maybe	***Gateway AiO PC***
Surface Acoustic Wave (Elo & GTT)	Yes (2)	Yes	No	***Lenovo AiO PC***
Traditional Infrared	Yes (2)	Yes	No	***Nexio 42" Monitor***
Waveguide Infrared (RPO)	Yes (2)	Yes	No	***None***
Acoustic Pulse Recognition (Elo)	Future (2)	No	No	Technology under development
Dispersive Signal Technology (3M)	Future (2)	No	No	Technology under development
Analog Resistive	No	No	No	--
Surface Capacitive	No	No	No	--
Force-Sensing	No	No	No	--

* Controller-dependent, not sensor-dependent

Multi-Touch Gestures On Non-Multi-Touch Screens

- **"Gesture-enhanced" single-touch technologies**
  - Capability of sensing two-finger gestures on single-touch analog-resistive, surface-capacitive, and DST touch-screens
  - Restrictions depend on implementation
    - Some require that fingers be moving (2 static touches = 1 touch)
    - It can never pass any Windows Touch Logo
- **Why it exists: *Marketing!***
  - Gestures are HOT, so device manufacturers want them
  - Today, multi-touch is mostly used to enable two-finger gestures
  - For mobile devices, p-cap is ~3X the cost of analog resistive, so enabling two-finger gestures on analog resistive is attractive
- **The result**
  - Poor user experience, due to the difficulty of keeping two fingers pressed hard enough against the screen

Windows 8 Touch

- **The Win8 Touch Logo specification is based on p-cap**
  - Win7 spec was based on optical, which had little relevance outside of desktops
  - Win8 spec creates a common touch capability for mobile phones, tablets, notebooks, and desktops
- **Basic spec requirements**
  - Minimum of 5 simultaneous touches
  - Respond to first touch in < 25 ms
  - Subsequent touches must be < 15 ms at 100 Hz for all touches
  - Pixel-level (< 1 mm) accuracy, including edges and corners
  - No jitter when stationary; < 1 mm when moving 10 mm
  - Pre-touch < 0.5 mm
  - **Finger separation** >= 12 mm horizontal/vertical, 15 mm diagonal
    - But on-screen keyboards and normal human behavior violates this!

Why Multi-Touch Has Become So Important…1

- **Apple**
  - Apple established multi-touch as a “must-have” for coolness. The result is that people of all ages expect every display they see to be touchable with multiple fingers
- **Gaming**
  - Gaming is a natural for multi-touch. Try playing air hockey without multi-touch…
- **Unintended touches**
  - One of the major values of multi-touch is to allow the system to ignore unintended touches (palm rejection, grip suppression, etc.). As desktop screens become more horizontal (recline) this will become even more important.

Why Multi-Touch Has Become So Important…2

- **Multi-user collaboration**
  - When two people want to collaborate on a large screen (e.g., a student and teacher on an interactive “whiteboard” LCD), multi-touch is essential. Identifying which touch belongs to which user is still difficult, however.

How Many Touches Are Enough?...1

- **The industry has multiple answers**
  - Microsoft has settled on 5 touches for Win8; they wanted 10
  - The p-cap touchscreen suppliers under 30” either say “10” or “as many as possible” (e.g., 3M’s p-cap supports 60+ touches)
  - The large-format touchscreen suppliers say that 40 is enough
- **The key questions to ask:**
  - Does the touchscreen ***ignore*** all other touches beyond X?
  - Does the touchscreen support “***palm rejection***”?
    - If the answers are “NO”, it’s a problem!

How Many Touches Are Enough?...2

- **The answer actually depends on the application**
  - For a small mobile device, 2-5 (one hand) are enough
  - For a single-user app on any device (even an 82" screen), it's hard to see why more than 10 (two hands) are needed
  - For a multi-user app, it depends…
    - For a 55-inch gaming table, 40 (8 hands) is not unreasonable
      - The key touchscreen specification is probably response time
    - For a 65-inch interactive "whiteboard" LCD, 20 (4 hands) is probably enough, although an argument can be made for 40
      - BUT, the key touchscreen specifications are entirely different: minimum stylus tip size, pre-touch, jitter, ink-lag, etc. can all be critical

Source: FlatFrog

#1 Reference On Multi-Touch

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

"If you can only manipulate one point … you are restricted to the gestural vocabulary of a fruit fly. We were given multiple limbs for a reason. It is nice to be able to take advantage of them."

Bill Buxton, 2008
Principal Researcher,
Microsoft Research

Capacitive Touch Technologies

- Projected Capacitive (P-Cap)
- ITO Replacement Materials
- Surface Capacitive

Source: Apple

Projected Capacitive

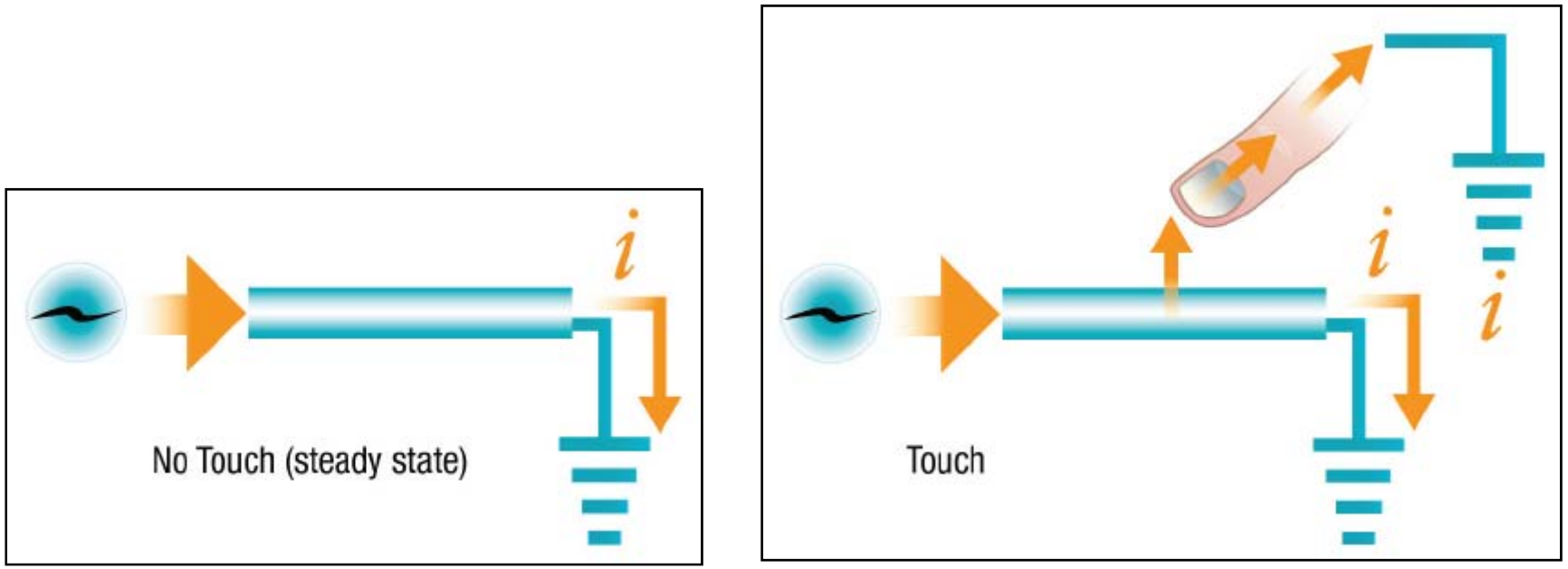
Projected Capacitive…1

- **iPhone, iPad and other products using projected capacitive (p-cap) have set the standard for touch in more than *ONE BILLION* consumers' minds**
  - Multiple simultaneous touches
  - Extremely light touch
  - Flush surface (zero-bezel)
  - Excellent optical performance
  - Reliable and durable
  - Fully integrated into the user experience – effortless & fun

Source: TabletPC2.com

Projected Capacitive…2

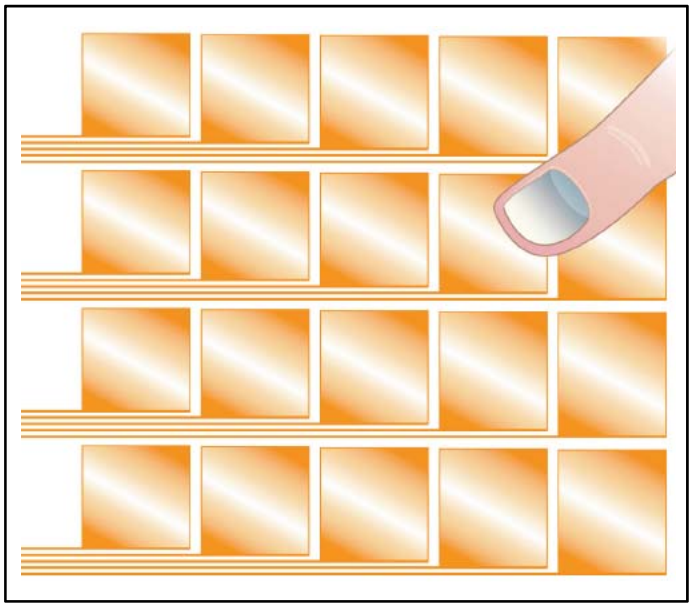
- **Self-capacitance principle**



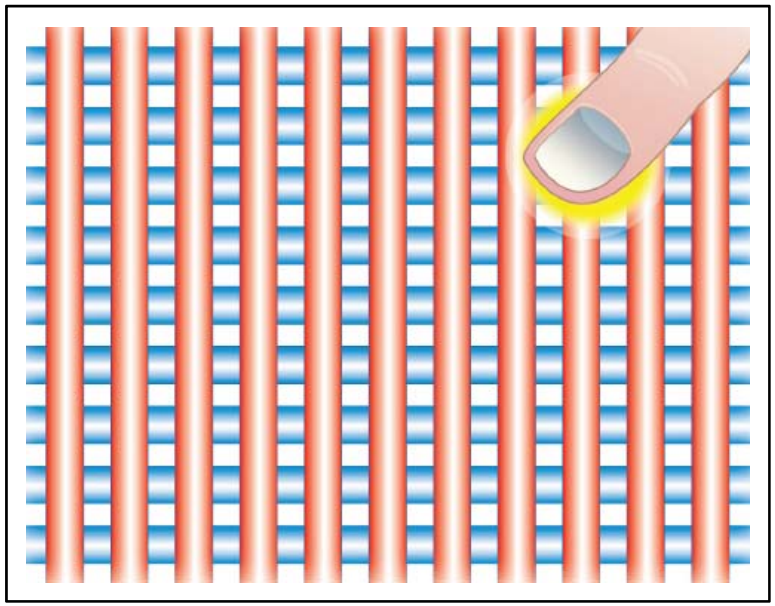
Source: 3M

Projected Capacitive…3

- **Self-capacitance electrode variations**



- Multiple separate pads in a single layer
- Each pad is scanned individually



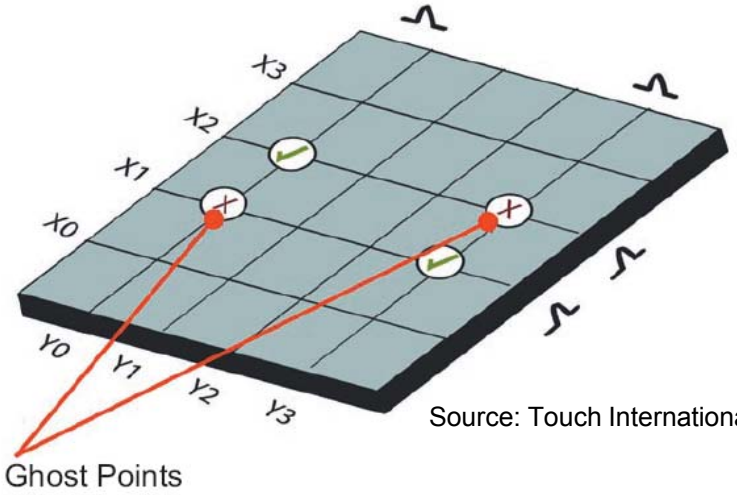
Source: 3M

- Rows and columns of electrodes in two layers
- Row & column electrodes are scanned in sequence

Projected Capacitive…4

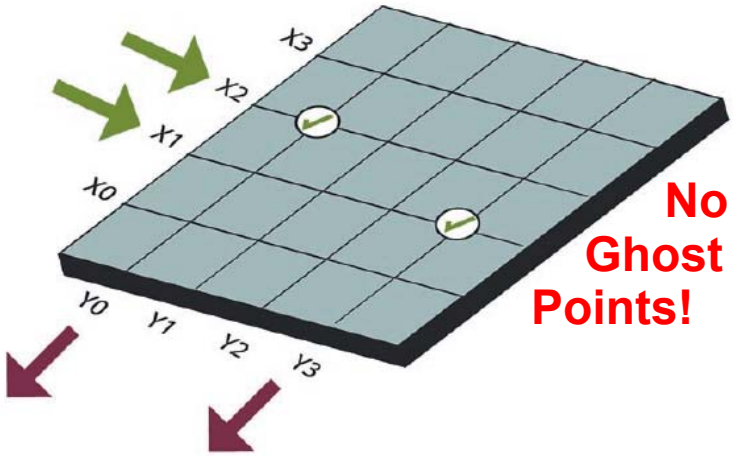
- **The problem with self-capacitance**

Self Capacitance



Source: Touch International

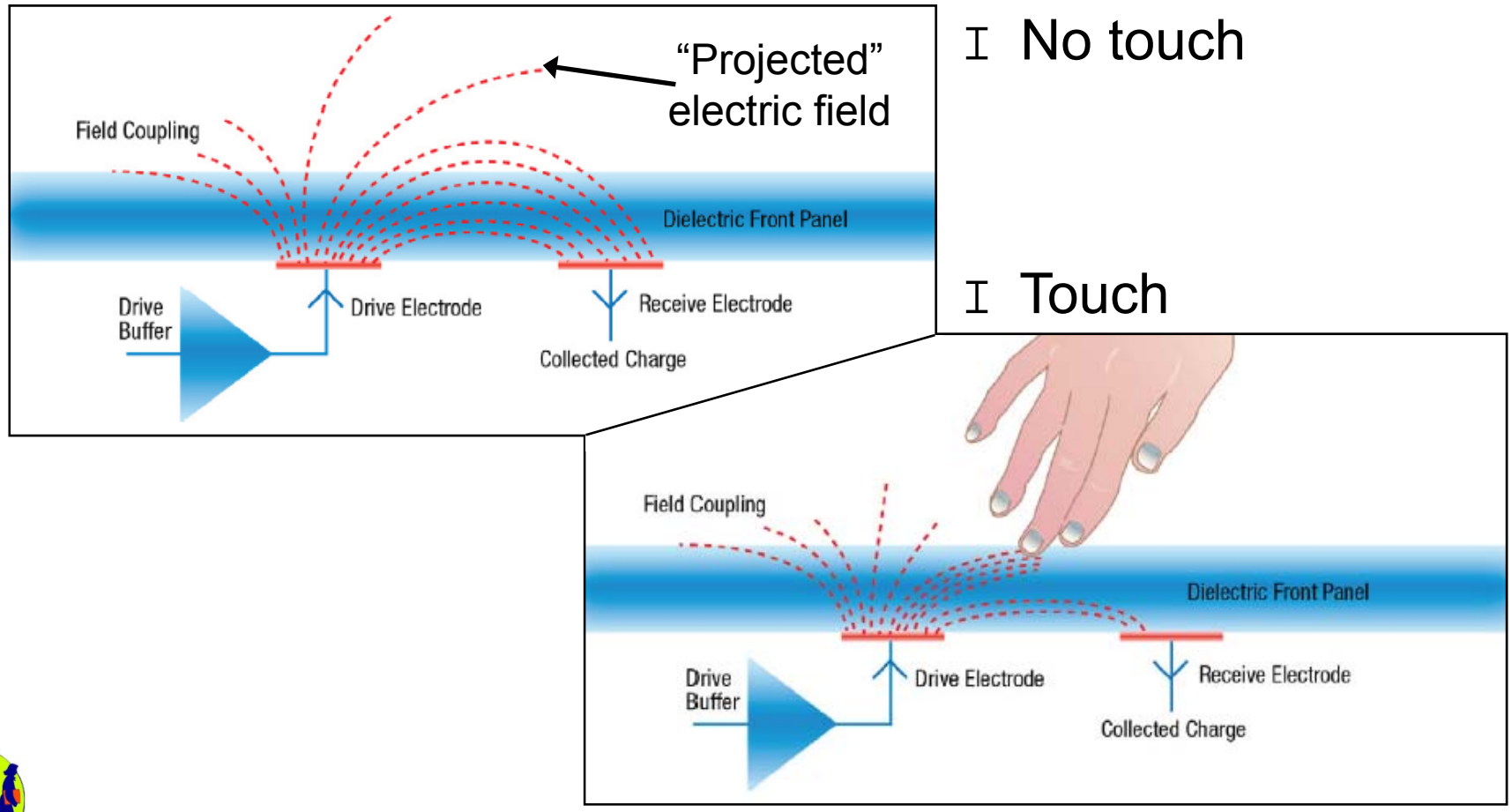
Mutual Capacitance



- Touches that are diagonally separated produce <u>two maximums on each axis</u> (real points & ghost points)
  - Ghost points: False touches positionally related to real touches

Projected Capacitive…5

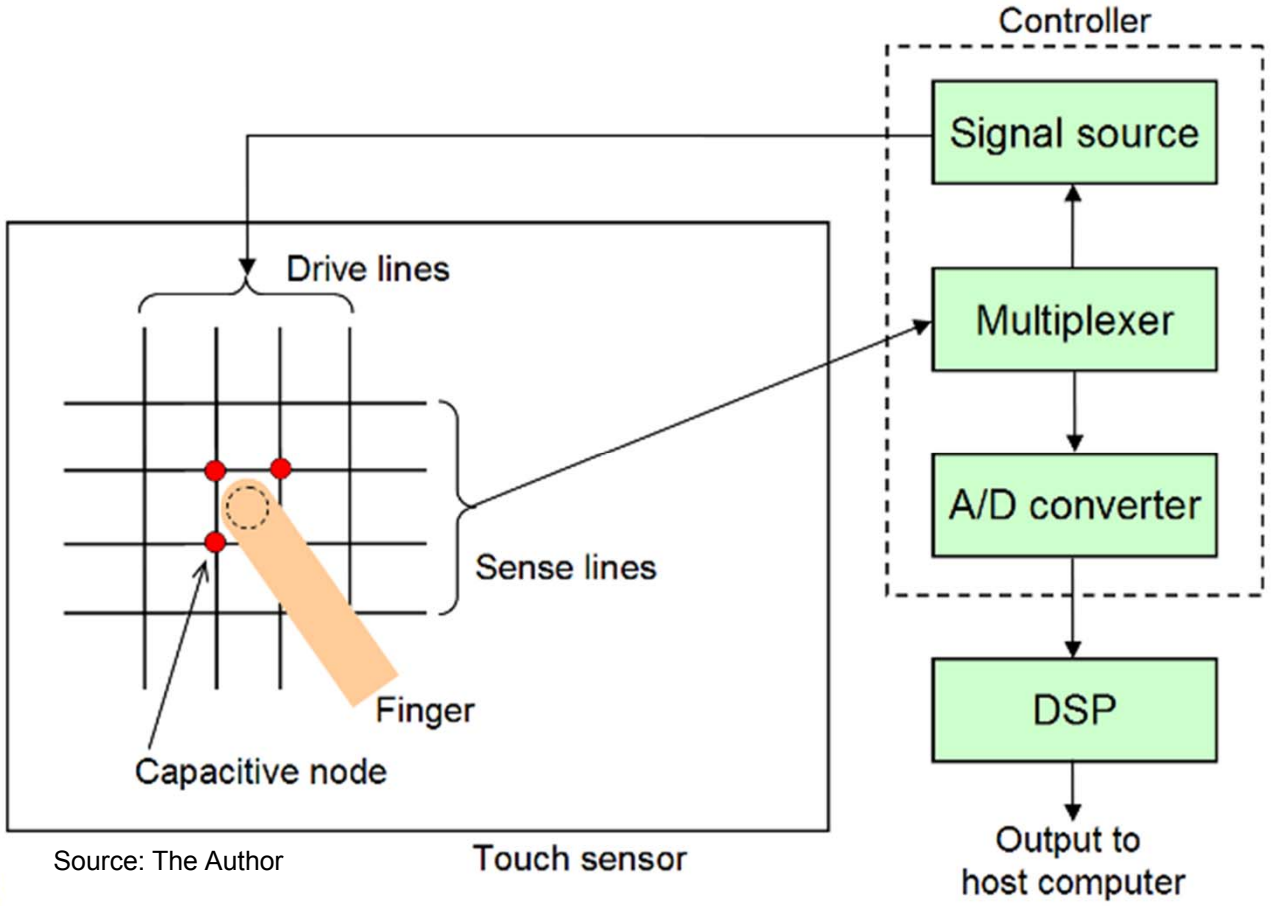
- **Mutual-capacitance principle**



Source: 3M

Projected Capacitive…6

- **Mutual capacitance example (Apple iPhone)**

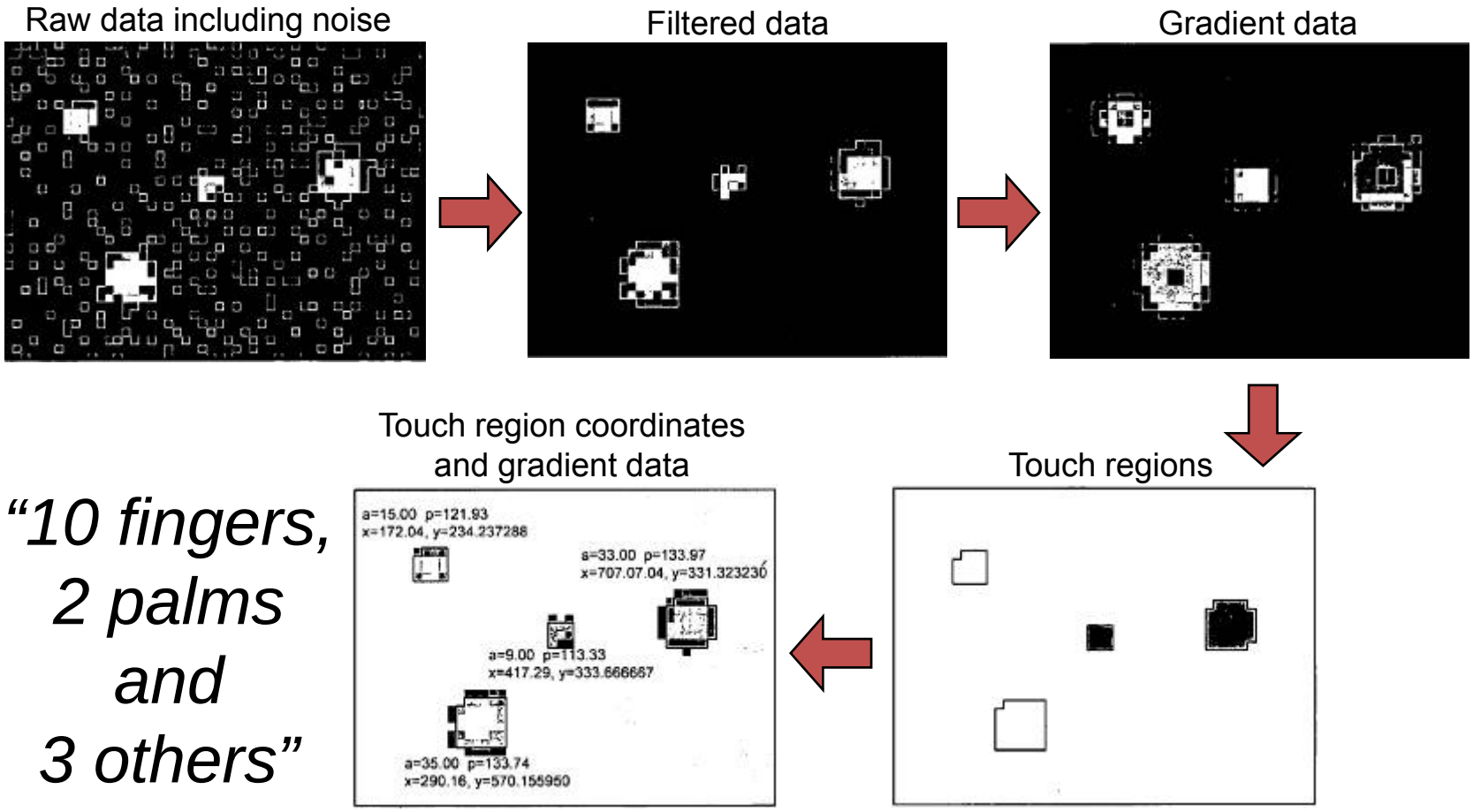


Source: The Author

Source: Apple

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

Projected Capacitive…7

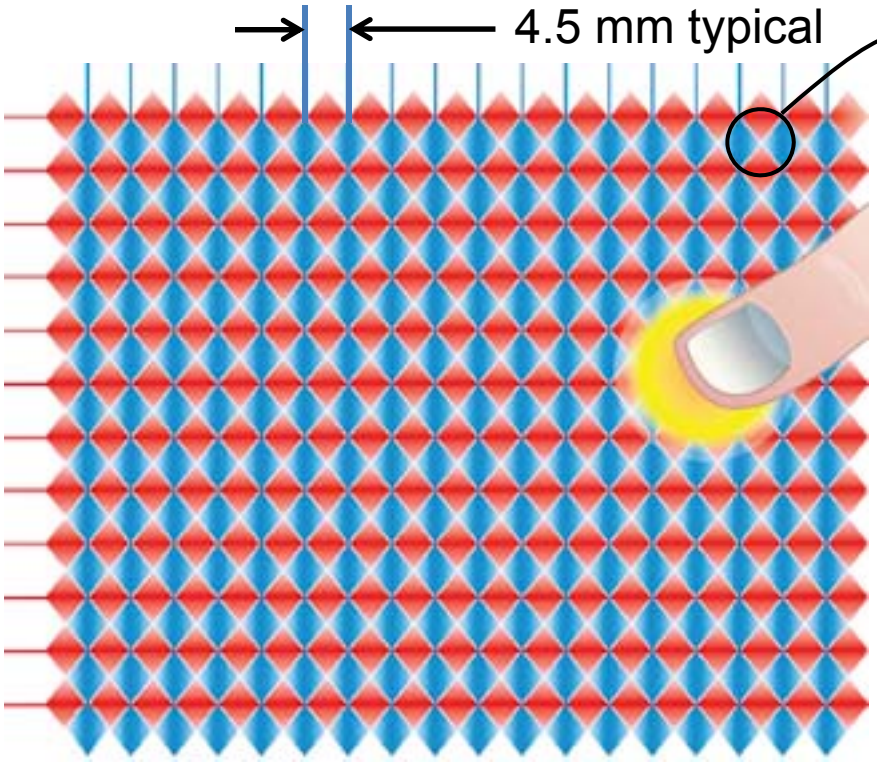


"10 fingers, 2 palms and 3 others"

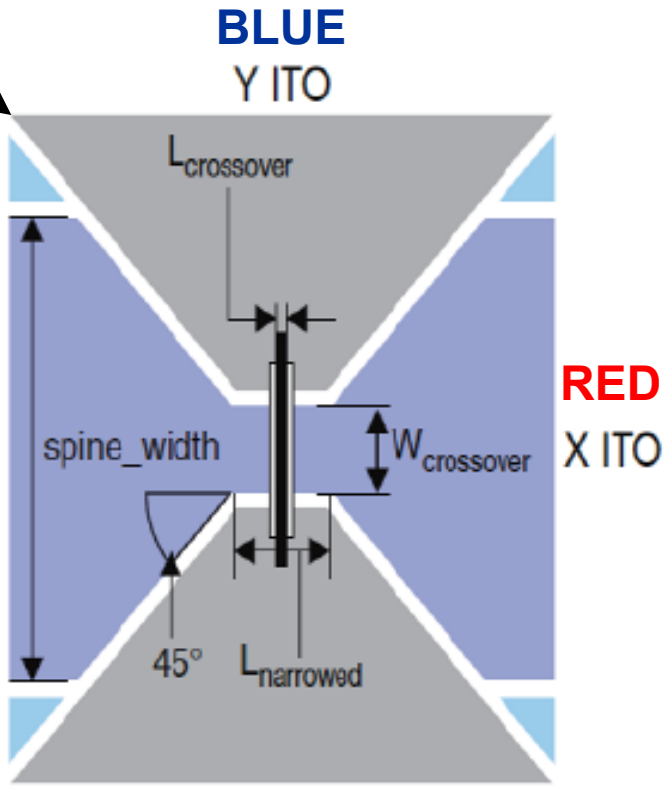
Source: Apple Patent Application #2006/0097991

Projected Capacitive…8

- "Interlocking diamond" electrode configuration



Source: 3M



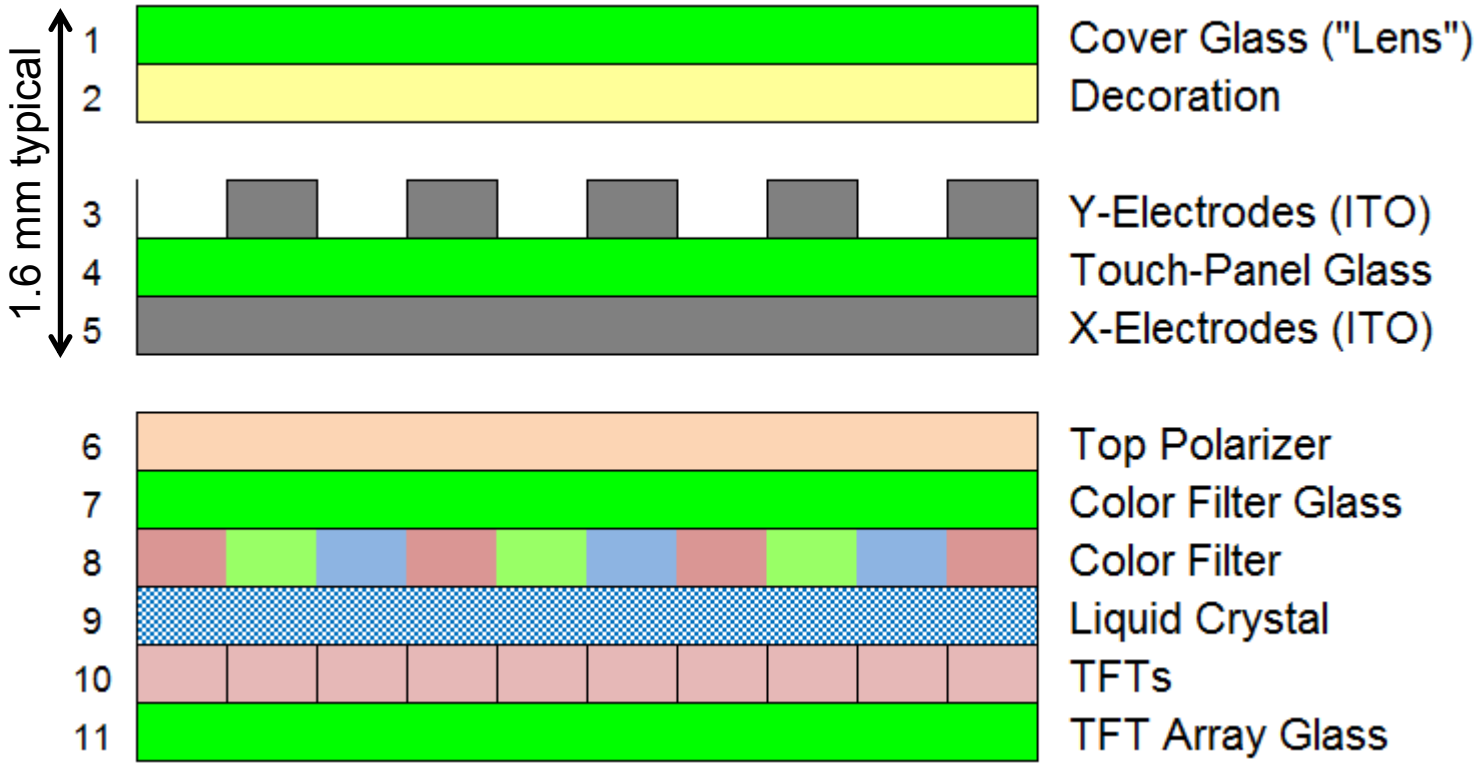
Source: Atmel

Projected Capacitive…9

Self-Capacitance	Mutual Capacitance
Older technology, but still used	Newer technology
Limited to 1 or 2 touches with ghosting	Two or more unambiguous touches
Lower immunity to LCD noise	Higher immunity to LCD noise
Lower touch accuracy	Higher touch accuracy
Sensor is usually a diamond pattern	Allows more flexibility in pattern design
Harder to maximize SNR	Easier to maximize SNR
Simpler, lower cost controller	More complex, higher-cost controller
Usually a single-layer sensor	Usually a two-layer sensor (or one-layer with “bridges”)

Projected Capacitive…10

- **Standard p-cap "stackup"**



Source: The Author

Projected Capacitive…11

- **Variations in standard p-cap stackup**
  - Lamination (using OCA) to the cover glass and/or to the LCD
  - Two ITO films (PET) instead of one glass substrate
    - Lower transmissivity, wider borders due to routing, higher-cost ITO, higher lamination yields
  - Single layer of ITO on top of the glass with “bridges”
  - Two sheets of glass, each with one set of electrodes
  - Wide X-electrodes (“flooded X”) to shield the Y-electrodes from LCD noise
  - Grounded shield layer on the underside of the glass
  - And more…

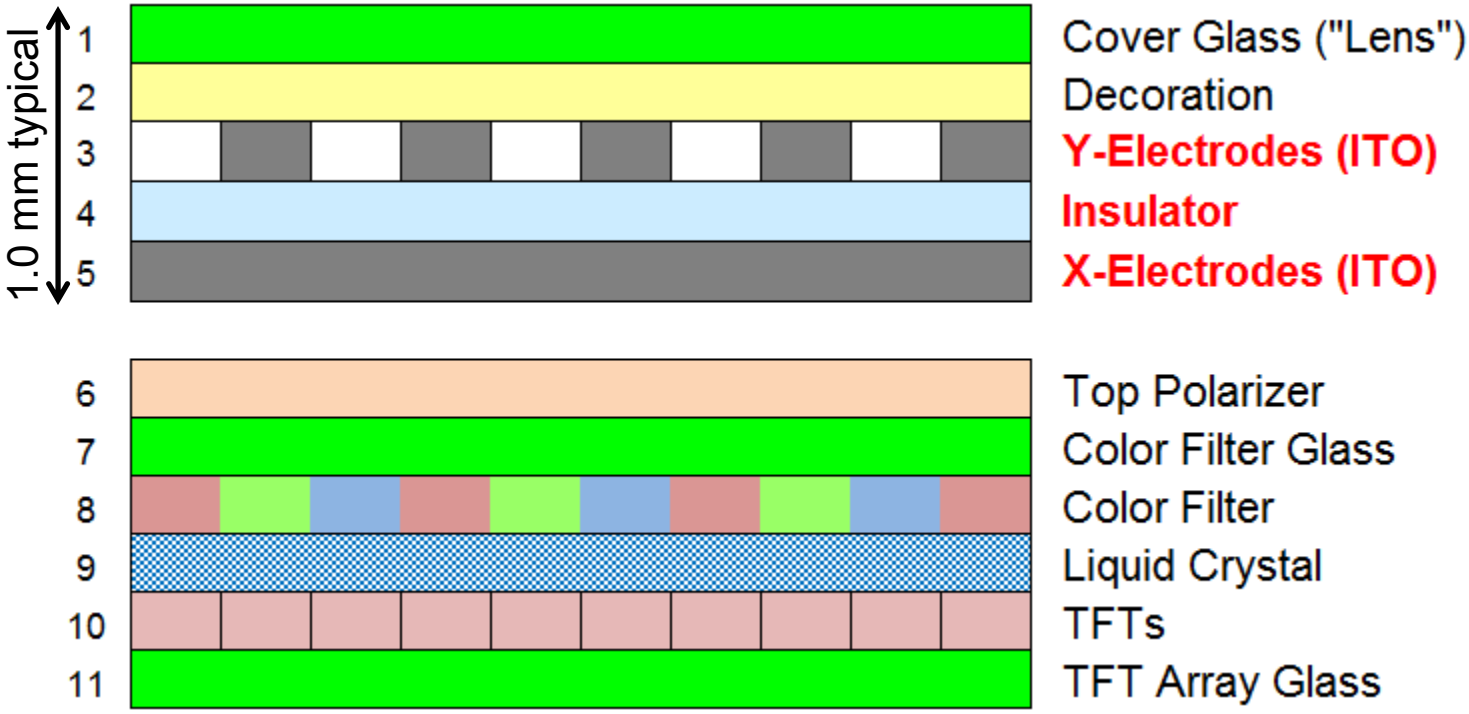
Projected Capacitive…12

- **PET vs. glass substrate**

	PET	Glass
Temperature Tolerance	80°C	125°C - 150°C
Aging Effects	Yellowing, curling, surface deformation	No known effect
Transparency	85%	=>90%
Resolution Capability	50 µm	1 µm
Stackup	Thinner	Thicker
Weight	Light	Heavier
Moisture Resistance	Good	Excellent
Lamination Yield	Excellent	Good
Mechanical Strengthening	None	Tempering
Cost	$	$$

Projected Capacitive…13

- “One-glass solution” p-cap stackup



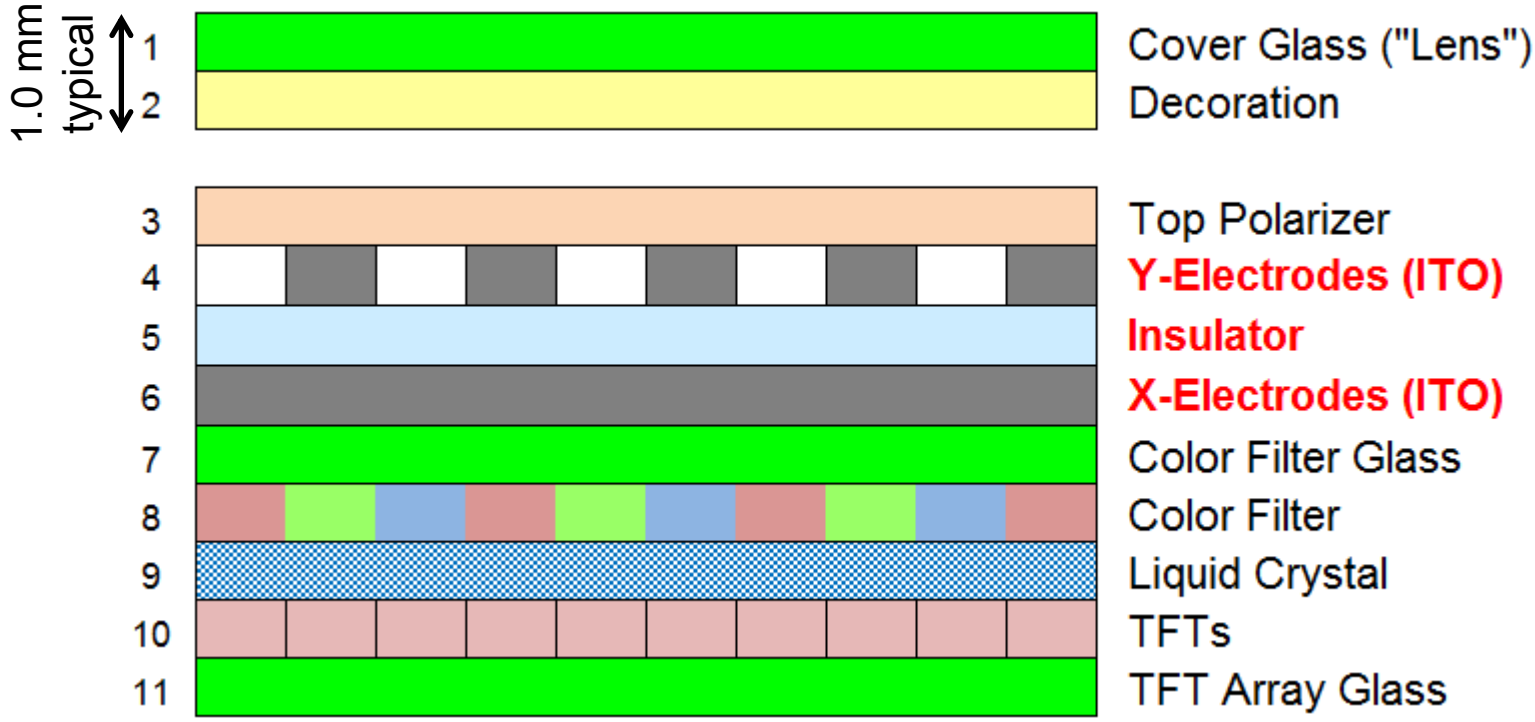
Source: The Author

Projected Capacitive…14

- **One-glass solution**
  - Also called “touch on lens”, “sensor on cover”, “direct patterned window” and many other names
  - Advantages
    - Eliminates the touchscreen’s glass substrate, making the end-product thinner and lighter
    - Competitive weapon against on-cell from LCD suppliers
  - Disadvantages
    - Requires close cooperation with cover-glass makers, or increased vertical integration (preferable)
    - Yields are lower (more complex operations)
    - Bendable cover glass can affect touch performance
    - Harder to shield touchscreen from LCD noise
  - Variations
    - Y-electrode on underside of cover glass; X-electrode on PET film

Projected Capacitive…15

- **On-cell p-cap stackup**



Source: Author

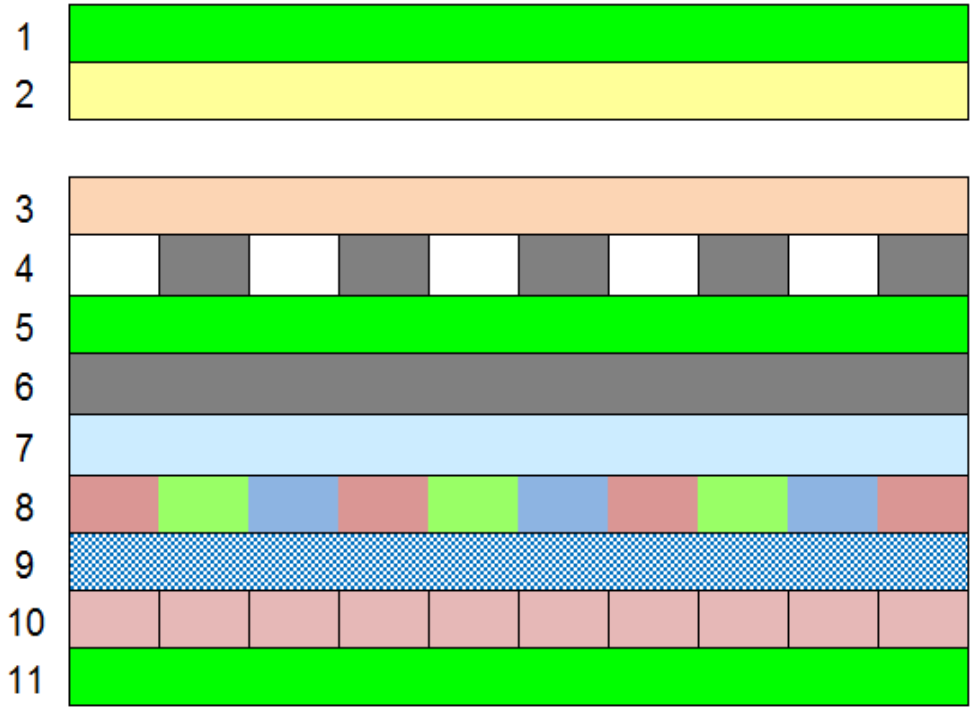
Projected Capacitive…16

- **One-glass vs. on-cell is really about the war between the *Touch-Panel Industry* and the *LCD Industry***
  - The benefit to the end-user is the same
    - One less piece of glass makes the product thinner and lighter
  - Supply-chain considerations, manufacturing cost & yield, and what the device OEM/ODM wants to buy are all important

	One-Glass Solution	On-Cell
Touch Module-Maker	Makes cover-glass	Makes nothing
	Buys controller and attaches it to module	Buys nothing
	Sells integrated touch + cover-glass module	Sells nothing
LCD Manufacturer	Sells standard LCD	Changes LCD fab process to add electrodes
		Buys controller and adds it to the LCD electronics
		Sells touch-enhanced LCD
Device OEM/ODM	Buys LCD & module	Buys LCD & cover-glass

Projected Capacitive…17

- **Hybrid on-cell/in-cell p-cap stackup (Synaptics)**



Source: The Author

Projected Capacitive…18

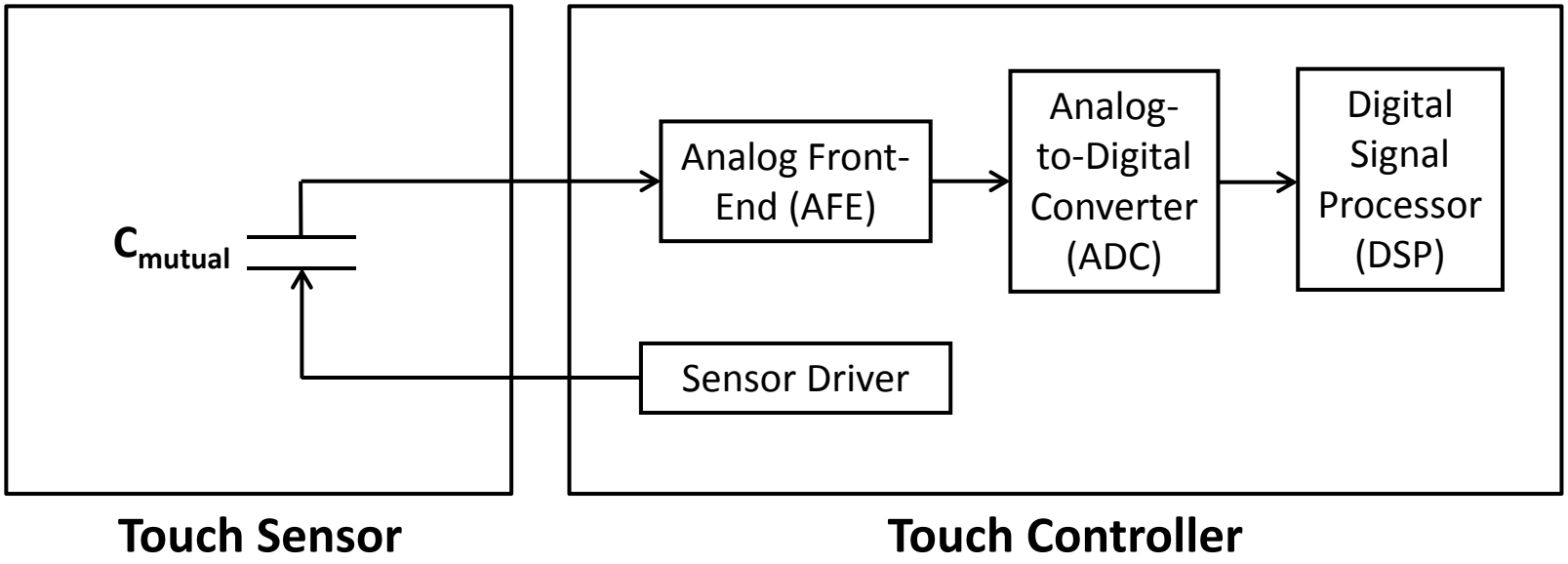
- **One more sensor variation: 10-micron wires between two sheets of PET or glass**
  - Commonly used for large-format touchscreens
  - Two main suppliers: Visual Planet & Zytronic, both in the UK

9 floor-to-ceiling Visual Planet touchscreens in the University of Oregon Alumni Center

Source: The University of Oregon

Projected Capacitive…19

- **P-cap controllers**



Projected Capacitive…20

- **P-cap controller suppliers**

Atmel
Cypress
Synaptics

vs.

AD Semi	Pixcir
AMT	Raydium
Azoteq	Renasas
Cirque	Samsung
EETI	Sentelic
EMC	SiS
FocalTech	**Silicon Labs**
Ilitek	Sitronix
Maxim	ST Micro
Melfas	**TI**
M-Star	Weltrend

Projected Capacitive…21

- **Controllers**
  - Key variable is the number of electrodes (matrix size)
    - Larger screens generally require multiple (ganged) controller chips
  - High signal-to-noise ratio (SNR) is a key characteristic ➔ enables stylus use
  - Most innovation in p-cap is being done by the controller suppliers
- **Controller questions**
  - Are controller suppliers the wild card in the one-glass vs. on-cell battle?
  - Innovation: After performance, cost, stylus, hover, & gestures, what's left?
  - When will commoditization happen?

Source: Synaptics

LG-Prada mobile phone with Synaptics' p-cap touch-screen; launched 3 months before the iPhone!

Projected Capacitive…22

- **Options (ITO-based)**
  - Top-surface treatment (AR, AG, AF, AC, AB…)
  - Degree of indexing matching on ITO (invisibility)
  - Stackup variations, as already described
  - Number of electrodes per inch (dpi/resolution)

- **Size range**
  - 2” to 100”+
    - ITO up to 32” (46” demo); wires up to 100”+

Projected Capacitive…23

- **Advantages**
  - Unlimited multi-touch
  - Extremely light touch (zero force)
  - Enables “zero-bezel” industrial design
  - High optical quality (ITO)
  - Very durable (protected sensor)
  - Unaffected by debris or contamination
  - Works with curved substrates (on PET)
- **Disadvantages**
  - Finger or tethered pen only ➔ This is rapidly changing!
  - High cost ➔ Mostly in the sensor; ITO replacements will help
  - Challenging to integrate due to noise sensitivity & “tuning”

Projected Capacitive…24

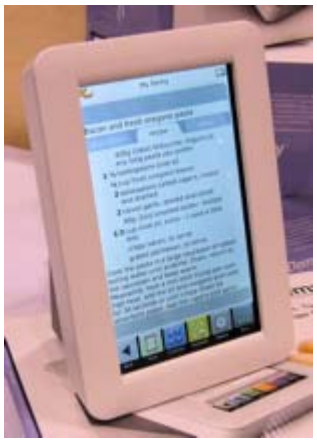
- **Applications**
  - Consumer devices
    - Mobile phones
    - Tablets, netbooks, notebooks, AiOs
    - Almost any consumer device
  - Vertical-market devices
    - Signature-capture terminals
    - "Through-glass" interactive retail signage
- **Market share**

	2011
Revenue	63%
Volume	71%

Source: Mildex

Source: Verifone

Demy Digital Recipe Reader



Source: Photo by Author

Projected Capacitive…25

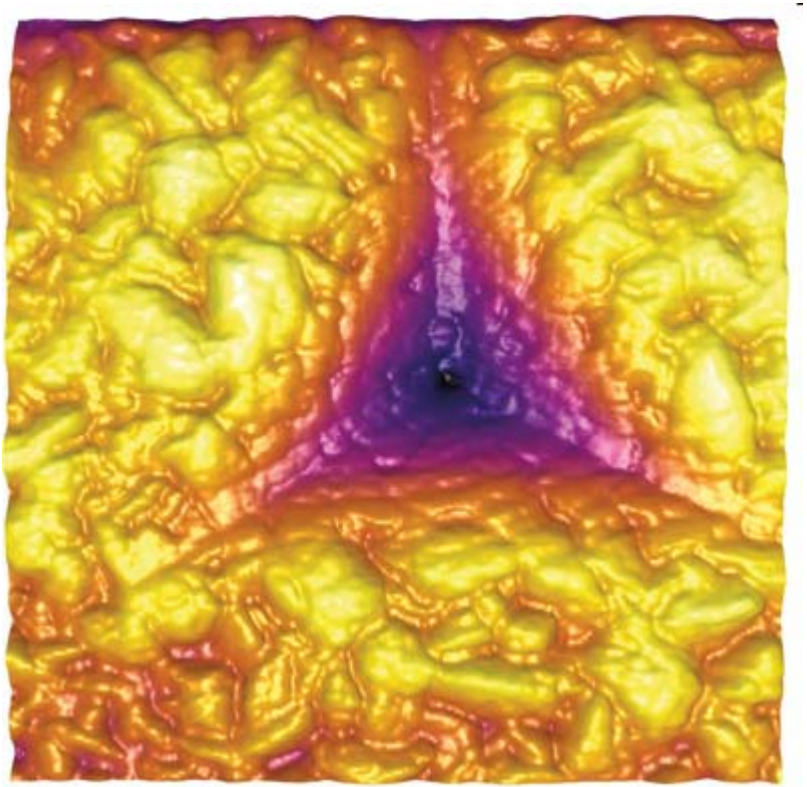
- **Adoption of P-Cap In Commercial Markets (Forecast)**
  - Healthcare – Rapid, within FDA-cycle constraints
    - Buying for the future with a very long product life
    - Zero-bezel, multi-touch, light touch are all important
  - Gaming – Rapid, within gaming regulation constraints
    - Casinos want to attract the Millennium Generation
    - Multi-touch is very important; zero-bezel is less so
  - Point of Information – Moderate
    - Software-driven; zoom gesture could be the key
  - Industrial – Slow
    - Multi-touch may be important; zero-bezel & light touch are less so
  - Point of Sales – Very slow
    - Zero-bezel is the only driver; “flat-edge resistive” is good enough

Projected Capacitive…26

- **Suppliers**
  - Modules
    - TPK (biggest), Wintek, Nissha, Panjit, Digitech, CMI, Young Fast, Touch International, 3M, Ocular, and >20 more
  - Sensors (only)
    - Cando (part of AUO Group), Sintek Photronics, other former color-filter manufacturers, former STN LCD manufacturers (total number = ?)
  - Controllers (only)
    - Atmel, Cypress, Synaptics, Maxim, Avago, Pixcir, Sitronix, EETI, SIS, Melfas, MasTouch, Texas Instruments, and >15 more…
- **Supplier countries**
  - Taiwan, USA, China, Japan, Korea, UK, Israel, South Africa…

Projected Capacitive…27

- **Market trends**
  - P-cap has become a *de facto* standard
  - Growth is starting to moderate
  - Top three controller suppliers account for ~70% of revenue
  - Top three module suppliers account for ~70% of revenue
  - Prices are still dropping, but the rate is slowing
  - Massive capacity expansion continued in 2011
  - There's still no significant interest in touch on standard notebooks
  - Commercial applications are just beginning to transition
  - A few small-order suppliers are appearing, but it's still hard to buy
  - The technology name has changed to just "capacitive"



Source: Asylum Research (800 nm scan of ITO)

ITO Replacement Materials

ITO Replacements…1

- **Why replace ITO?**
  - **Costly to pattern & needs high temperature processing**
  - Highly reflective (IR = 2.6) & tinted yellow; brittle & inflexible
  - Relies on “environmentally questionable” Chinese zinc mines*
- **Replacement material objectives**
  - **Solution processing (no vacuum, no photolithography)**
  - Higher transmissivity & same resistivity (matched to niche)
  - Same or lower material cost than ITO
- **Five replacement candidates**
  - Metal mesh
  - Silver nanowires
  - Carbon nanotubes
  - Conductive polymers
  - ITO inks

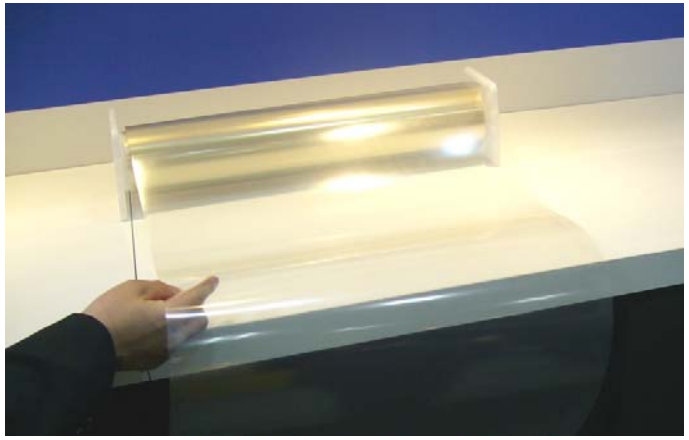
* 63% of estimated 2007 production of indium

ITO Replacements…2

- **Metal mesh – it feels like we're right on the verge…**
  - **Atmel** announced they will start supplying XSense™
    - Metal-mesh sensor printed using material from CIT (Conductive Ink Technology) in the UK
  - **Unipixel** seems close to actual production of UniBoss™
    - Metal mesh roll-to-roll printable in a single pass at room temperature
    - Partnered with TI for p-cap controllers
    - Partnered with Carestream for film manufacturing
  - **3M** is developing roll-to-roll p-cap film sensors
    - Production will be by 3M/Quanta joint venture in Singapore
    - Patterning uses 3M's micro-replication technology
    - Material is rumored to be silver nanowires or other metal (mesh)
  - Others include PolyIC, CDT, Suzhou NanoGrid, Carestream, etc.

ITO Replacements…3

- **Silver nanowires**
  - **Cambrios**
    - Synthesis of inorganic material (e.g., silver) from soluble precursors, followed by assembly of the resulting materials into nanostructures
    - Cambrios has been coating rolls of PET with their material ("ClearOhm") in a roll-to-roll production facility since early 2007
    - Cambrios is working with all the Japanese resistive suppliers



Source: Nikkei Business Publications

  - **Others**
    - PolyIC, Sigma Technologies, Carestream, Ferro, Suzhou NanoGrid, Saint-Gobain, Cima NanoTech, Blue Nano, and others

ITO Replacements…4

- **Carbon nanotubes**
  - **Leaders have changed over the last couple of years**
    - Was Eikos and Unidym
    - Now C3Nano, Canatu, Toray, SWeNT and others
  - Performance isn't good enough yet to beat silver nanowires
    - Also separation problems

ITO Replacements…5

- **Conductive polymers** (e.g., PEDOT/PSS)*
  - **Fujitsu & Kent Displays are currently using**
    - Fujitsu claims 5X to 10X longer touch-screen lifetime
      - Roll-to-roll film manufacturing
    - BUT, conventional wisdom is that PEDOT has inferior transparency and degrades under UV…
  - **Development leaders**
    - Agfa, Heraeus, Kodak
  - **Issues**
    - Low performance

* *poly(ethylene dioxythiophene) / poly(styrene sulfonate)*

ITO Replacements…6

- **ITO inks**
  - On-again, off-again market interest
    - NanoMarkets' forecast is effectively zero through 2017
  - ITO ink is nanoparticles (e.g., 10 nm) of ITO dispersed in a solvent with additives
    - Leaders are Sumitomo and Ulvac
  - Can be inkjet-printed at atmospheric pressure, but requires high-temperature (450°C) thermal annealing to achieve lowest sheet resistivity
  - Nobody's currently doing it in touchscreen sensor production
    - Performance to date hasn't been good enough
    - Metal mesh and/or silver nanowires seem much more promising

ITO Replacements…7

- **Realities (summary)**
  - It's about the ITO in touchscreens, not in LCDs
    - ITO used in LCDs is < 1% of cost (~$4 for a 40" display)
    - LCD makers are extremely reluctant to make changes in fabs
  - It's about the processes that it requires, not about the ITO itself
    - The dominance of patterned-ITO touchscreens (p-cap) over uniform-ITO touchscreens (resistive) has changed the picture
    - A 10" p-cap tablet touchscreen is $25 sensor, $5 controller
  - It's not really about flexible displays, at least not right now
  - It's not really about the indium supply

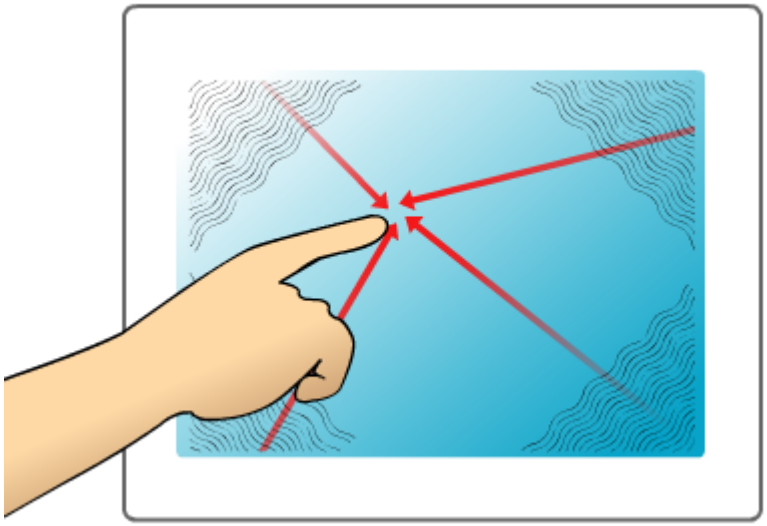
ITO Replacements…8

- **Predictions**
  - Most current capital-intensive, fab-based, p-cap module suppliers will resist ITO replacements because they have to maintain a targeted return on their invested capital
    - ITO-replacements represent a competitive threat to them
  - An entirely new group of much less capital-intensive module suppliers will arise to compete with the existing suppliers
    - An obvious example is the joint venture between 3M and Quanta that's based in Singapore and focusing on CE products
  - Five years from now, as much as 50% of p-cap sensors will be made using an ITO-replacement material
    - 10 years from now, p-cap fabs will be like many passive-LCD fabs today (fully depreciated and unused)

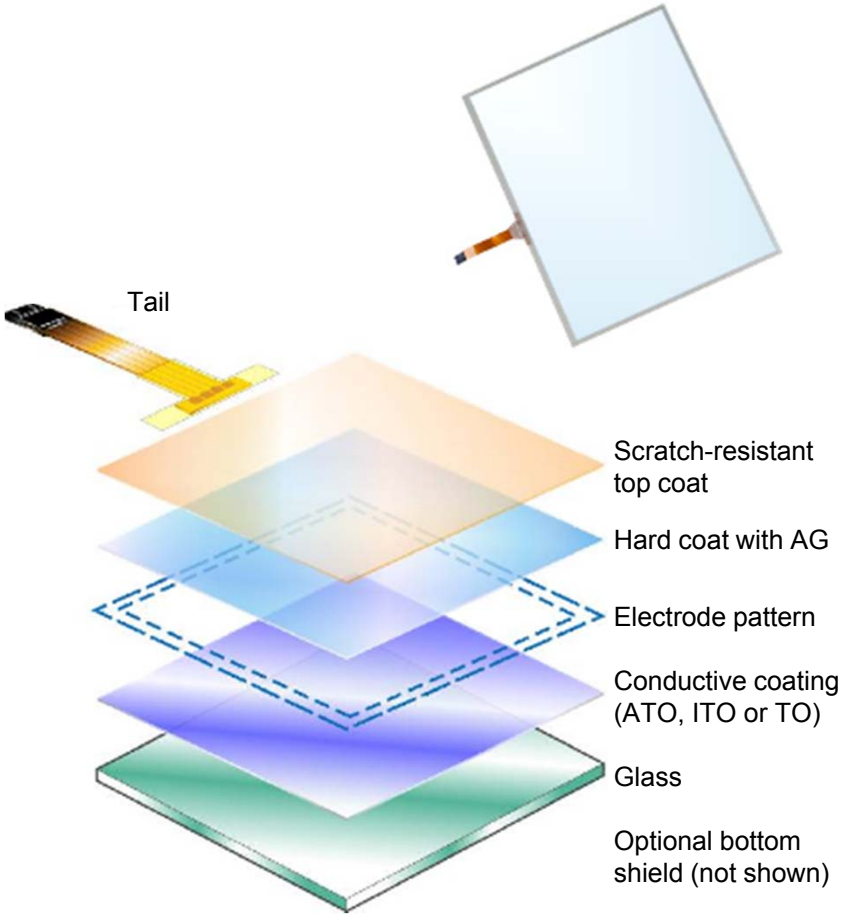
Source: 3M

Surface Capacitive

Surface Capacitive…1



Source: Elo TouchSystems

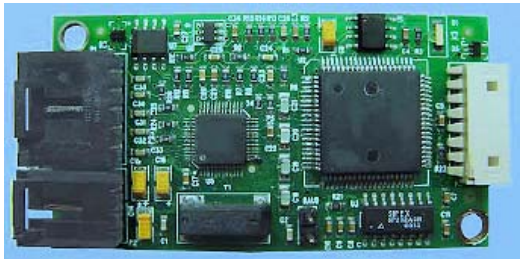


Source: 3M

Surface Capacitive…2

- **Variations**
  - Rugged substrate
- **Size range**
  - 6.4” to 32”
- **Controllers**
  - 3M, Microchip (Hampshire), eGalax, and Digitech
- **Advantages**
  - Excellent drag performance with extremely smooth surface
  - Much more durable than analog resistive
  - Resistant to contamination
  - Highly sensitive

Source: 3M



Source: Interactive Systems

Surface Capacitive…3

- **Disadvantages**
  - Finger-only (or tethered pen)
  - Calibration drift
  - Susceptible to EMI (no mobile use)
  - Moderate optical quality (85% - 90% transmissivity)
- **Applications**
  - Regulated (casino) gaming
  - Kiosks
  - ATMs
- **Market share**

	2011
Revenue	<1%
Volume	<1%

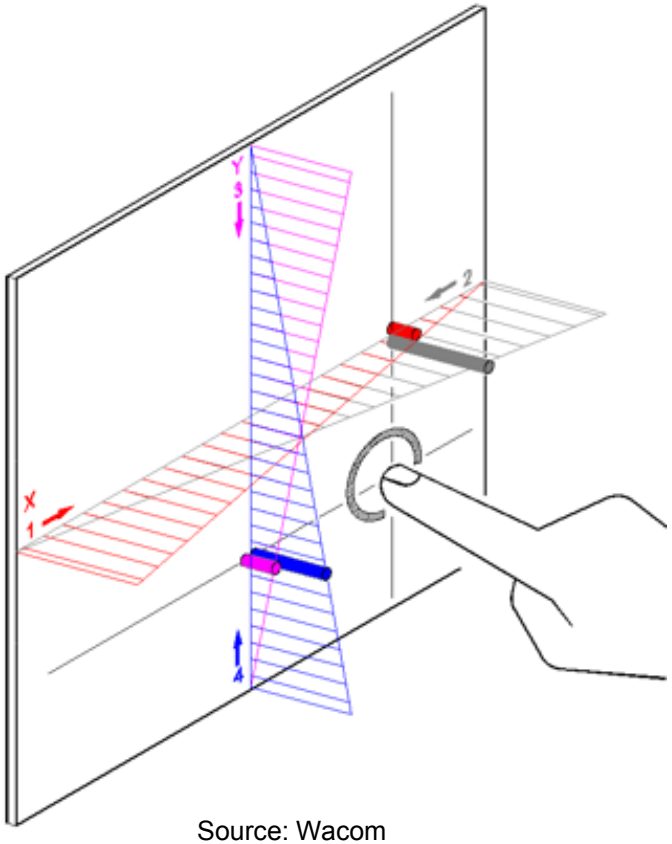
Source: 3M

Surface Capacitive…4

- **Suppliers**
  - 3M, DigiTech, DanoTech, Elo TouchSystems, EELY, eTurbo, Touch International, Higgstec…
  - 16+ suppliers (dominated by 3M)
- **Market trends**
  - Surface capacitive has leveled off and will start to shrink
    - No multi-touch capability; other significant disadvantages
    - Casinos (major market) are starting to experiment with other touch technologies
  - ASP is forecasted to drop 25% over the next five years
  - It will be an irrelevant, obsolete technology in 5-10 years

Variation #1: Wacom's RRFC[Ö] Surface Capacitive Technology

- **How it works**
  - AC voltage on 2 adjacent corners; DC voltage on the other 2 corners
    - Creates a linear voltage AND a ramp-shaped electrostatic field on surface
  - Controller switches signals around all 4 corners, creating 4 ramp fields vs. single flat field in standard capacitive
    - Current flow is measured in each case
  - Resulting signal representing touch event is independent of all capacitance effects except those due to finger touch
  - Controller does additional digital signal processing to compensate for factors that affect accuracy and drift



Source: Wacom

(Trademark = CapPLUS)

Ö RRFC = **R**eversing **R**amped **F**ield **C**apacitive

Wacom's RRFC Technology…2

- **Advantages**
  - Solves all the problems of traditional surface capacitive
    - Works in mobile & stationary devices (10" to 32" now; 46" capable)
    - Unaffected by grounding changes, EMI, variations in skin dryness & finger size, temperature, humidity, metal bezels, etc.
    - Works through latex or polypropylene gloves
    - Allows 4X thicker hardcoat for improved durability
    - Screen works outdoors in rain and snow
  - Uses same ASIC as Wacom's EMR pen digitizer, so dual-mode input is lower cost & more efficient (e.g., in Tablet PC)
- **Disadvantages (2 big ones!)**
  - No multi-touch
  - Sole-source supplier

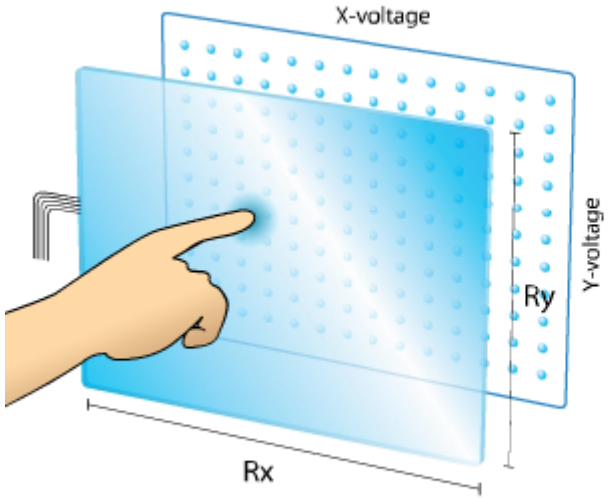
Resistive Touch Technologies

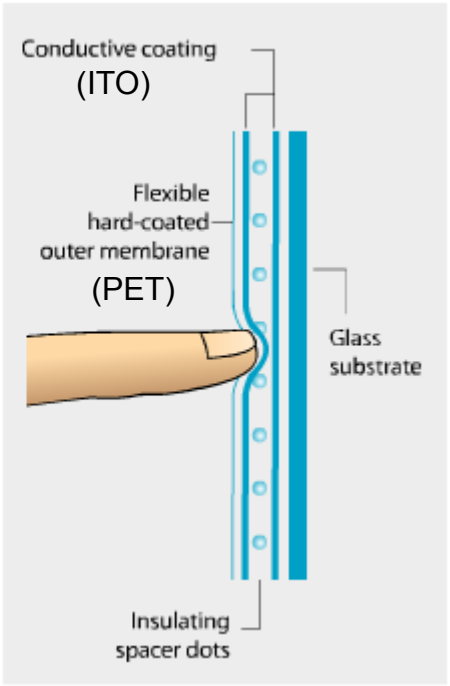
- Analog Resistive
- Analog Multi-Touch Resistive

Source: Engadget

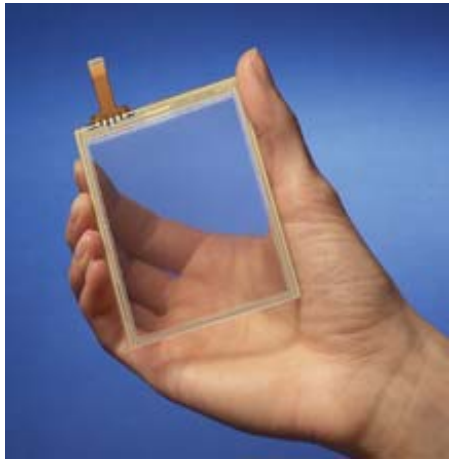
Analog Resistive

Analog Resistive…1



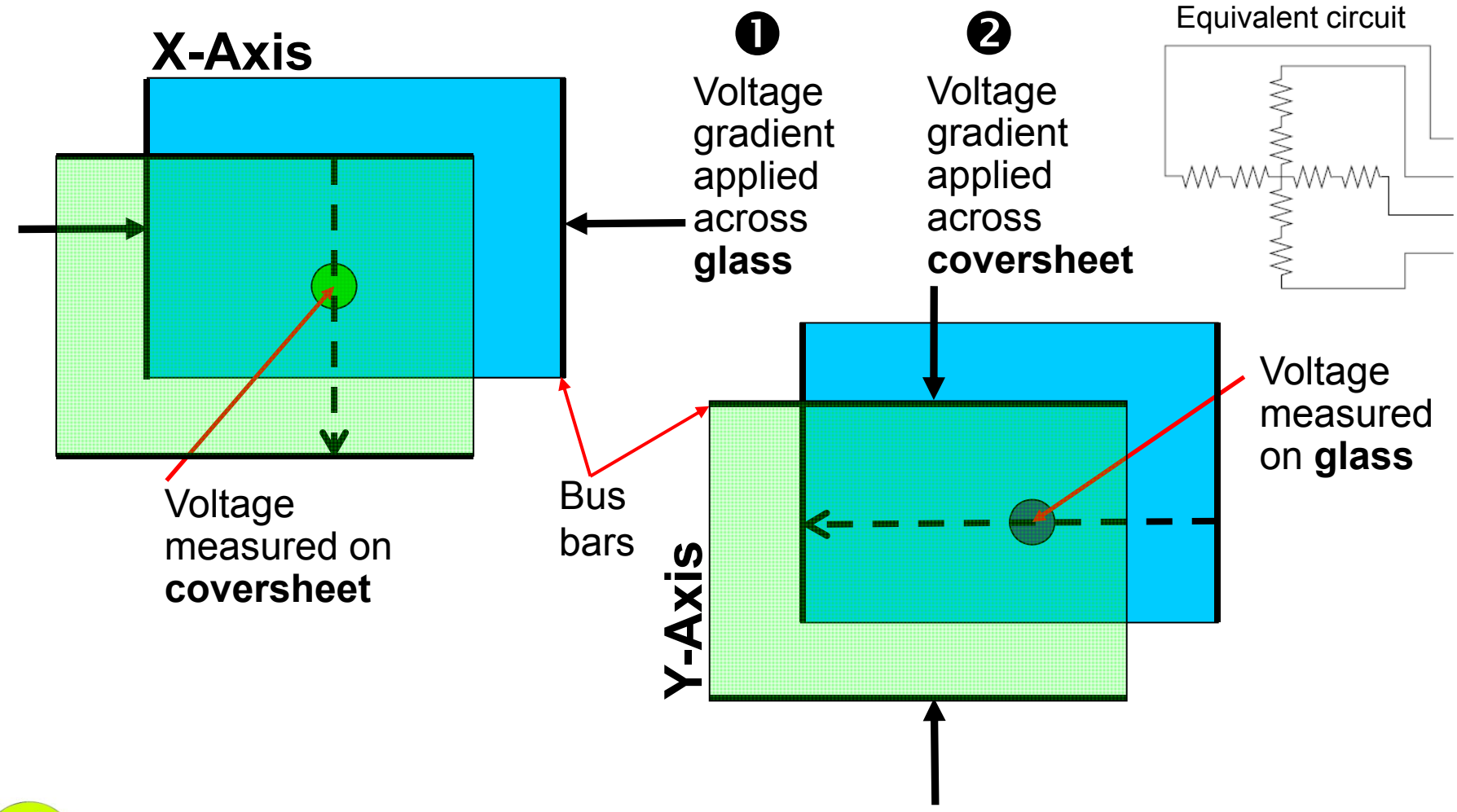


Source: Elo TouchSystems

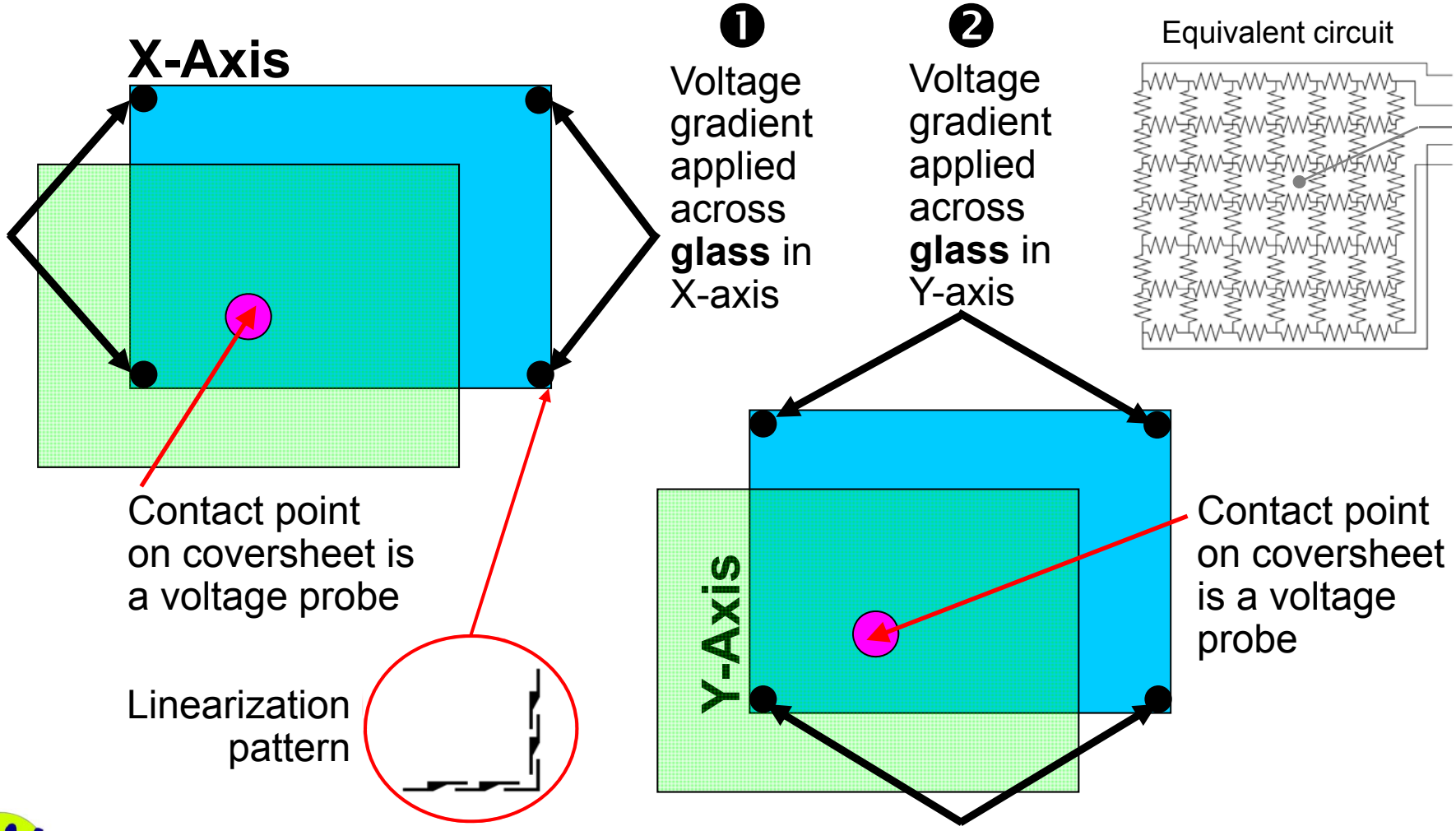


Source: Bergquist

Analog Resistive…2
(4-Wire Construction)



Analog Resistive…3
(5-Wire Construction)



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 (AR, AG, AF, AC, AB), 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

Source: Liyitec

Source: Microchip

Analog Resistive…6

- **Disadvantages**
  - Not durable (PET top surface is easily damaged)
  - Poor optical quality (10%-20% light loss)
  - No multi-touch
- **Applications**
  - Mobile devices (shrinking)
  - Point of sale (POS) terminals
  - Automotive
  - Industrial
  - Wherever cost is #1
- **Market share**

	2011
Revenue	12%
Volume	33%

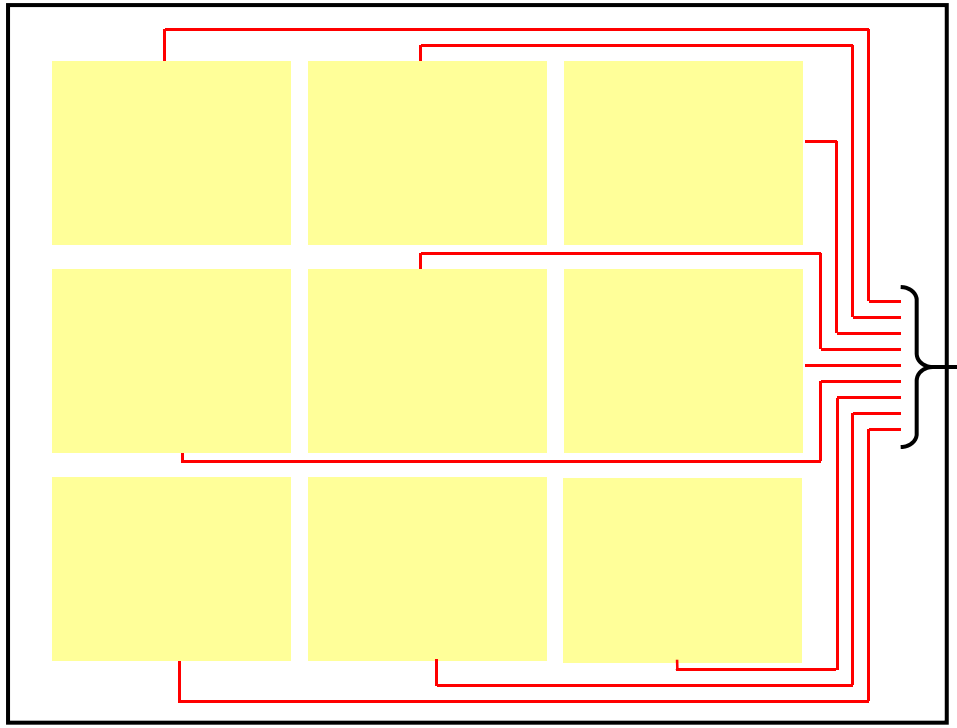
Analog Resistive…7

- **Suppliers**
  - Nissha, Young Fast, EELY, Shoei, Fujitsu Components, SMK, Nanjing Wally, Gunze, Panasonic, J-Touch, Liyitec, Mutto…
  - 60+ suppliers
- **Market trends**
  - Analog resistive is shrinking in units and revenue, being replaced by p-cap in most consumer applications
  - Analog resistive is still significant in commercial applications, especially POS and industrial
  - Analog resistive is still important in mobile phones in Asia because of stylus capability
    - Replacing this usage realistically requires a passive stylus, which requires a very high SNR and/or an ITO-replacement sensor material with low resistivity

Analog Multi-Touch Resistive

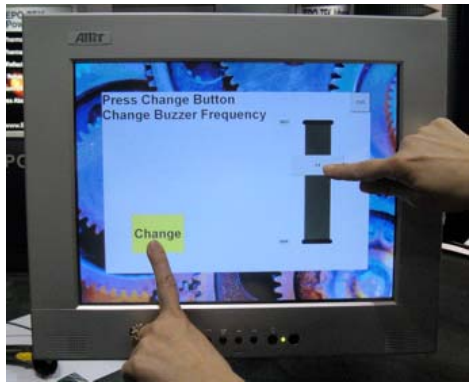
Analog Multi-Touch Resistive…1

❖ **Segmented type (commercial)**



Multi-Touch Controller

Opaque switch panel (the original purpose of matrix resistive)

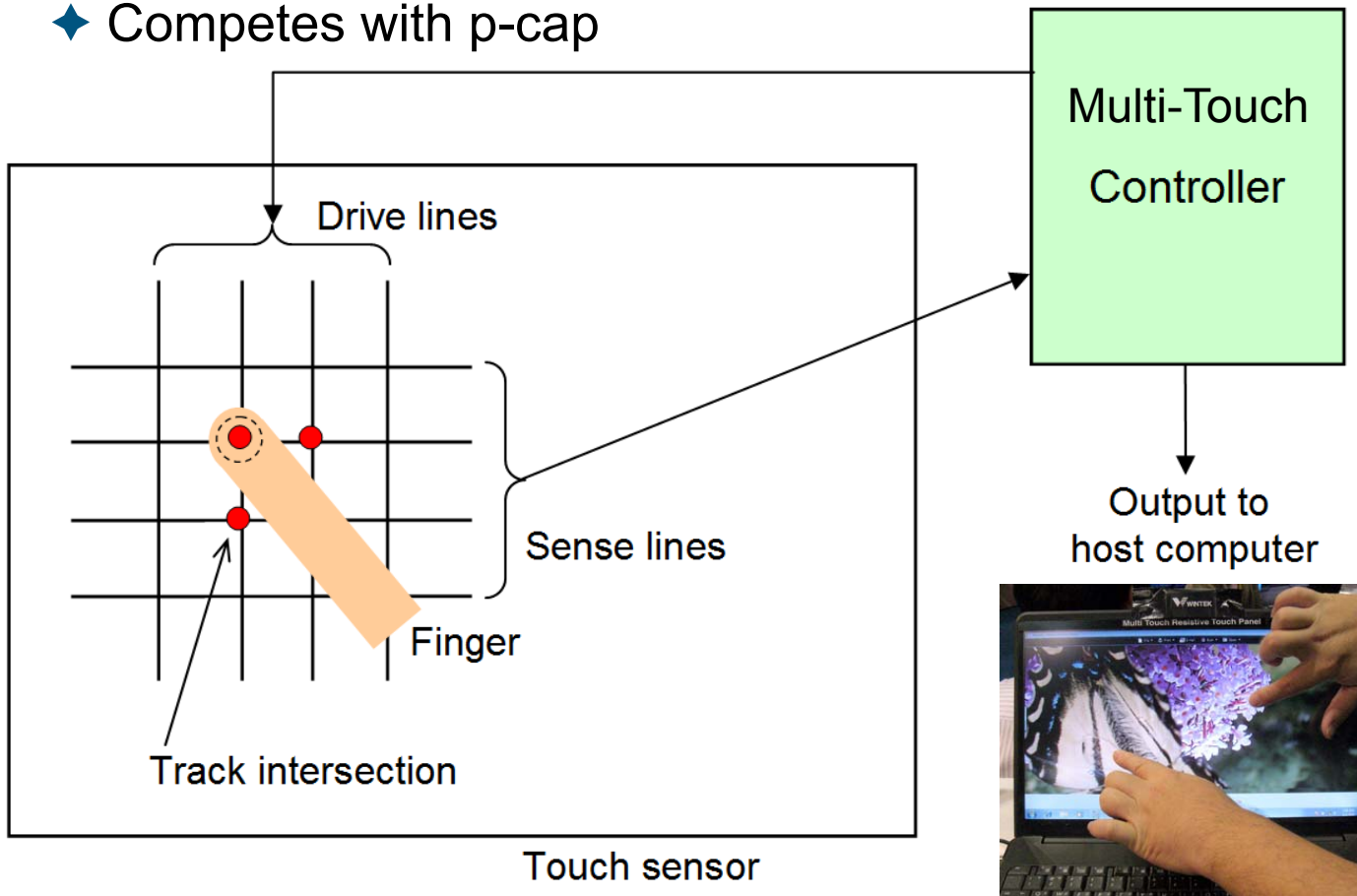


Source: Apex

- ✦ Touch sensor
  - Single-layer (shown)
  - Two-layer matrix

Analog Multi-Touch Resistive…2

- **"All points addressable" (APA) type**
  - Competes with p-cap

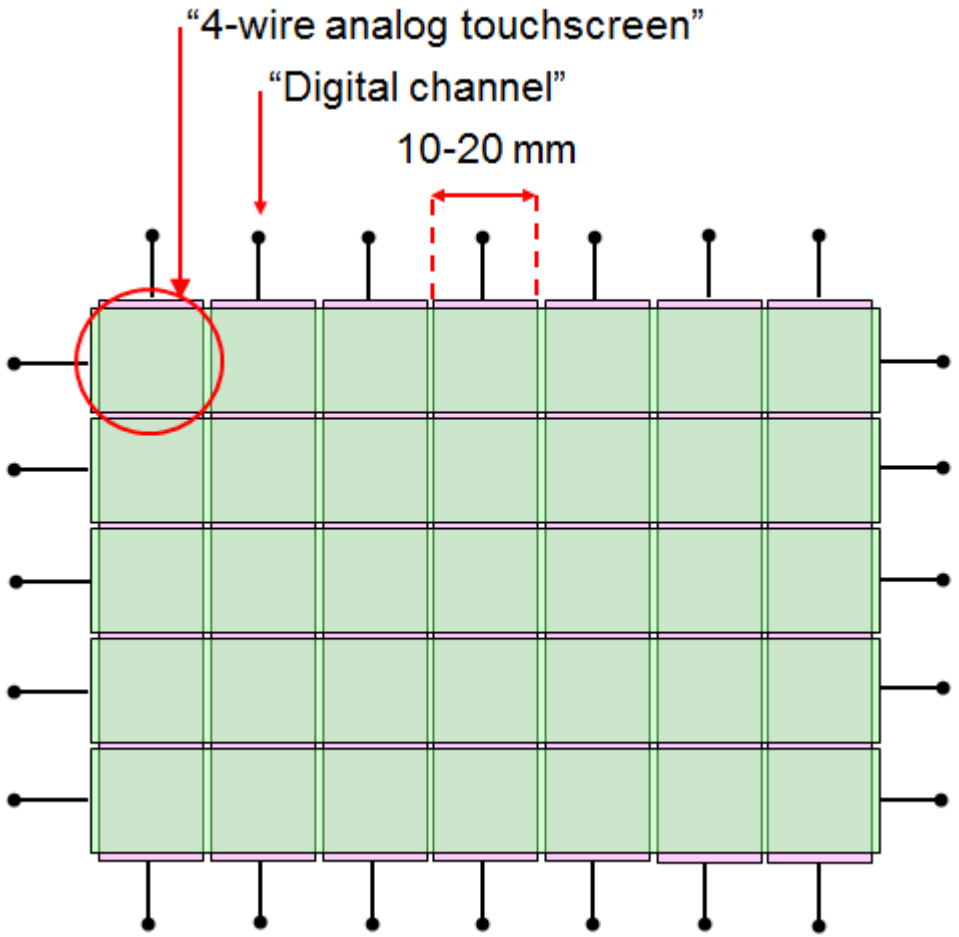


Source: Photo by Author

Analog Multi-Touch Resistive…3

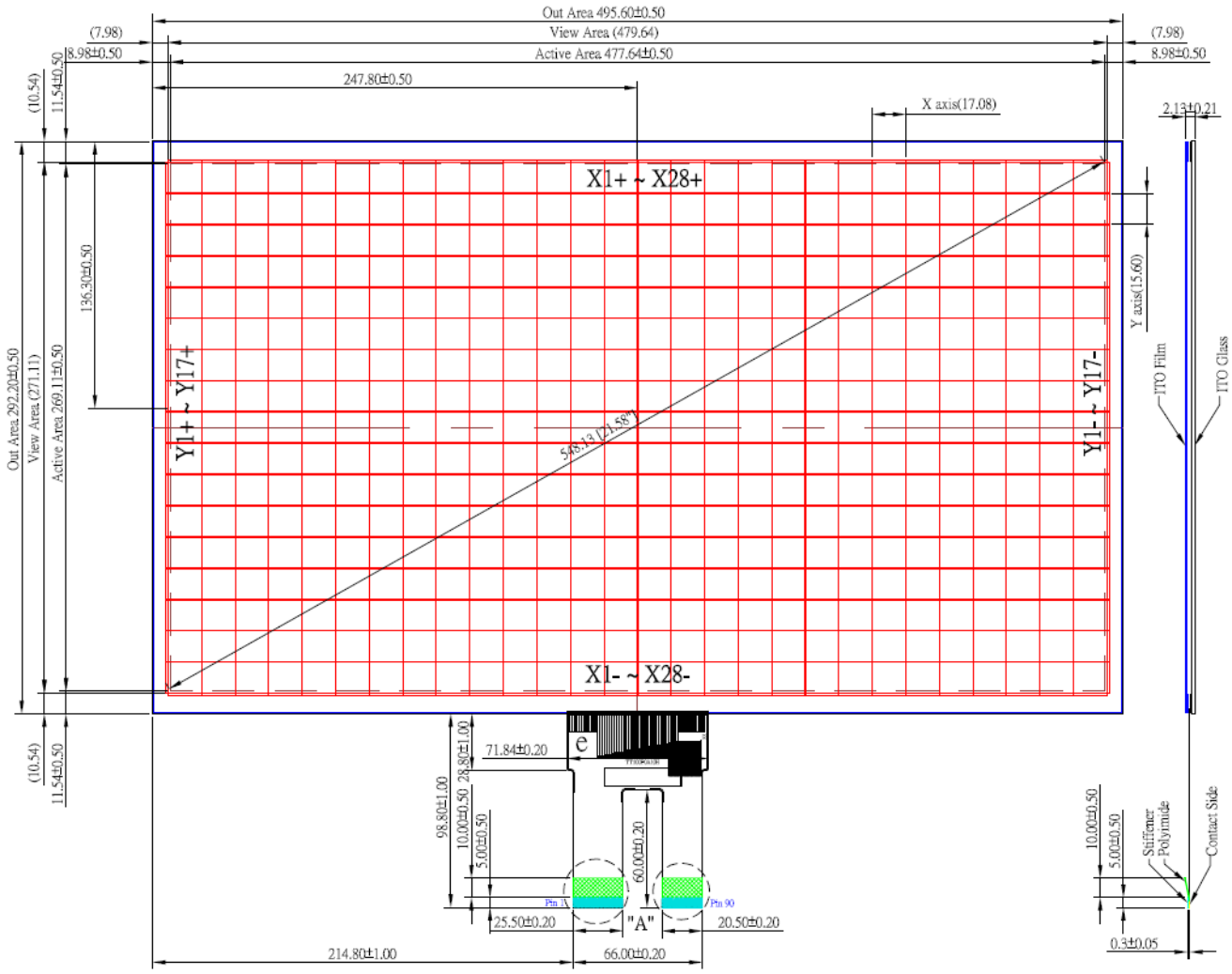
- **Multiple names**
  - AMR (**A**nalog **M**ulti-Touch/**M**atrix **R**esistive)
  - MARS (**M**ulti-Touch **A**nalog **R**esistive **S**ensor
  - "Hybrid analog-digital"
- **Primary limitation**
  - Can't touch with two fingers on the same square

Typical AMR design for consumer product



Source: Author

Analog Multi-Touch Resistive…4



Actual Product

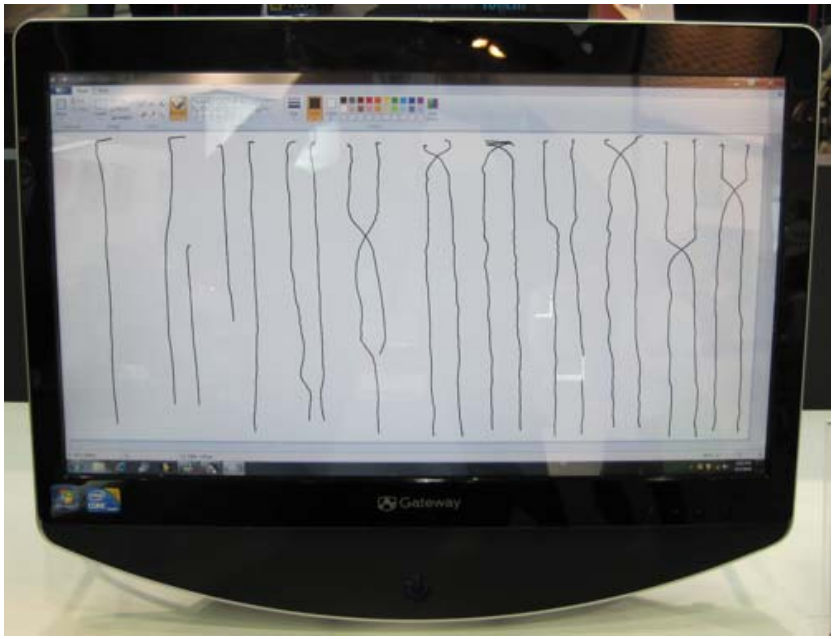
21.5” analog multi-touch resistive by eTurboTouch

28 x 17 lines
= 17 mm x 16 mm squares
(90 pins)

23” = 35 x 22 lines
15 mm x 13 mm
(114 pins)

Analog Multi-Touch Resistive…5

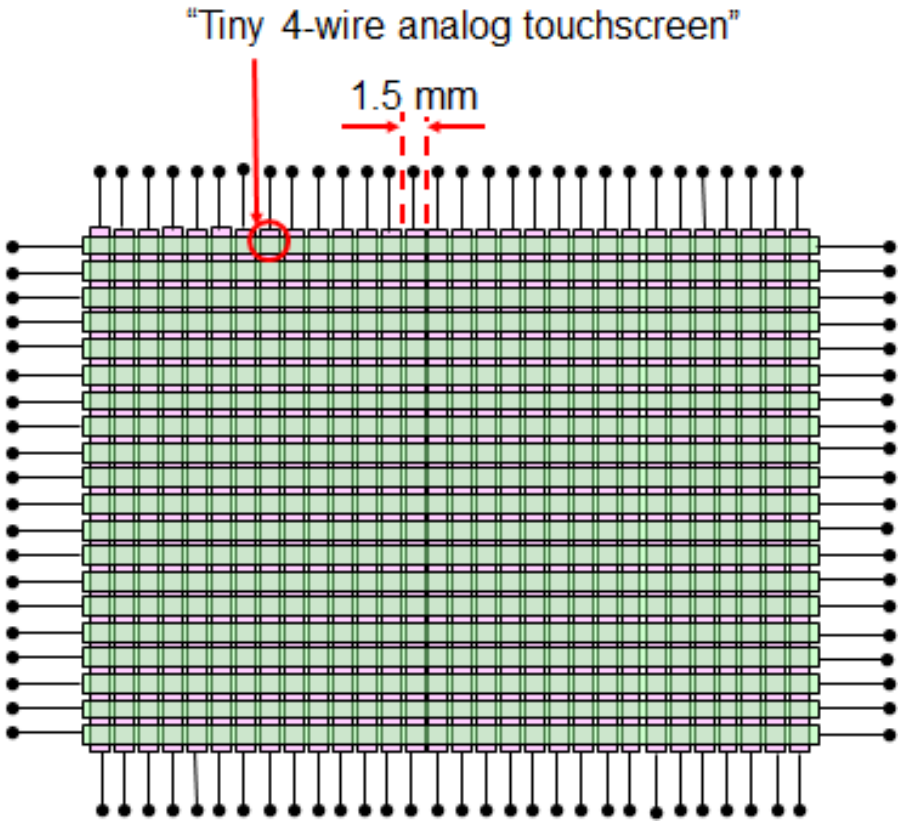
- **Gateway ZX6910 AiO with 23” AMR touchscreen from eTurboTouch**
  - Example of a failed consumer product with 15x13 mm AMR
    - Drawing parallel lines with two closely held fingers



Source: Photos by Author

Analog Multi-Touch Resistive…6

- **Stantum's variation (iVHS)**
  - "Interpolated Voltage-Sensing Matrix", sometimes called "digital resistive"
  - Stantum's strategy is to license controller IP to IC manufacturers
    - ST Micro & SMSC
    - 250-290 I/O's per chip
  - Aimed at tablets
  - Fine pitch results in much higher number of connections than AMR (400+ on a 10" tablet screen)



Source: Author

Analog Multi-Touch Resistive…7

- **Stantum's successes**
  - Co-developed a pen & finger solution with Nissha for 5.7" to 12" tablets (*To be announced on Monday*)
  - Licensed IP to a US-based semiconductor vendor developing a controller optimized for 5.7" to 12" tablets
  - Design win with a tier-1 OEM for a pen & finger A4 e-reader targeted at education and note-taking

  - Two 7" tablets for military applications (one by Harris)
  - 10.4" professional lighting-control application (Europe)
  - Signed a licensing agreement with a tier-1 OEM for a mobile enterprise tablet

Analog Multi-Touch Resistive…8

- One of Stantum's shipping OEM products

Source: Harris

"A new 7-inch Android tablet that's so hard-as-nails it would make a Galaxy Tab go home and call its mother" (*Engadget*)

Analog Multi-Touch Resistive…9

- **Variations (summary)**
  - Segmented, for vertical-market applications
  - All points addressable (APA), competes with p-cap
    - Large-square (AMR, multiple suppliers): Failed consumer products
    - Medium-square (Touch International): Successful in commercial
    - Small-square (Stantum): Successful in commercial
- **Constructions**
  - Film/Glass, Film/Film, etc. (same as analog resistive)
- **Options**
  - Technically same variety as analog resistive, but less demand
- **Size range**
  - 3” – 25” for AMR, but not actually in production in all sizes
  - 5.7” to 12” for Stantum’s iVSM

Analog Multi-Touch Resistive…10

- **Controllers**
  - AD Semi & others for AMR
  - Home-grown for some like Touch International
  - ST Micro & SMSC for Stantum
    - Number of touch points is controller-dependent (2-10)
- **Advantages**
  - Multi-touch
  - Simple & familiar resistive technology
  - Lower cost than p-cap
- **Disadvantages**
  - Poor durability (PET top surface)
  - Poor optical performance
  - Non-zero touch force
- **Applications**
  - Commercial mobile & stationary applications

Analog Multi-Touch Resistive…11

- **Market share**
  - << 1%
- **Suppliers**
  - eTurboTouch, Touch International, Stantum, Mildex, Mutto, EETI…
- **Market trends**
  - No really successful consumer products
    - Cost too high, poor performance
  - Limited success in commercial applications
    - Cost too high for the limited benefits

Stantum's music controllers were the first commercial product to use multi-touch (in 2005; the company was then known as Jazz Mutant)

Source: Jazz Mutant

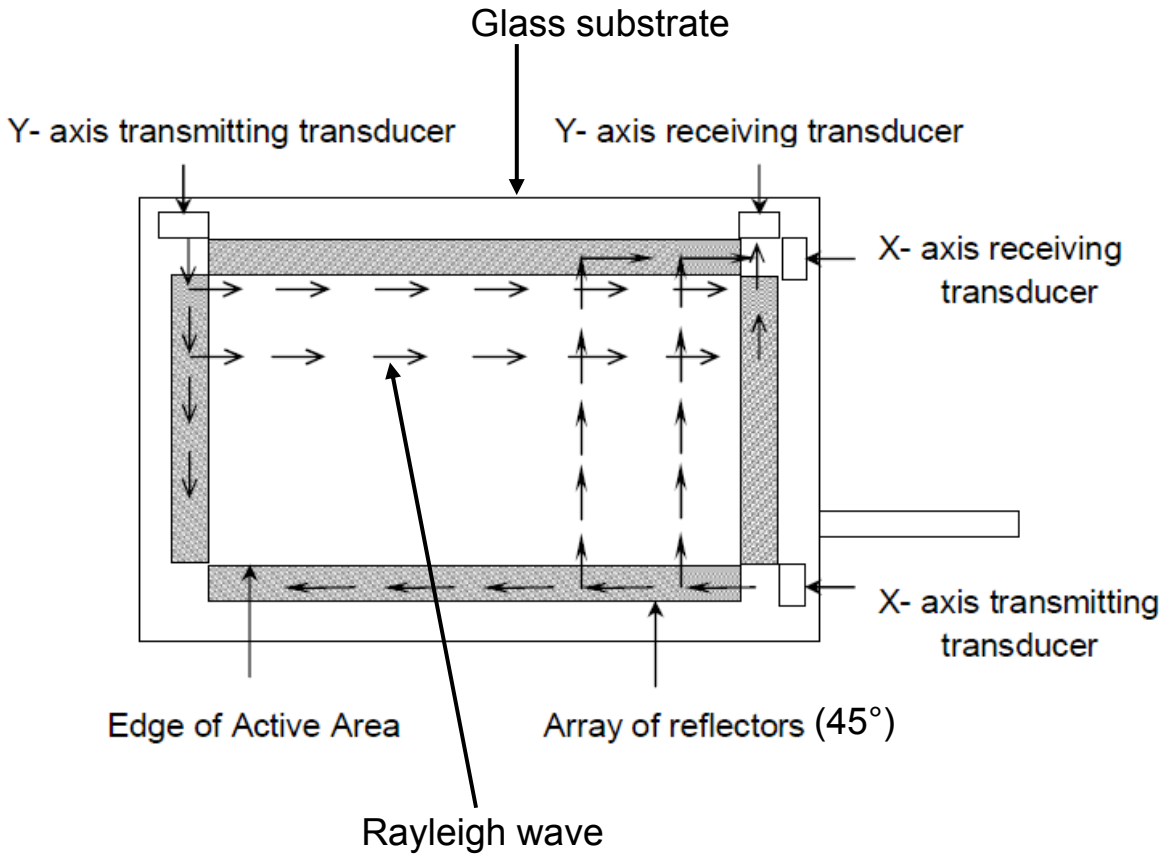
Acoustic Touch Technologies

- Surface Acoustic Wave (SAW)
- Acoustic Pulse Recognition (APR by Elo)
- Dispersive Signal Technology (DST by 3M)

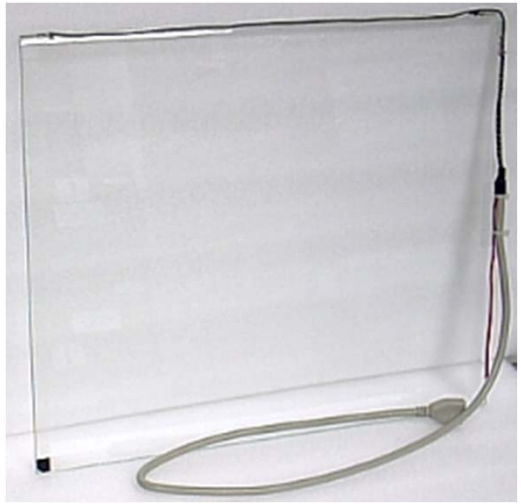
Source: Kodak

Surface Acoustic Wave

Surface Acoustic Wave…1

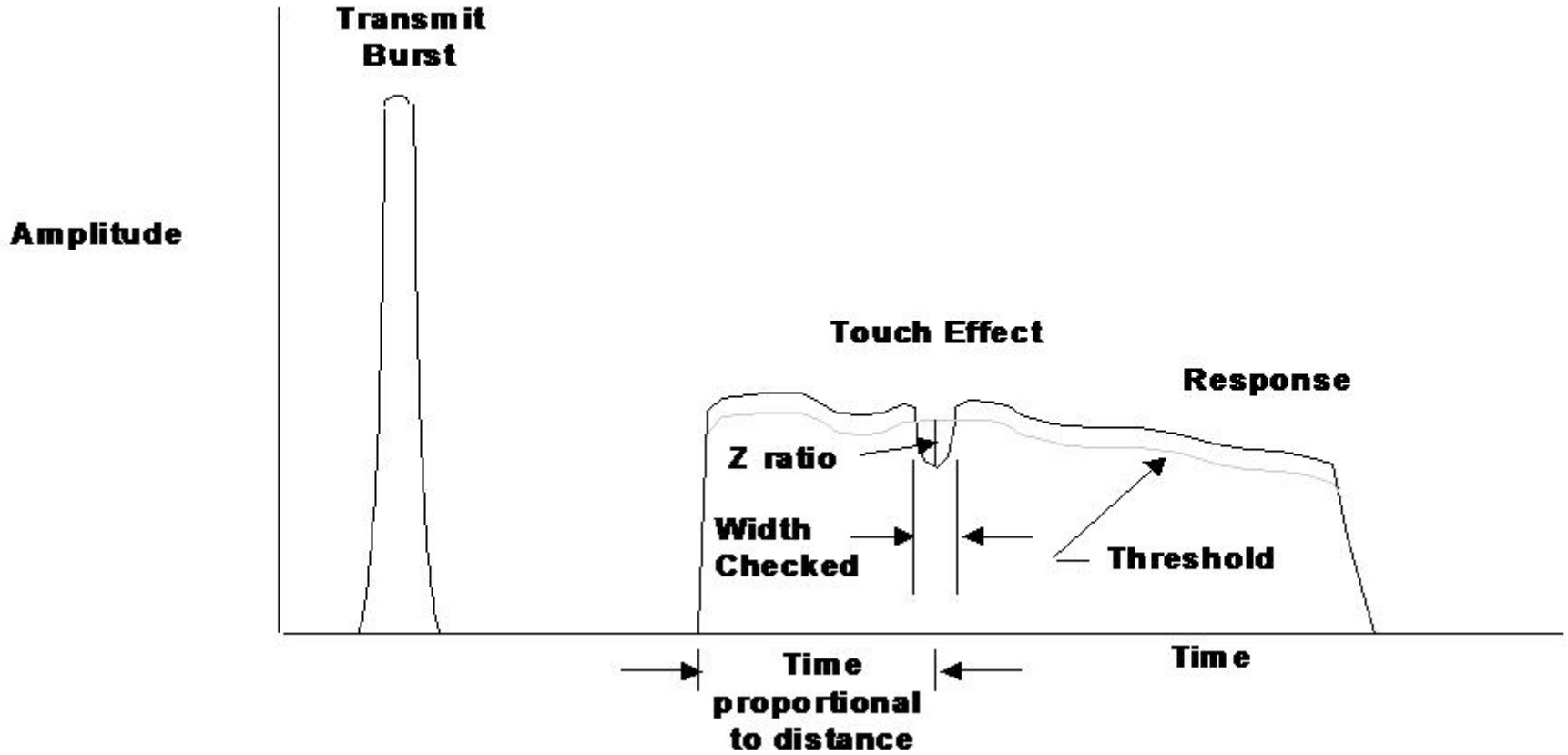


Source: Onetouch



Source: A-Touch

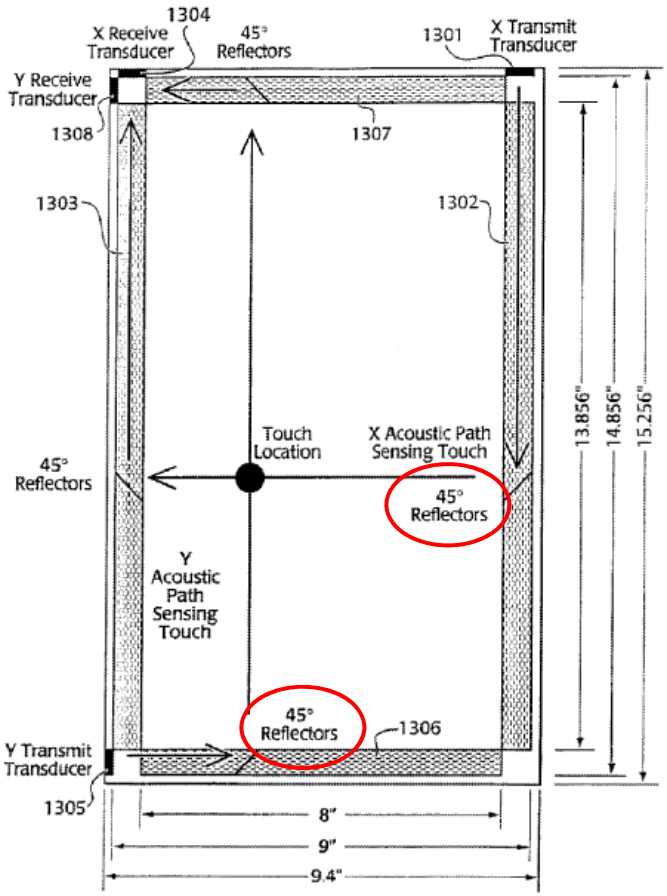
Surface Acoustic Wave…2



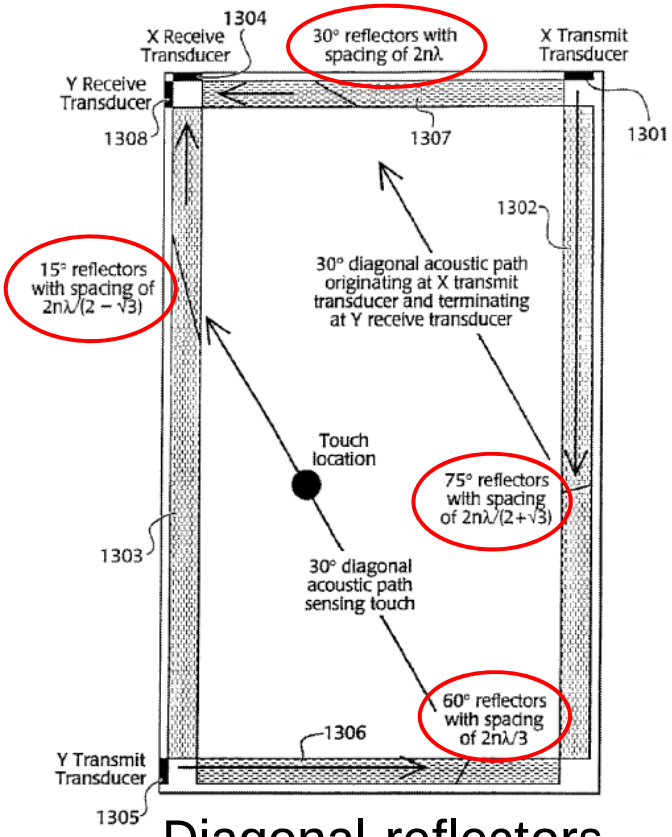
Source: Elo TouchSystems

Surface Acoustic Wave…3

- **How two touches are supported by SAW**



X & Y reflectors



Diagonal reflectors for “third axis” data

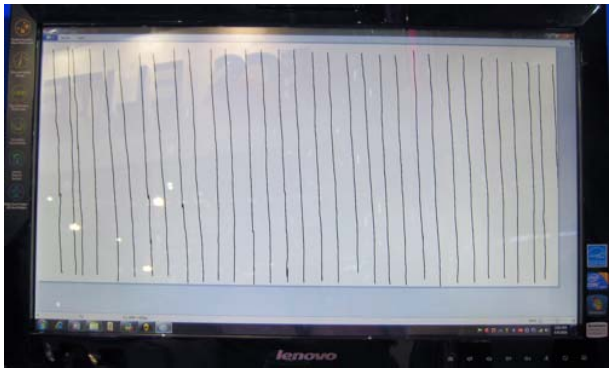
94

Source: US Patent Application 2010/0117993

Surface Acoustic Wave…4

- **Two-touch SAW from Elo/Tyco Electronics**
  - Was shipping in the 23” Lenovo A700 all-in-one desktop

Source: Lenovo



2-finger vertical lines

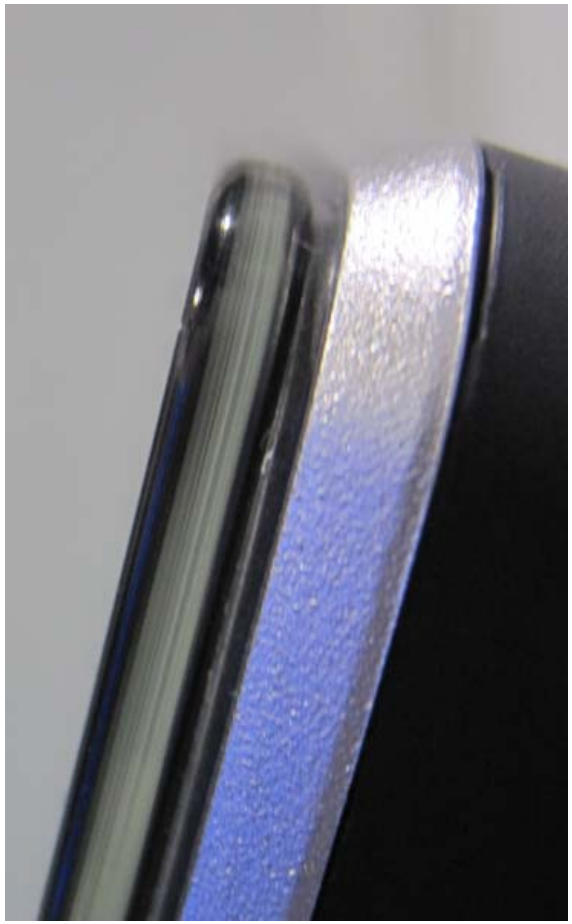
2-finger diagonal lines

Source: Photos by author

“There is no perfect touch technology”

Surface Acoustic Wave…5

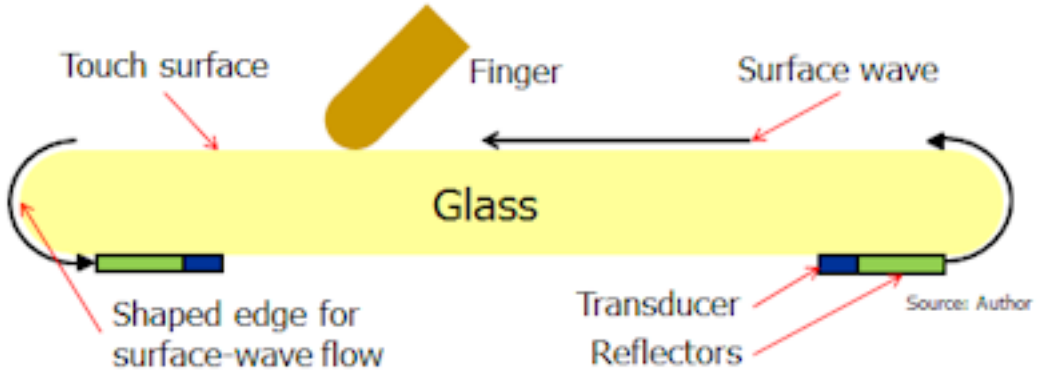
- Elo TouchSystems' zero-bezel SAW



Source: Photos by Author

Surface Acoustic Wave…6

- **Both Elo TouchSystems and General Touch (China) are emphasizing zero-bezel and two-touch SAW**
  - This makes sense because SAW and Win7 will be important in commercial applications for at least the next five years
  - Both companies put the piezos and reflectors on the back of the glass to achieve zero-bezel
  - For two-touch zero-bezel, Elo uses a single set of multiplexed reflectors on the back of the glass (see US7629969) instead of the two sets of reflectors used on top of the glass for two-touch normal bezel



Surface Acoustic Wave…7

- **Variations (summary)**
  - Single-touch vs. two-touch
  - Zero-bezel vs. standard bezel
  - Ruggedization, dust-proofing, surface treatments, etc.
- **Size range**
  - 6” to 52” (but some integrators won’t use it above 32”)
- **Controllers**
  - Proprietary
- **Advantages**
  - Clear substrate (high optical performance)
  - Very durable
  - Can be vandal-proofed with tempered or CS glass
  - Finger, gloved hand & soft-stylus activation

Surface Acoustic Wave…8

- **Disadvantages**
  - Very sensitive to any surface contamination, including water
  - Requires “soft” (sound-absorbing) touch object
  - Can be challenging to seal
  - Relatively high activation force (50-80g typical)
- **Applications**
  - Kiosks
  - Gaming
- **Market share**

	2011
Revenue	1%
Volume	<1%

Source: Euro Kiosks Network

Surface Acoustic Wave…9

- **Suppliers**
  - Elo TouchSystems, General Touch, Shenzhen Top-Touch, Leading Touch, Shenzhen KeeTouch…
  - 10+ suppliers
- **Market trends**
  - Two-touch and zero-bezel SAW is now available from Elo and General Touch
    - This is significant because it helps protects against the incursion of projected capacitive into SAW's markets
  - SAW will continue to grow through 2017 with only moderate penetration by p-cap
  - Chinese suppliers other than General Touch have significant difficult competing due to distribution and brand limitations

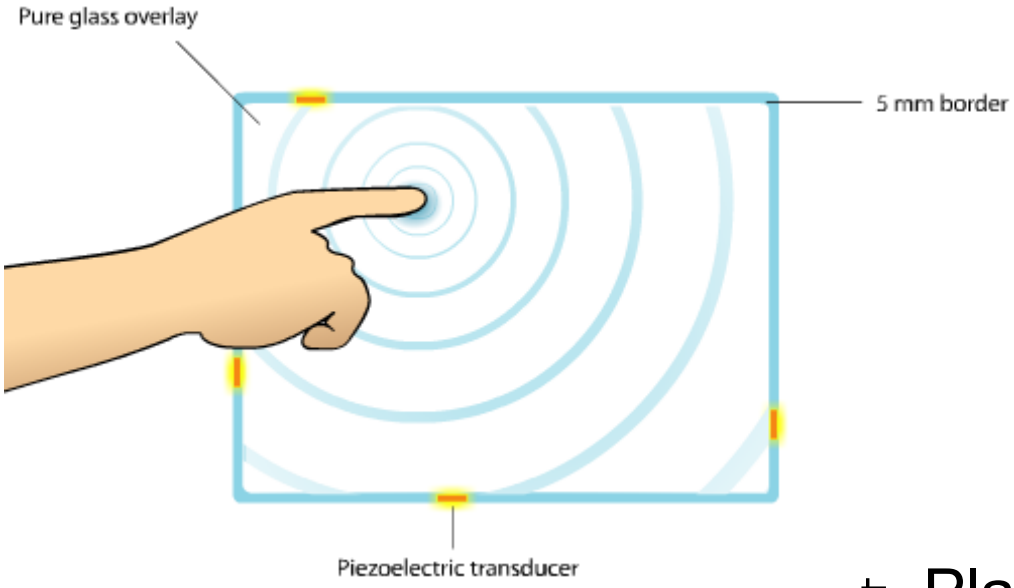
Acoustic Pulse Recognition (APR)

"Zero-Bezel"

Single piece of glass (no bezel); black margin is fired-on glass frit on underside

Source: Elo TouchSystems

Acoustic Pulse Recognition…1



Source: Elo TouchSystems

- Plain glass sensor with 4 piezos on the edges
- Table look-up of bending wave samples (“acoustic touch signatures”)

Acoustic Pulse Recognition…2

- **Variations**
  - "Stationary APR" from 10" to 52" with controller board
  - "Mobile APR" from 2.8" to 10" with controller ASIC
- **Size range**

  2.8" to 52"
- **Controllers**
  - Proprietary
- **Advantages**
  - Works with finger, stylus or any other touch object
  - Very durable & transparent touch sensor
  - Resistant to surface contamination; works with scratches
  - Totally flush top surface ("Zero-Bezel")
  - Very simple sensor (plain glass + 4 piezoelectric transducers)

Acoustic Pulse Recognition…3

- **Disadvantages**
  - No “touch & hold”; no multi-touch
    (both are under development & may appear eventually)
  - Requires enough touch-force (tap) to generate sound
  - Control of mounting method in bezel is critical
- **Applications**
  - POS [e.g., Walgreens], kiosks, gaming, mobile devices
- **Market share**
  - <1% (first production in Elo monitors was at the end of 2006)
- **Supplier**
  - Elo TouchSystems (sole source)
- **Market trends**
  - Elo has begun shipping APR to mobile device OEMs
  - eBook readers are the best fit (elimination of screen overlays)

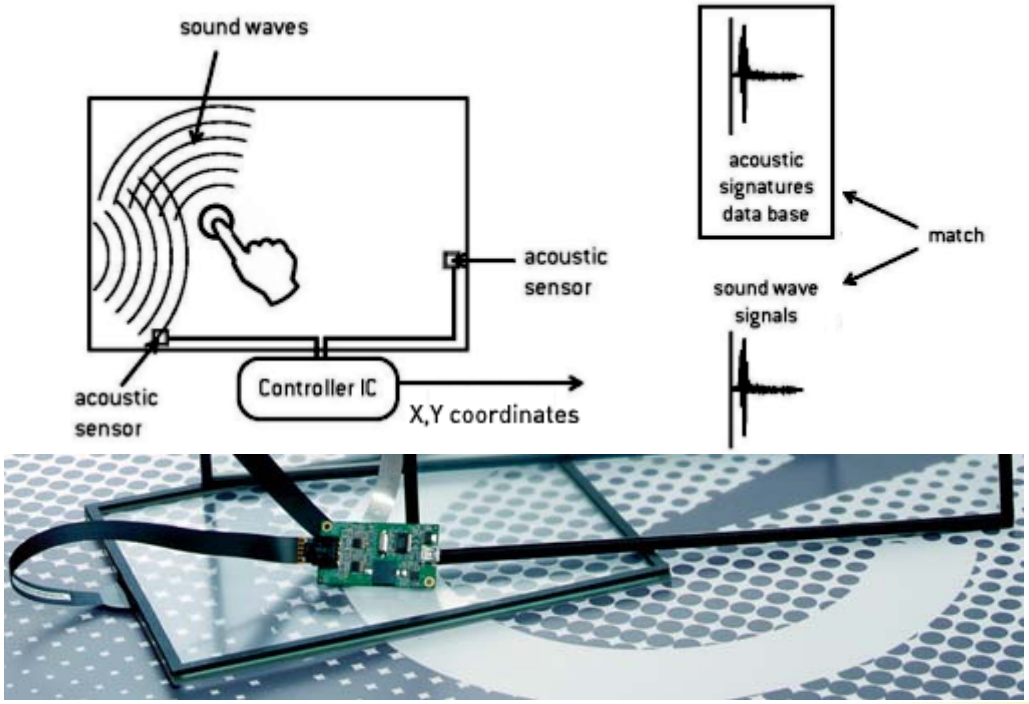
Acoustic Pulse Recognition…4

Elo's "Zero-Bezel" APR with capacitive buttons & scroll-wheel in lower-right corner, all on a single sheet of glass (SID 2009)

Acoustic Pulse Recognition…5

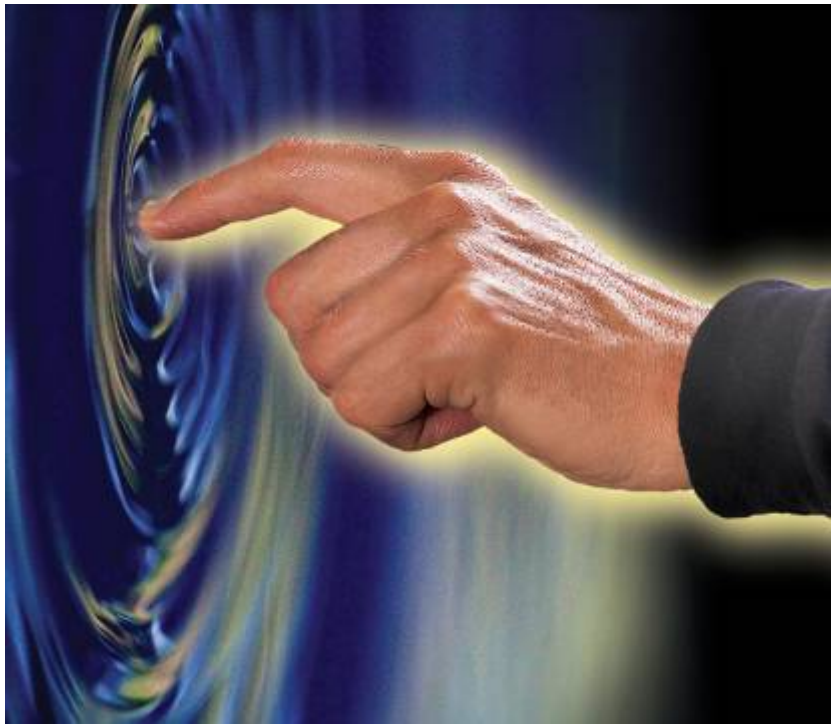
❖ APR and Sensitive Object

- ✦ Elo/Tyco Electronics purchased Sensitive Object ("SO") (www.sensitive-object.com) on 1/27/10 for **$62M**
- ✦ Sensitive Object's technology ("ReverSys") is so similar to APR that the two companies cross-licensed in July, 2007



It's taken Elo quite a lot of time to fully absorb Sensitive Object; new products leveraging both APR and ReverSys should be appearing by the end of 2012

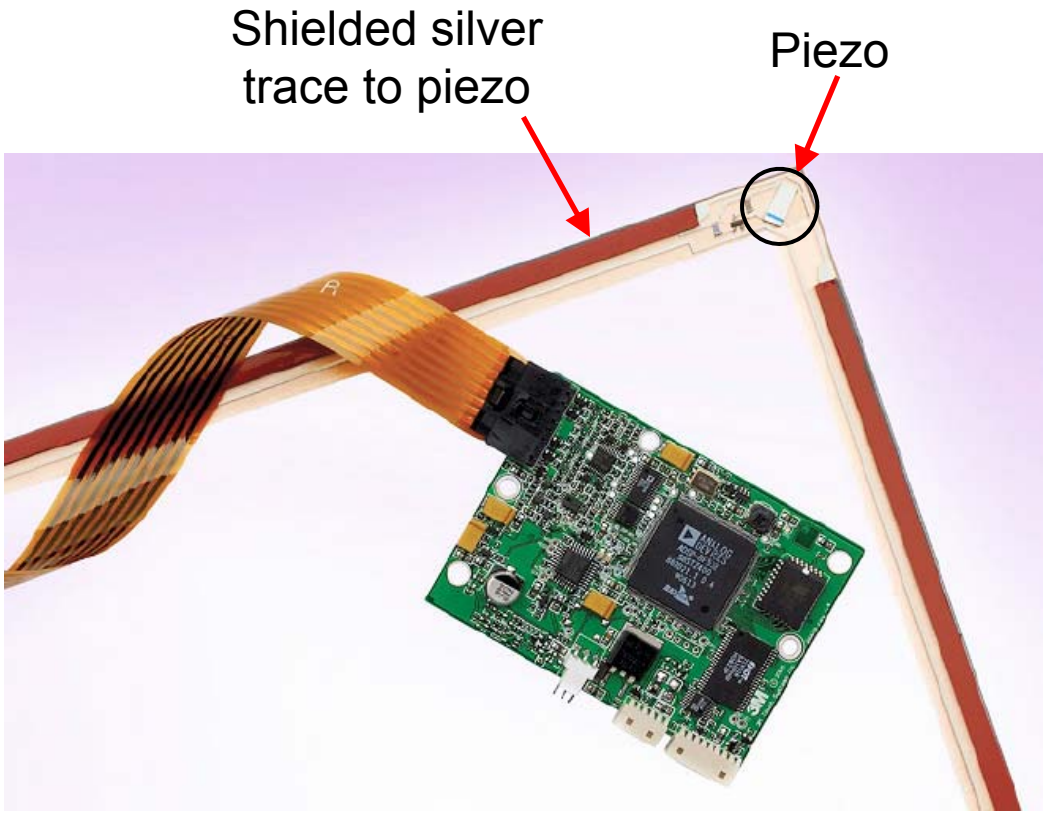
Source: Sensitive Object



Source: 3M

Dispersive Signal Technology (DST)

Dispersive Signal Technology…1

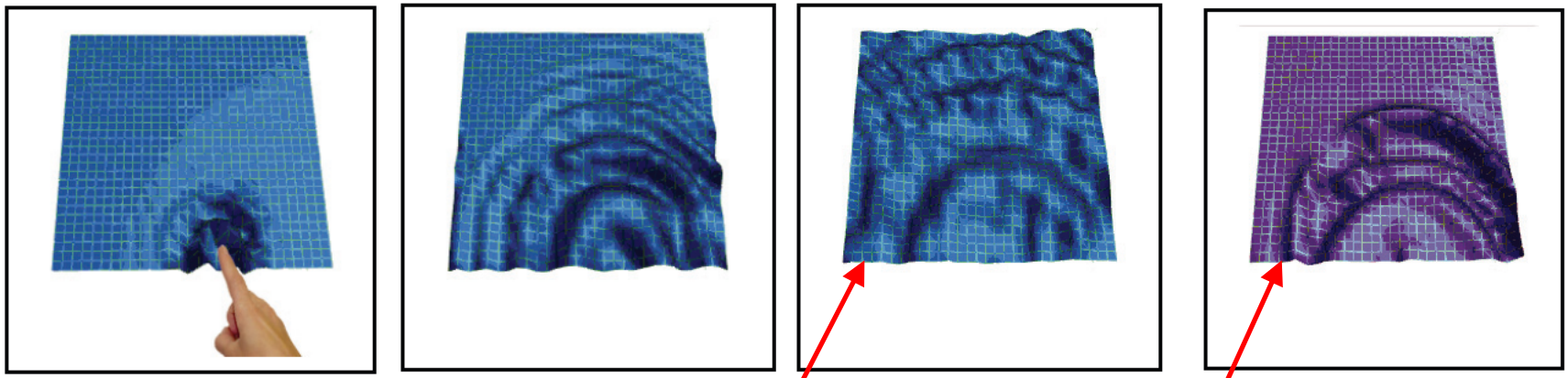


Source: 3M

- Plain glass sensor with 4 piezos in the corners
- Real-time analysis of bending waves in the glass ("time of flight" calculation)

Dispersive Signal Technology…2

- **Visualization of effect of bending waves on a rigid substrate**



Initial Touch Contact

Progressing Dispersion with the Beginning of Reflection Effects Down

Highly Complex Dispersion Pattern with Reflections

Post-Algorithm Pattern

Waveform that would be sampled by APR

Waveform resulting from processing by DST algorithms

Dispersive Signal Technology…3

- **Variations**
  - None
- **Size range**

  32” to 55” (3M recently expanded upper limit from 46” to 55”)
- **Controller**
  - Proprietary
- **Advantages**
  - Very simple sensor (plain glass + 4 piezoelectric transducers)
  - Works with finger, stylus or any other touch object
  - Very durable & transparent touch sensor
  - Operates with static objects or scratches on the touch surface
  - Fast response; highly repeatable touch accuracy; light touch

Dispersive Signal Technology…4

- **Disadvantages**
  - No “touch & hold”; no multi-touch
  - Control of mounting method in bezel is critical
- **Applications**
  - Interactive digital signage; point-of-information (POI)
- **Market share**
  - < 1%
- **Supplier**
  - 3M (sole source)
- **Market trends**
  - DST still has a relatively low market profile due to 3M’s very conservative rollout
  - 3M avoids cannibalizing their surface-capacitive sales (<32”)

APR vs. DST Technology Comparison

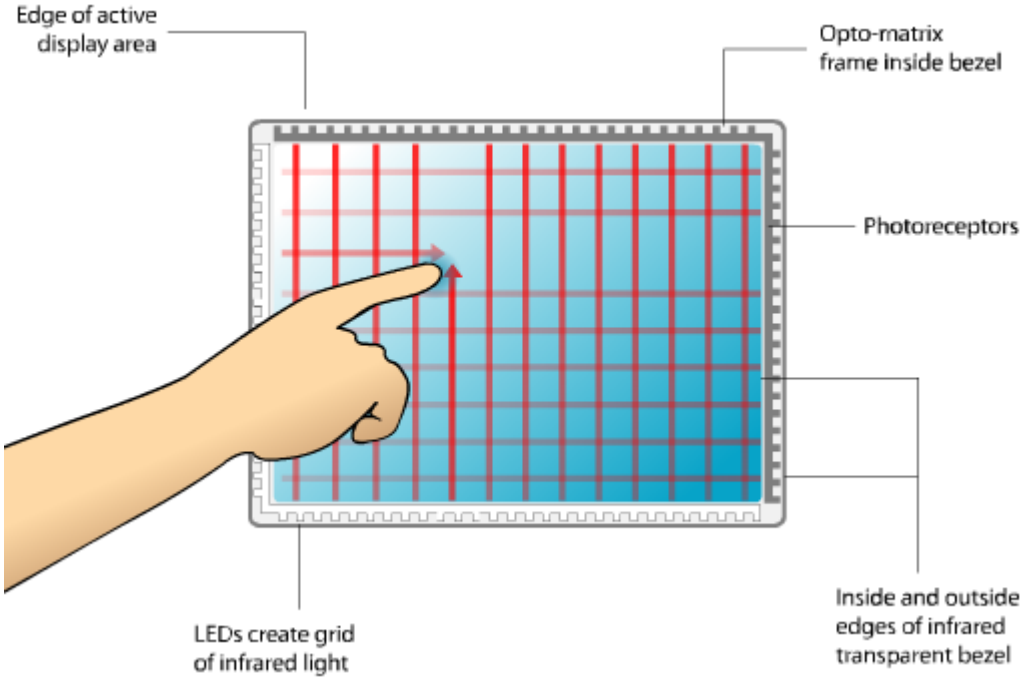
Characteristic	APR	DST	Notes
Size range	2.8”-52”	32”-46”	3M surface capacitive is 5.7”-32”
Methodology	Table lookup	Real-time	
Measurement	Bending waves	Bending waves	
Multi-touch	Under development	Gestures announced	3M’s “multi-touch gestures” only work with two moving points
Touch & hold	Under development	No	
Activation force	Moderate	Light	
Controller	Chip (mobile) Board (fixed)	Board (fixed)	
Mounting	Critical	Critical	
Availability	In monitors; components for mobile devices	In monitors	Neither technology has reached the “drop-in touch-screen” component state yet
Others	Similar	Similar	Performance, materials, surface treatment, interface, etc.

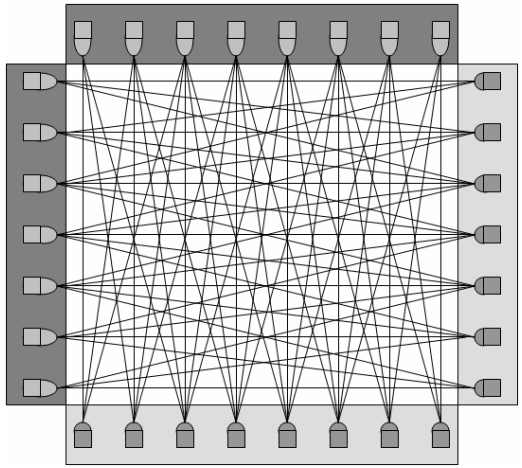
Optical Touch Technologies

- Traditional Infrared
- Waveguide Infrared (DVT by RPO)
- “High-Finger-Count” Multi-Touch Infrared
- Camera-Based
- Planar Scatter Detection (PSD)
- Vision-Based

Traditional Infrared

Traditional Infrared…1





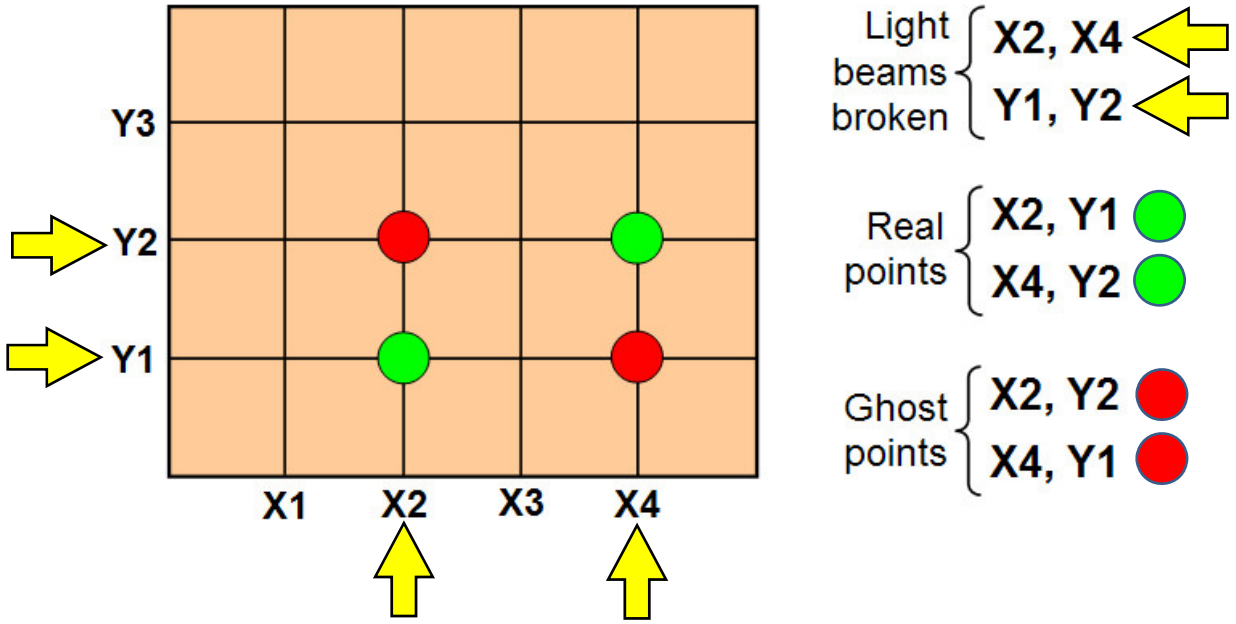
Source: Elo TouchSystems

Traditional Infrared…2

- **Variations**
  - Bare PCA vs. enclosed frame; frame width & profile height; no glass substrate; enhanced sunlight immunity; force-sensing
- **Size range**
  - 8” to 150”
- **Controllers**
  - Mostly proprietary, except IRTouch
- **Advantages**
  - Scalable to very large sizes
  - Multi-touch capable (2 touches, but with “ghost” points)
  - Can be activated with any IR-opaque object
  - High durability, optical performance and sealability
  - Doesn’t require a substrate

Traditional Infrared…3

- **Multi-touch in traditional infrared**
  - 2+ touches
  - "Ghost" points are the problem, and **there's no good solution**



Source: Drawing by Author

Traditional Infrared…4

- **Disadvantages**
  - Profile height (IR transceivers project above touch surface)
  - Bezel must be designed to include IR-transparent window
  - Sunlight immunity can be a problem in extreme environments
  - Surface obstruction or hover can cause a false touch
  - Low resolution
  - High cost

- **Applications**
  - POS
  - Kiosks
  - Large displays (digital signage)
- **Market share**

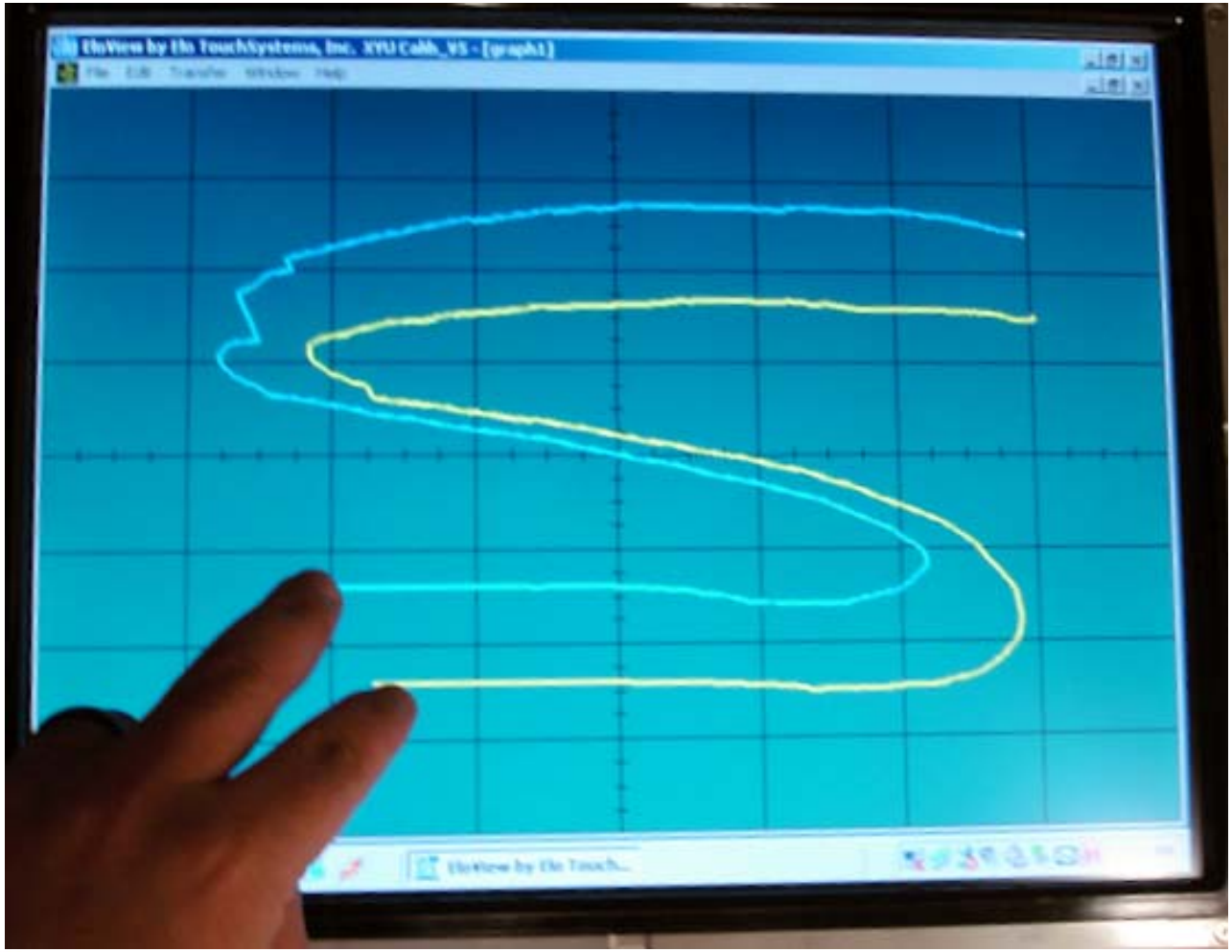
	2011
Revenue	1%
Volume	<1%

Traditional Infrared…5

- **Suppliers**
  - Elo TouchSystems, IRTouch, OneTouch, Minato, Nexio, Neonode…
  - 10+ suppliers
- **Market trends**
  - Interest in IR is growing as Asian vendors bring down prices, large displays become more common, and digital signage becomes more affordable
  - IR is growing, but isn't keeping up with the market

50" plasma display with infrared touch-screen from Netrax

Traditional Infrared…6



Elo's ill-fated "XYU" multi-touch traditional infrared. The two-touch version was first shown as an engineering prototype in 2008; it never made it out of the lab due to excessive cost

Traditional Infrared…7

- **Mobile Infrared:** Neonode mobile phone implemented with traditional IR touch (2009)
  - Same battery life as iPhone
  - Low profile height (~1.7mm)
  - Finger-only
  - No multi-touch
- *Neonode couldn't complete in the cellphone market and went bankrupt in 2009*

Source:
Neonode &
Pen Computing

Sony e-book readers (2010)

Source: PC World

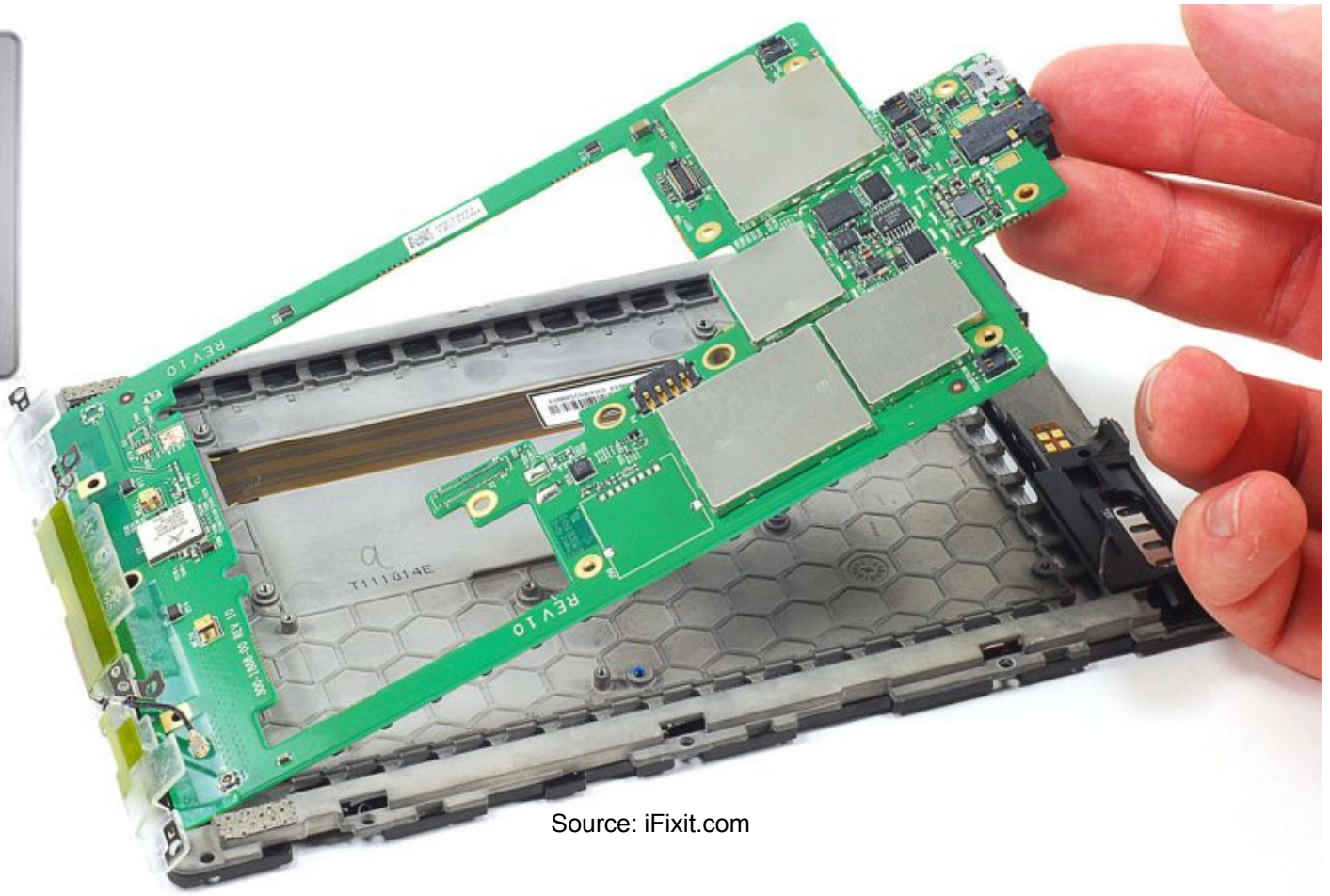
Traditional Infrared…8

- **Neonode in 2012 has become the largest supplier of touchscreens for eReaders!**
  - Amazon Kindle and B&N Nook both use Neonode
  - Neonode has strong IP on methods of minimizing border width and profile height
  - Neonode has announced design wins in e-readers, smartphones, tablets, toys, printers, gaming consoles, in-flight infotainment systems, and automotive consoles
    - How much of it is real is unclear
  - Neonode doesn't supply any actual hardware, just licenses and engineering implementation consulting services

Traditional Infrared…9

- **Neonode in Kindle Touch Teardown**

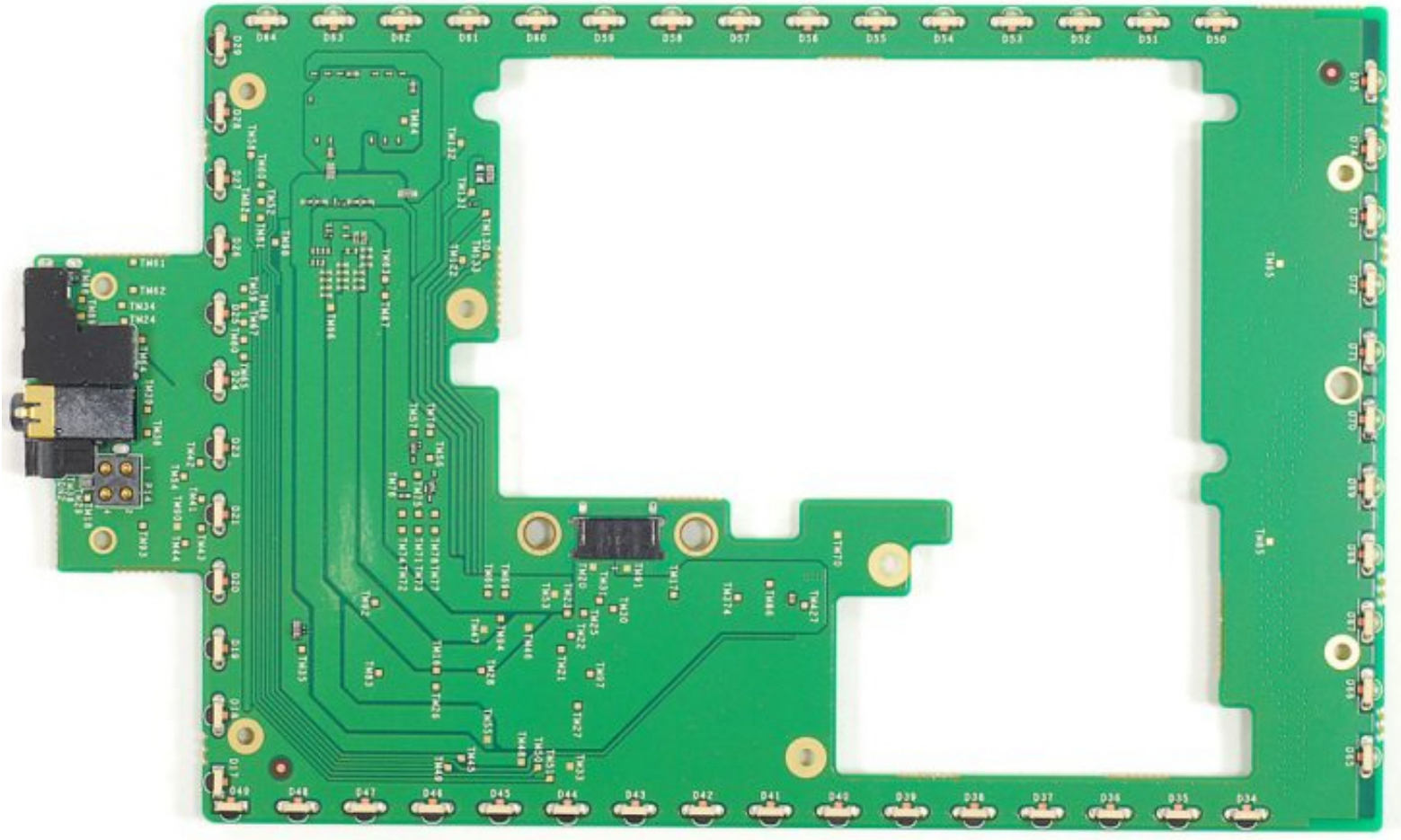
Source: Amazon



Source: iFixit.com

Traditional Infrared…10

- Neonode in Kindle Touch Teardown



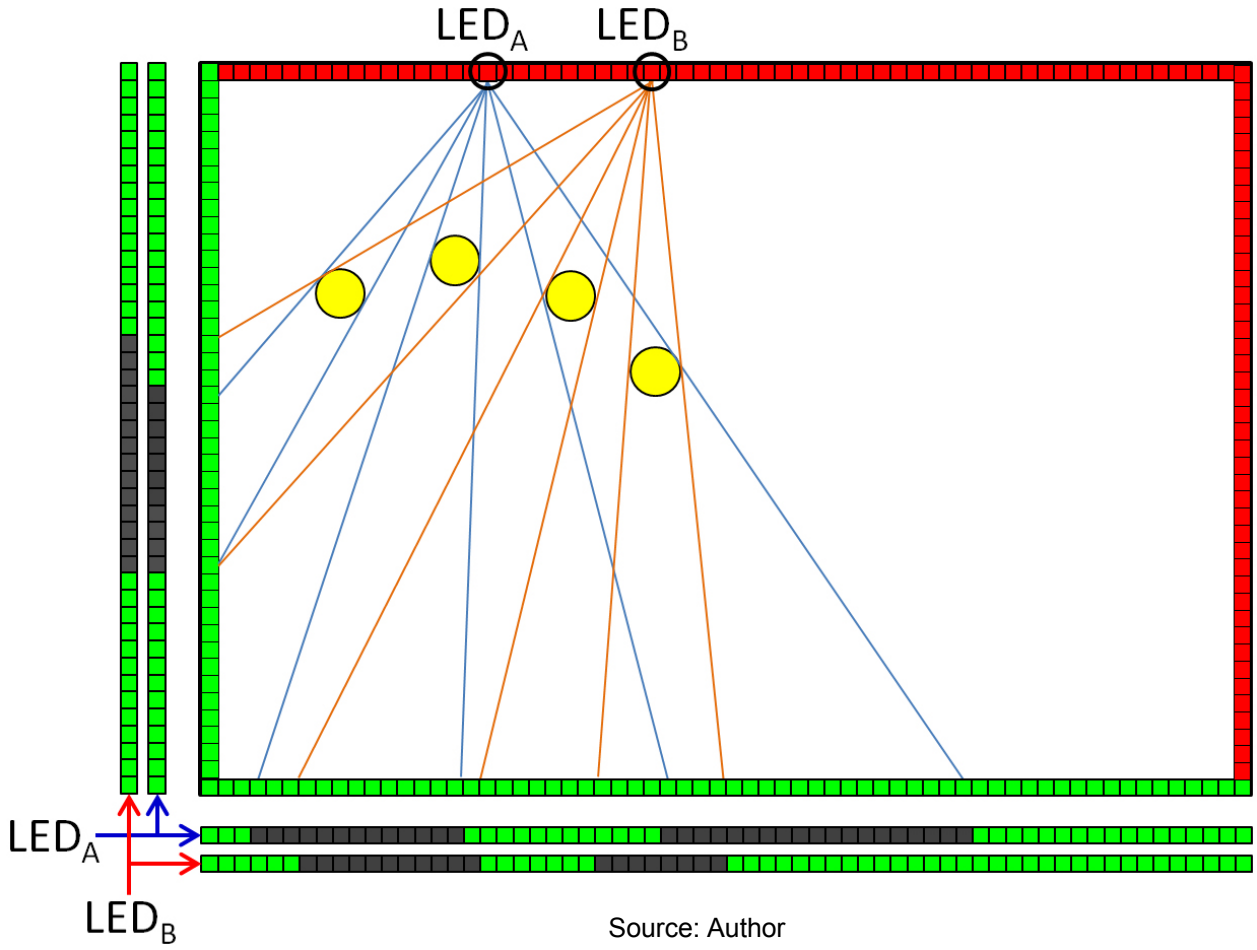
Source: iFixit.com

Source: Citron

"High Finger-Count" Multi-Touch Infrared

“High Finger-Count” Multi-Touch Infrared…1

- “PQ Labs” method

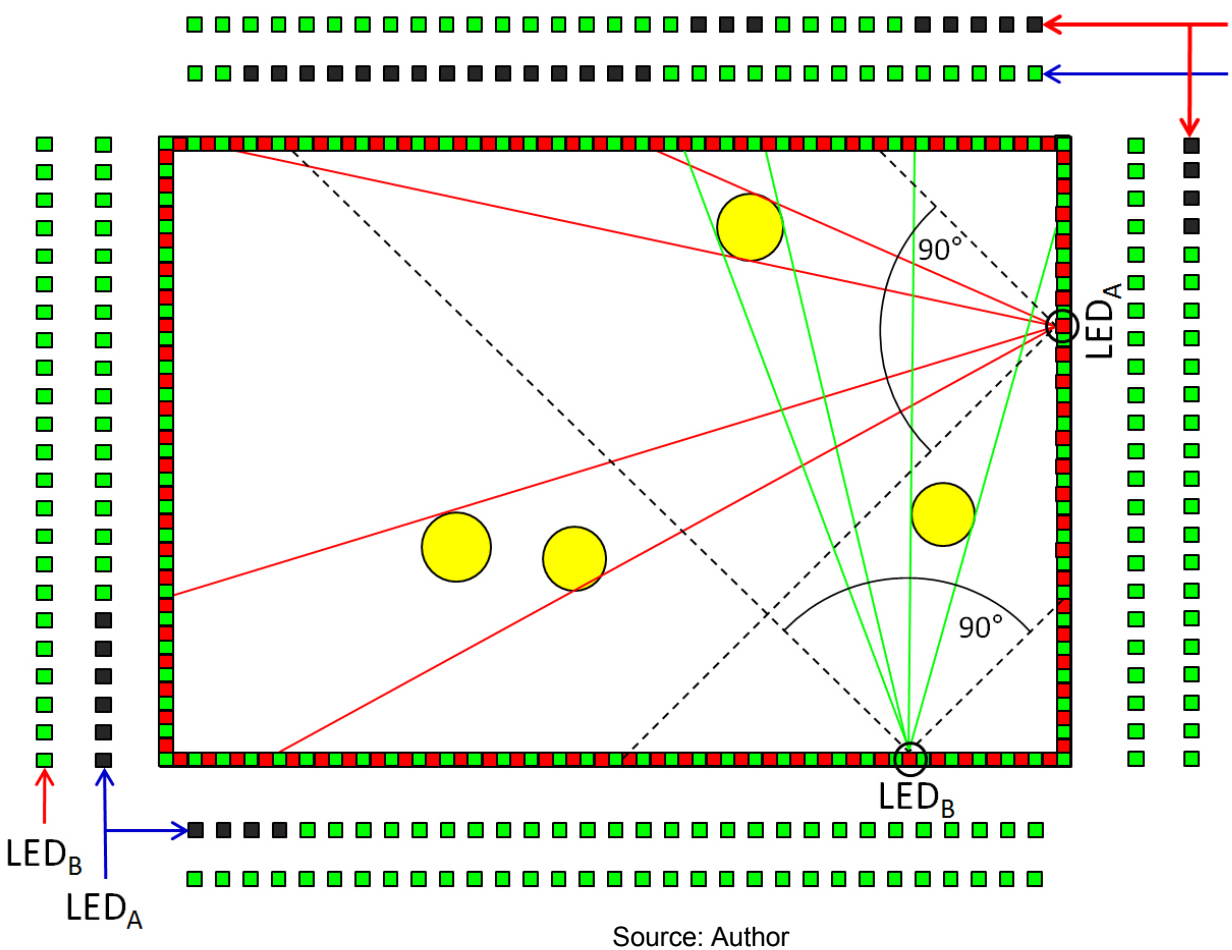


- 6 to 32 touches
- 32” to 103”

Source: Author

“High Finger-Count” Multi-Touch Infrared…2

- “PulseIR” (Image Display Systems) method

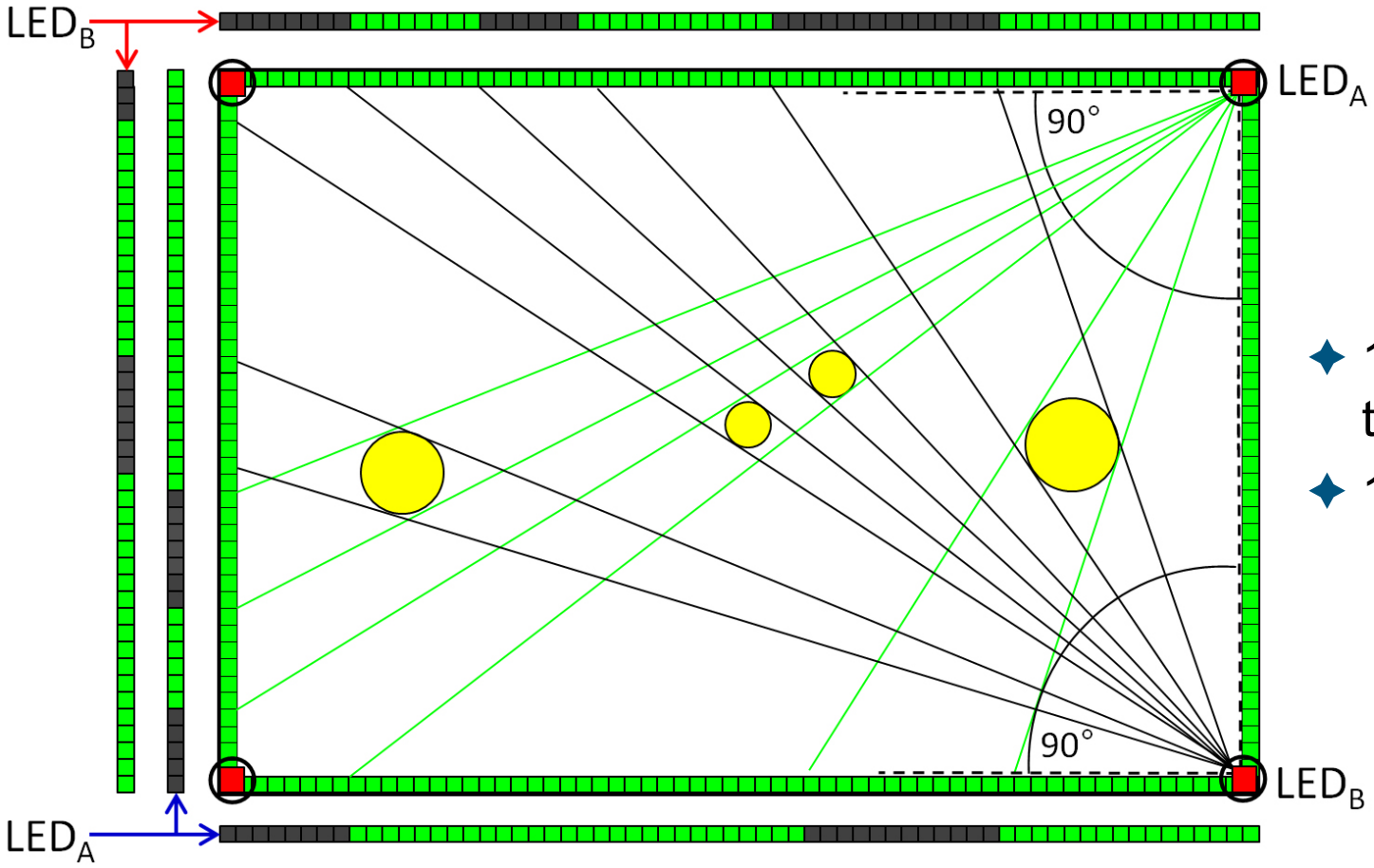


- 2 to 40 touches
- 5” to 103”

Source: Author

“High Finger-Count” Multi-Touch Infrared…3

- “TimeLink” method



- 10 to **48** touches
- 15” to 100”

Source: Author

"High Finger-Count" Multi-Touch Infrared…4

- **Variations**
  - Number of touch points: 2 to 48
  - Architecture: Almost every supplier is different (3 illustrated)
- **Size range**
  - (5"-32") to 103"
- **Controller**
  - Proprietary; generally requires a large amount of processing
- **Advantages**
  - High number of multi-touch points
  - Object-size recognition
  - Similar advantages to those of traditional infrared
    - Works with a finger, stylus or any other IR-opaque touch object
    - Scalable to very large sizes (at some cost)
    - High durability and sealability
    - Doesn't require a substrate

“High Finger-Count” Multi-Touch Infrared…5

- **Disadvantages**
  - Relatively low resolution (can get stair-stepping in lines)
  - Increased processing load as size and number of touches goes up
  - Different minimum-object-size spec for stationary & moving objects
  - Large objects close to emitters can decrease performance
  - As with any traditional IR system, pre-touch (or “pen-up”) is a big problem that gets worse as the screen size increases
  - Can’t meet Win8 Logo due to pre-touch and accuracy
- **Applications**
  - Multi-player games on large horizontal displays
  - Interactive digital signage
  - 3D design and interaction; data visualization for business
  - NOT interactive “whiteboard” displays due to pre-touch/pen-up

“High Finger-Count” Multi-Touch Infrared…6

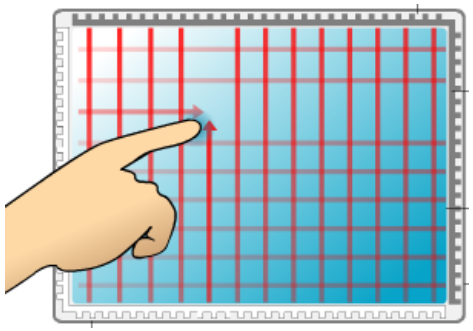
- **Market share**
  - << 1%
- **Suppliers**
  - PQ Labs, ZaagTech, Citron (DreaMTouch), Image Display Systems (PulseIR), TimeLink
- **Market events**
  - PQ Labs is suing ZaagTech for patent infringement
- **Market trends**
  - This is more of a technology looking for an application.
  - There is essentially no commercial software that makes use of 20-40 touches
  - Multi-player gaming could be exciting, but uniquely identifying the players is still a problem

Source: RPO

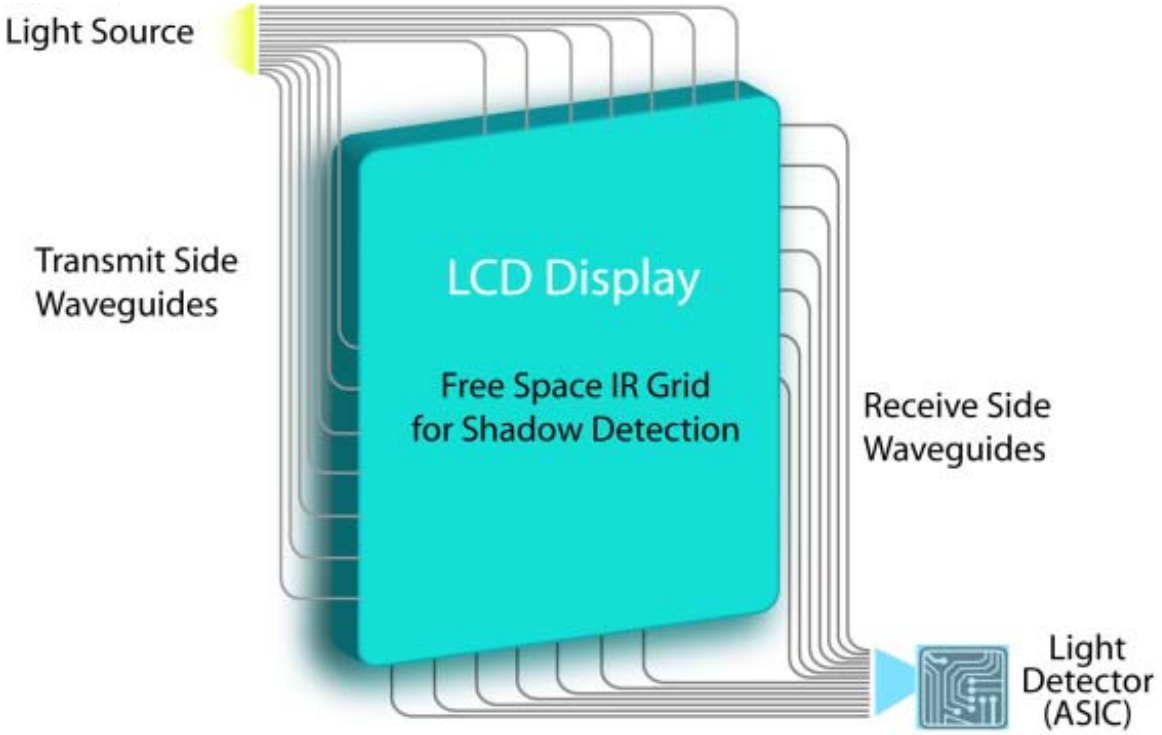
Waveguide Infrared

Waveguide Infrared…1

Traditional Infrared



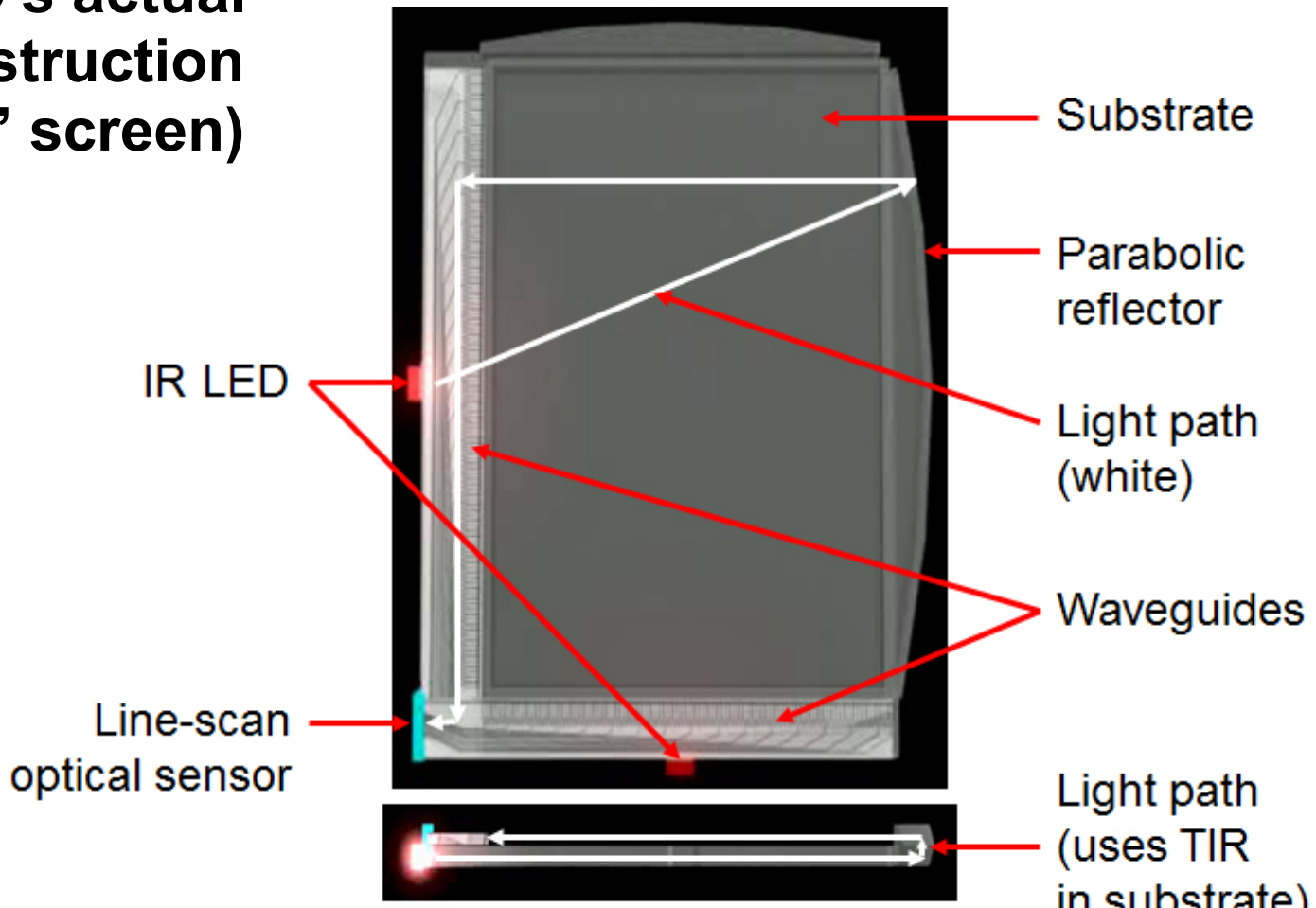
Principle



Source: RPO

Waveguide Infrared…2

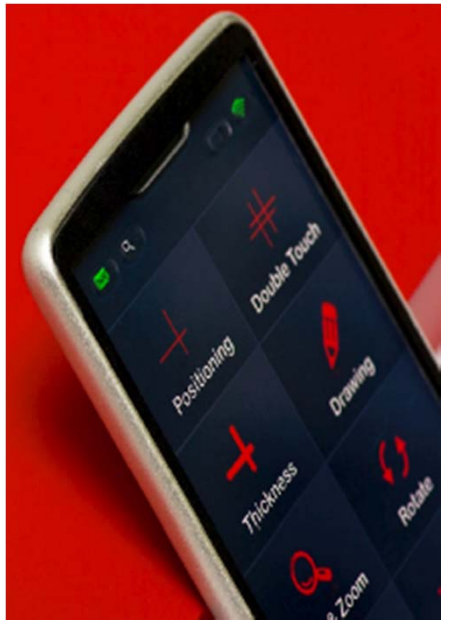
RPO's actual construction (3.5" screen)



Source: Photo by RPO; Annotation by Author

Waveguide Infrared…3

- **Variations**
  - None
- **Size range**
  - 3” to 14”
- **Controller**
  - Proprietary
- **Advantages**
  - Much lower cost than traditional IR
  - Very low profile height (0.5 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 (ghost touches minimized in firmware)



Source: RPO

Waveguide Infrared…4

- **Disadvantages**
  - Can't be scaled easily to large sizes (border width)
  - Power consumption
  - The "fly on the screen" problem (IR is only 200μ above substrate)
- **Potential applications**
  - Mobile devices & automotive
- **Market share**
  - None
- **Suppliers**
  - None (was RPO, an Australian startup)

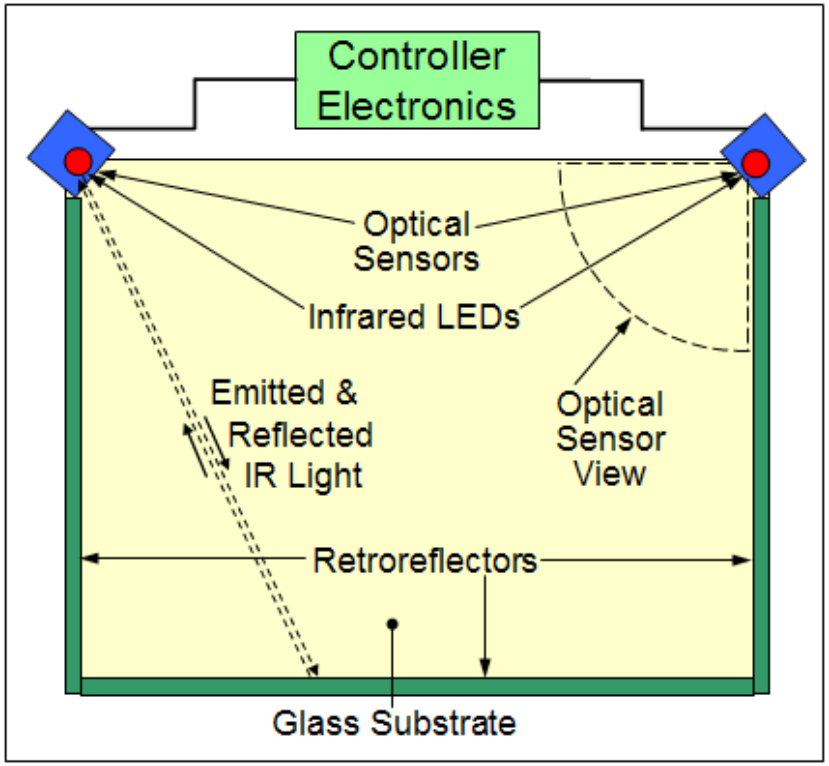
Waveguide Infrared…5

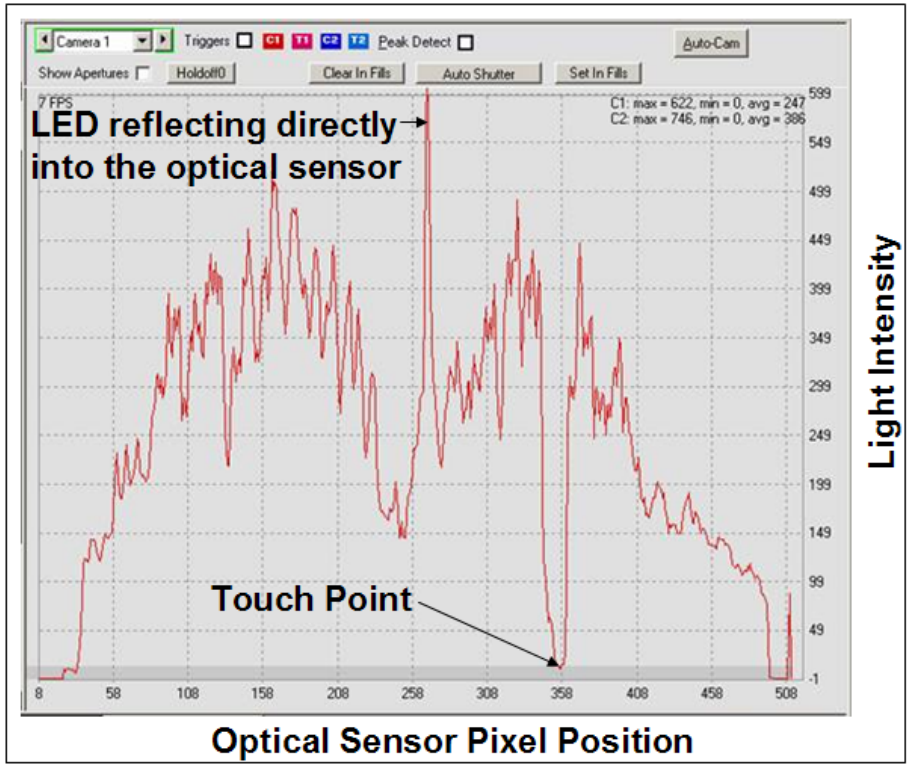
- **Market events**
  - RPO…
    - Announced IR optical-waveguide infrared touch at SID 2007
    - Showed improved performance at SID 2008
    - Showed larger sizes at SID 2009
    - Appeared in a 13.3” LG Display notebook at SID 2010
    - Went into “voluntary administration” (liquidation) in April 2011
    - Sold all assets to an NPE (patent troll) in February 2012 (along with Poa Sana’s assets… it’s a long story!)
- **Market trends**
  - The author considers this technology to be dead

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.

Camera-Based Optical

Camera-Based Optical…1

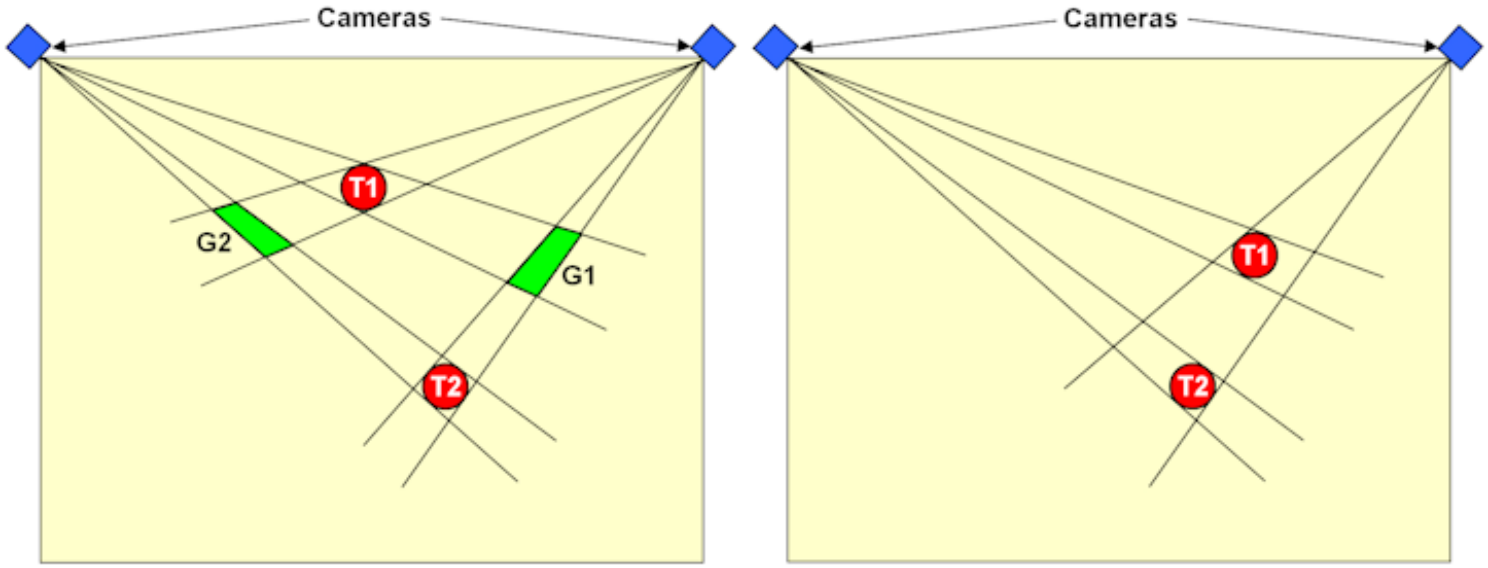




Source: NextWindow

Camera-Based Optical…2

- **Two touches with two cameras (Win7 market focus) has two main limitations**



Ghost touches

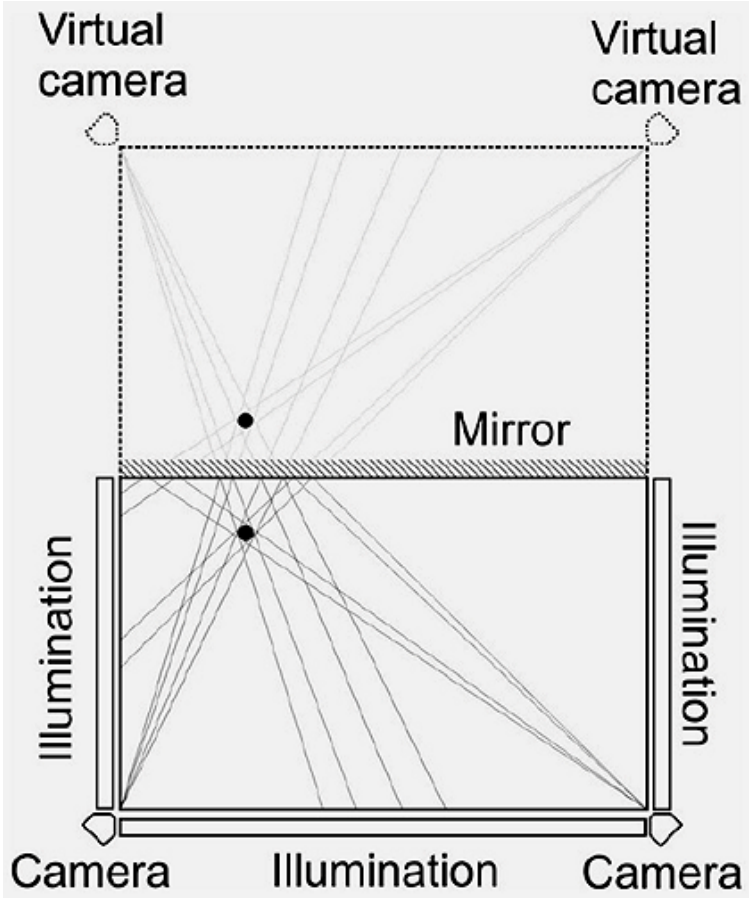
Source: Author

Occlusions

The quality of the touch experience depends on the sophistication of the algorithms that handle ghost touches and occlusions

Camera-Based Optical…3

- Adding a mirror adds “virtual cameras”



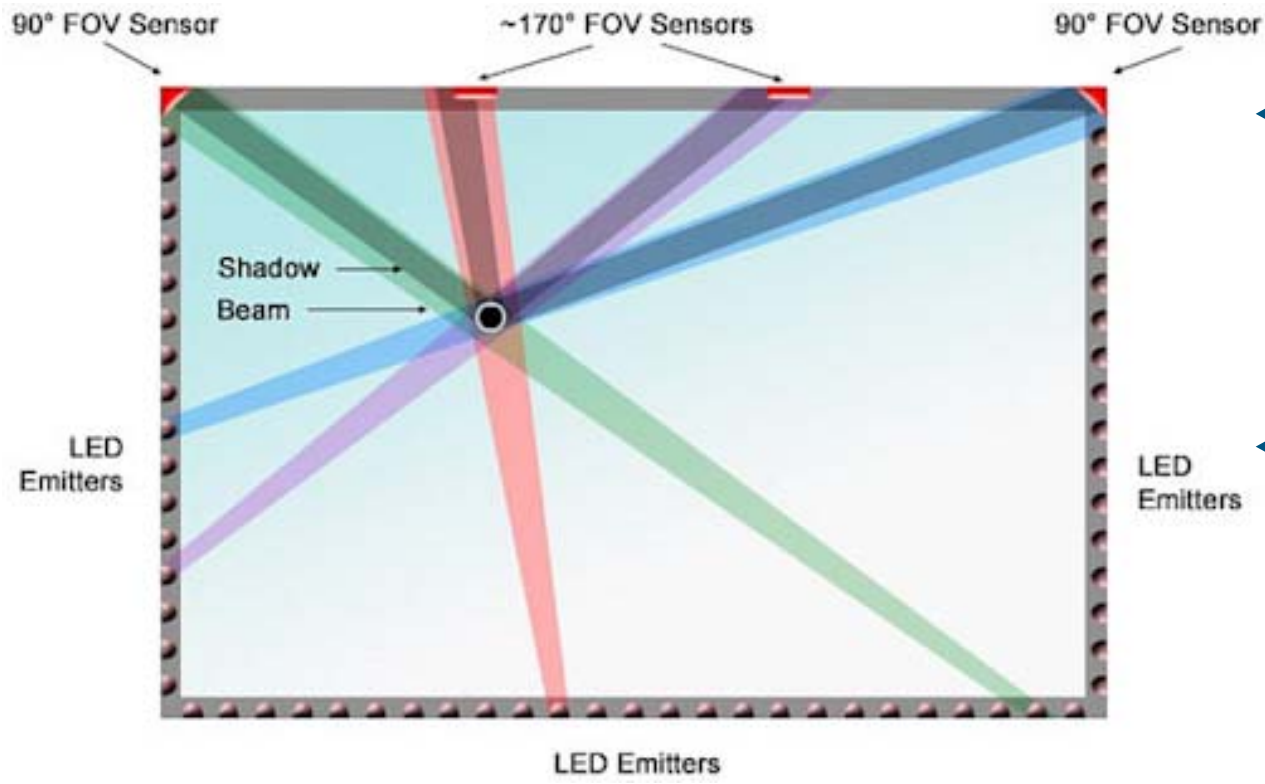
Source: Lumio

Camera-Based Optical…4

- **Camera-based optical touch with mirror**
  - SMART Technologies
    - Invented the concept in 2003 but decided not to productize because they believed it would not be sufficiently reliable
    - Lumio tried it in 2010 but found that four real cameras were better
  - Real cameras
    - Cost less when considering total system cost
    - Eliminate mirror alignment issues
    - Have less sensitivity to dust, dirt, and temperature change
    - May have less sensitivity to ambient light
    - Require fewer pixels for the same resolution
    - Require less CPU processing

Camera-Based Optical…5

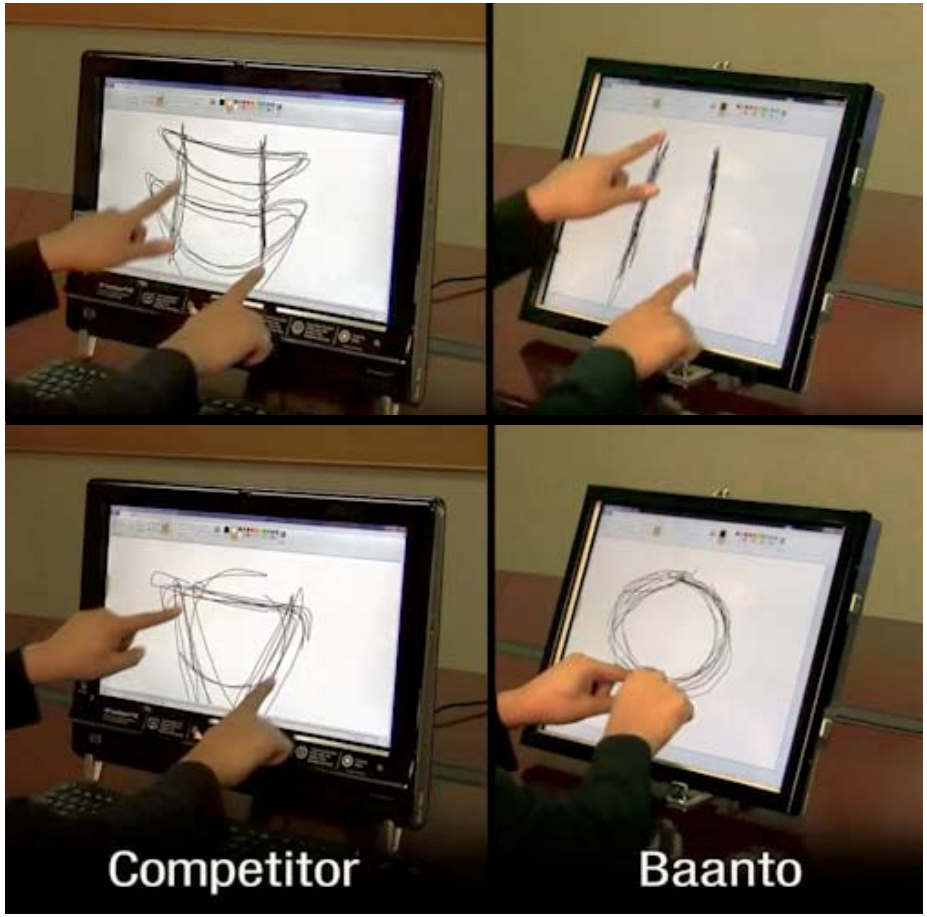
- **Baanto ShadowSense™ optical touch**



- Baanto's sensors aren't cameras; they're PIN diodes (photo-detectors)
- 940 nm LEDs provide back illumination instead of retro-reflectors

Camera-Based Optical…6

- **Baanto competitive comparison**



Camera-Based Optical…7

- **Variations**
  - OEM (e.g., NextWindow ➔ HP and Lumio ➔ Elo)
  - Bezel-integrateable by systems integrator
  - Built into open-frame monitor (Baanto)
  - Strap-on (aftermarket)
- **Size range**
  - 15” to 120”
  - ~90% of NextWindow’s volume is 18” – 26” AiOs
  - Baanto is focusing on 17” – 22” Elo-compatibles
- **Controllers**
  - Proprietary

Source: NextWindow

Camera-Based Optical…8

- **Advantages**
  - Stylus independence
  - Scalability to large sizes
  - Multi-touch (2-5 touches)
  - Object size recognition
  - Low cost
- **Disadvantages**
  - Profile height (~3 mm on a 19” screen)
  - The “unintended touch” problem
  - Screen rigidity requirement
- **Applications**
  - Consumer touch monitors & AiOs (market leader)
  - Interactive digital signage, point-of-information, & education

HP TouchSmart all-in-one computer
Source: HP

Camera-Based Optical…9

- **Market share**

	2011
Revenue	3%
Volume	<1%

These are tricky numbers due to the effect of SMART

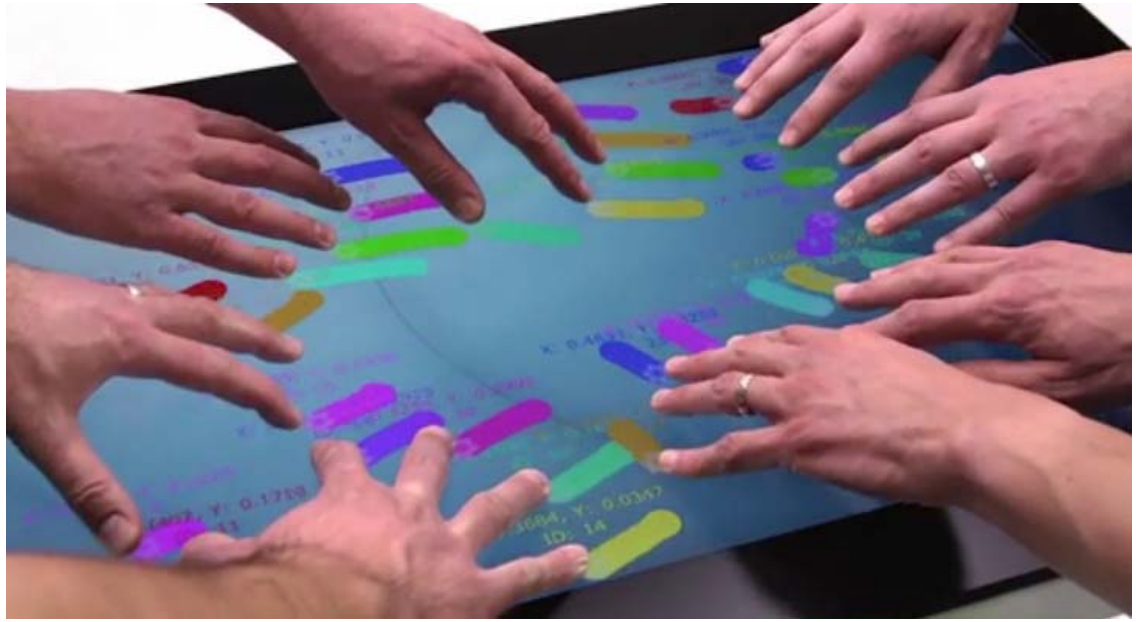
- **Suppliers**
  - NextWindow, Quanta, Qisda, Lumio, Xiroku/eIT, Baanto, LGD, IRTouch, (SMART)

Dell ST2220T Touch Monitor

- **Market event**
  - NextWindow meets Windows-8 Touch Logo using 6 cameras (four corners plus two on the top edge)
  - Quanta seems to be exiting the optical touch business

Camera-Based Optical…10

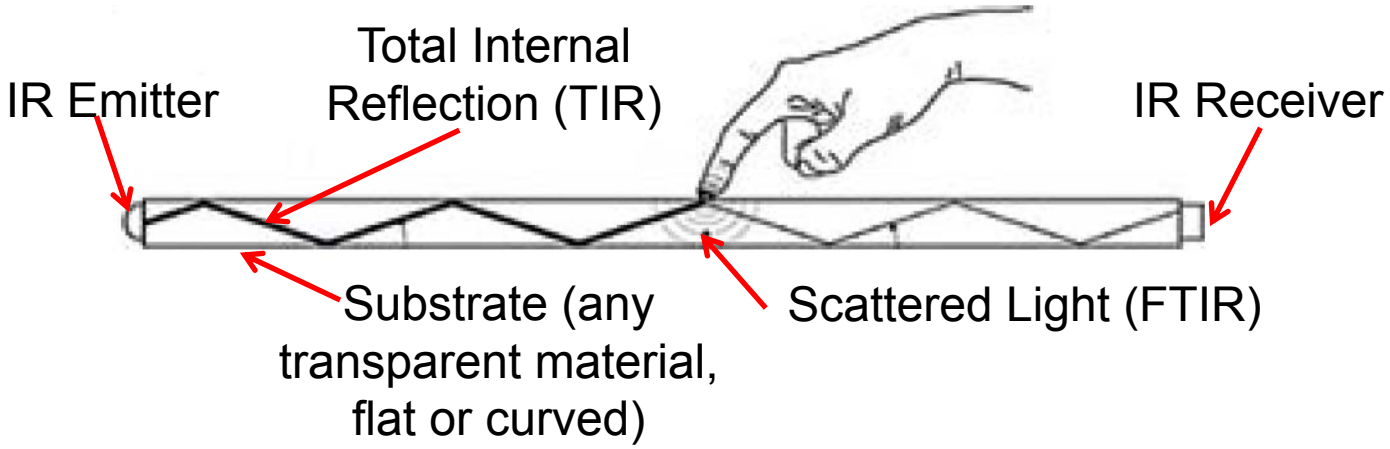
- **Market trends**
  - Touch on the consumer desktop (i.e., in AiOs) has failed to take off due to lack of applications, which has limited the growth of camera-based optical
  - Camera-based optical touch is ideal for large-format, but…
    - The interactive digital-signage market hasn't emerged yet
    - Interactive information on large screens is still a niche market
    - The education market (whiteboards) has been slow to adopt optical because of entrenched resistive and electromagnetic technologies

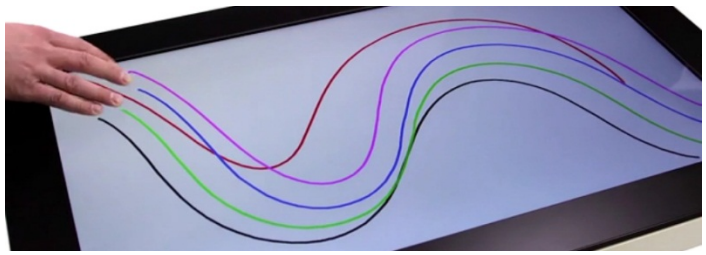


Source: FlatFrog

Planar Scatter Detection

Planar Scatter Detection…1





Source: FlatFrog

Planar Scatter Detection…2

- **Variations**
  - None (yet)
- **Size range**
  - 32” (with display) at launch in May, 2012
  - Capable of 3” to 100”
- **Substrates**
  - Glass or acrylic; can be curved
  - No minimum thickness
- **Advantages**
  - Flush surface; 40 touches; extremely fast refresh (up to 1,000 Hz)
    - 20 touches @ 100 Hz each is standard
  - Any touch object, including passive or active stylus; 400 dpi
  - Meets Win-8 specs (“in 32-inch & other sizes”)

Source: FlatFrog

Planar Scatter Detection…3

- **Disadvantages**
  - Initial product is a 32” display for $5,500 MSRP (+$190 housing)
  - Designed for indoor use (no sunlight) without dust or smoke
    - Limited to 30°C ambient
    - Sensitive to contamination on surface
  - Scaling to larger sizes is similar to traditional infrared
    - ~200 IR emitter-receiver pairs required for 32” display
  - Small company with limited resources
- **Applications**
  - Realistic: Gaming, digital signage, POI, medical, hospitality, command & control,
  - Questionable: POS, consumer electronics, education
- **Market share**
  - Just starting…

Planar Scatter Detection…4

- **Suppliers**
  - FlatFrog (Sweden)
- **Market event**
  - First customer shipment in May, 2012
  - First usage of planar scatter detection (PSD)

Source: FlatFrog

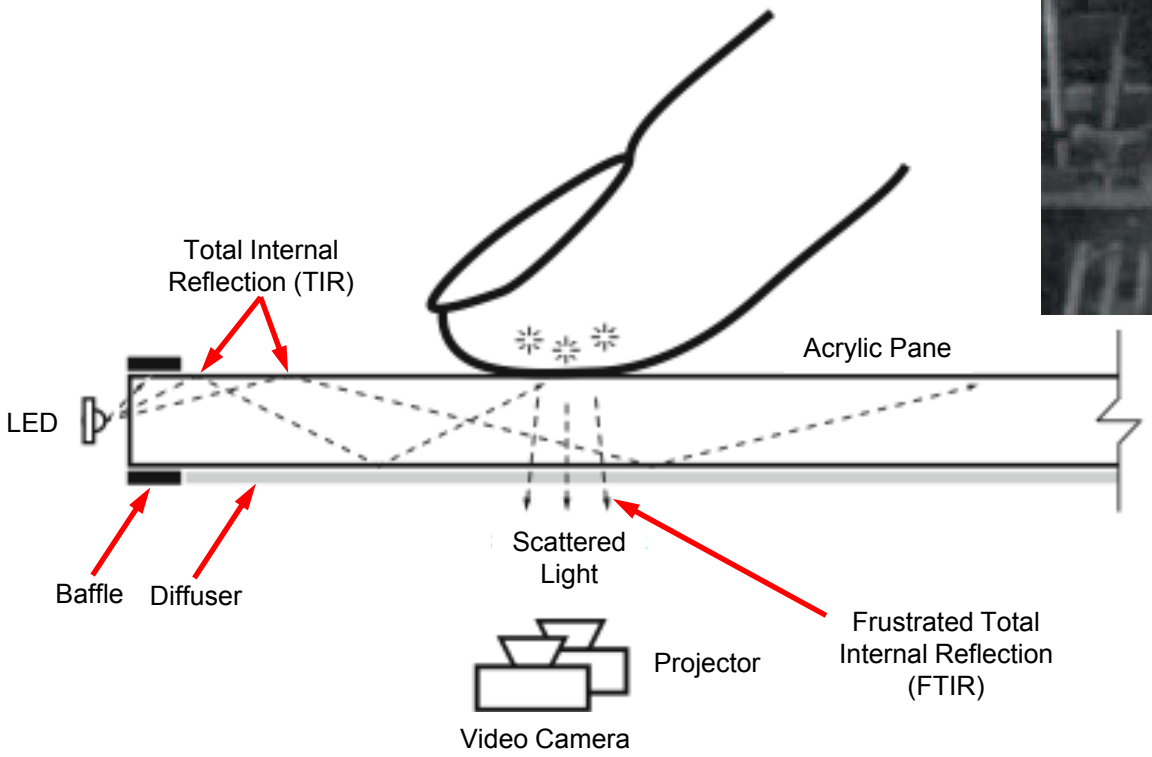
- **Market trends**
  - FlatFrog needs a big partner or more investment to ramp production into the 1,000s
  - PSD appears to be higher-performance (indoors) than camera-based optical or traditional infrared; whether the technology has a chance to beat these incumbents depends on FlatFrog's success

Vision-Based

Source: Perceptive Pixel

Vision-Based…1

- **Principle (simplest version)**



Multiple touch points;
Image taken without a diffuser
(Source: Perceptive Pixel)

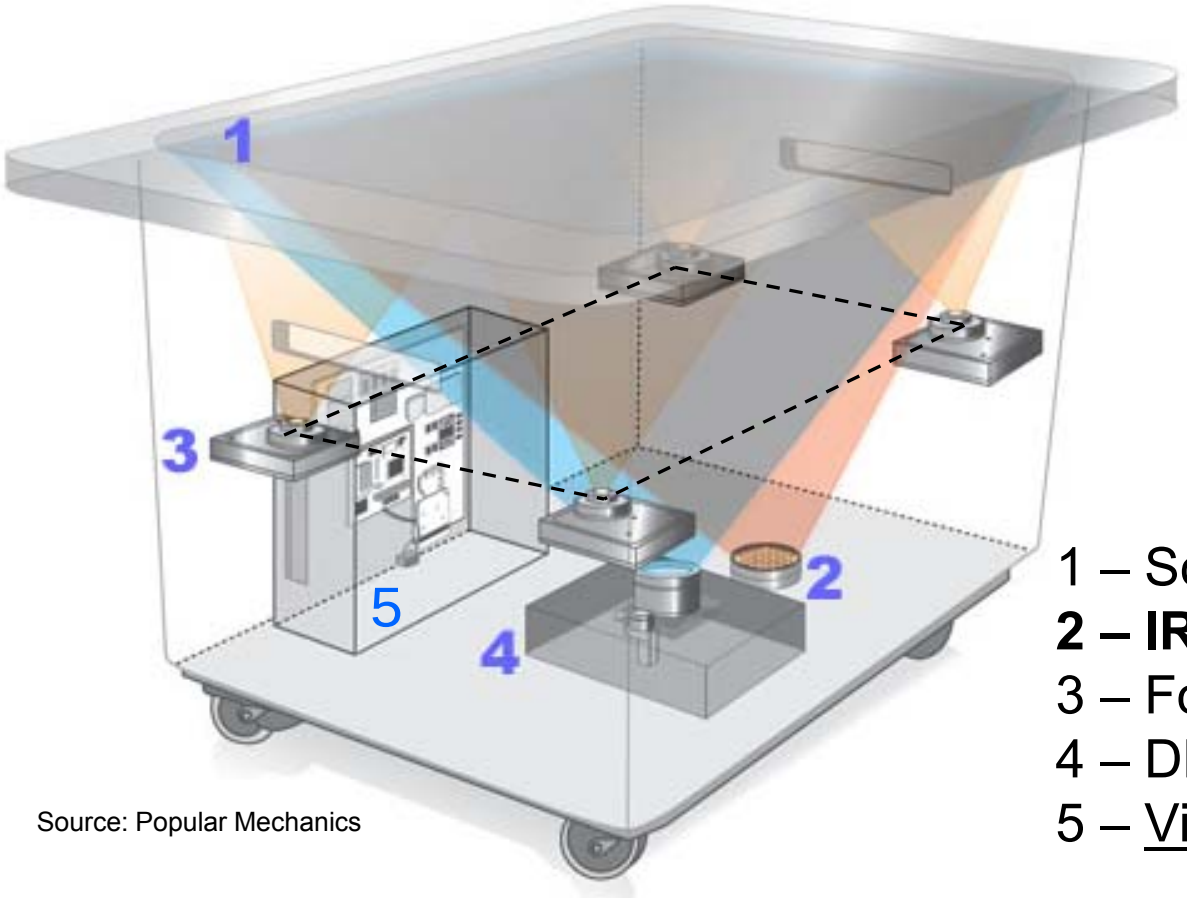
Source: Perceptive Pixel

Vision-Based…2

Microsoft Surface (v1)

"Surface computing is about integrating the physical and virtual worlds through the use of vision-based touch"

Source: Information Display



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…3

- **Samsung SUR40 with Microsoft Surface 2.0**

Document on surface

Source: Microsoft

Source: TechCrunch.com

Vision-Based…4

- **Samsung SUR40**
  - 40” full-HD (1920x1080) Samsung LCD (55 ppi)
    - 4” thickness includes 2.9 GHz PC with embedded 64-bit Win-7
  - Corning Gorilla Glass bonded to LCD
    - Display still has some bezel height (not a flush surface)
  - **In-cell touch:** 8 display pixels per aSiGe IR light sensor (8 ppi)
    - By far the most sophisticated in-cell light-sensing so far
    - IR light source is added to the backlight
    - aSiGe sensor is 15X more sensitive than aSi, but that means the touch-screen is **15X more sensitive to ambient IR**
  - 50+ simultaneous touch points
    - Surface image-processing software is Microsoft’s primary value-add
  - $8,400 – targeted at enterprise
  - Microsoft has a 3-4 year exclusive on the SUR40

Vision-Based…5

- **Variations**
  - Projection
    - IR injected into the cover glass; touch points seen via FTIR
    - IR illuminates underside of cover glass; touch points reflect IR
  - LCD in-cell light-sensing touch
- **Size range**
  - As described, 30” and up
- **Substrates**
  - Projection: glass or acrylic
- **Advantages**
  - Ideal data source for analysis by image-processing software
  - Object recognition by “reading” tokens on objects
  - Potentially unlimited number of touch points

Vision-Based…6

- **Disadvantages**
  - Projection
    - All the usual disadvantages of projection
  - LCD in-cell light-sensing
    - Sensitivity to ambient IR (in SUR40 implementation)
- **Applications**
  - Interactive “video walls”; digital signage; high-end retail
- **Market share**
  - << 1%
- **Suppliers**
  - Microsoft & Samsung (Surface v2.0)
  - Perceptive Pixel (Jeff Han’s famous videos)
  - GestureTek (now Qualcomm) & others
  - Do-It-Yourself

http://www.maximumpc.com/article/features/build_your_own_multitouch_surface_computer?page=0,0

Source: NORTD

Vision-Based…7

- **Market event**
  - First customer shipment of Samsung's SUR40 in 1Q-2012
- **Market trends**
  - Because a rear-projection, vision-based touch system can be assembled very easily, it's the most common platform used for university research in touch
  - Some level of customer dissatisfaction with SUR40/Surface-2.0's performance and ambient-IR sensitivity
  - Use of "touch tables" in TV shows has increased significantly
    - Hawaii 5-0 is just one of many examples
  - Interest in vision-based touch continues to increase
    - Google "touch table" for a view of related activity, but realize that not all touch-tables are vision-based

Embedded Touch Technologies

- In-Cell Light-Sensing
- In-Cell Pressed Capacitive
- In-Cell Self-Capacitive
- In-Cell Voltage-Sensing
- On-Cell P-Cap
- Hybrid On-Cell/In-Cell P-Cap
- On-Cell Analog Resistive

Source: TMD

In-Cell & On-Cell

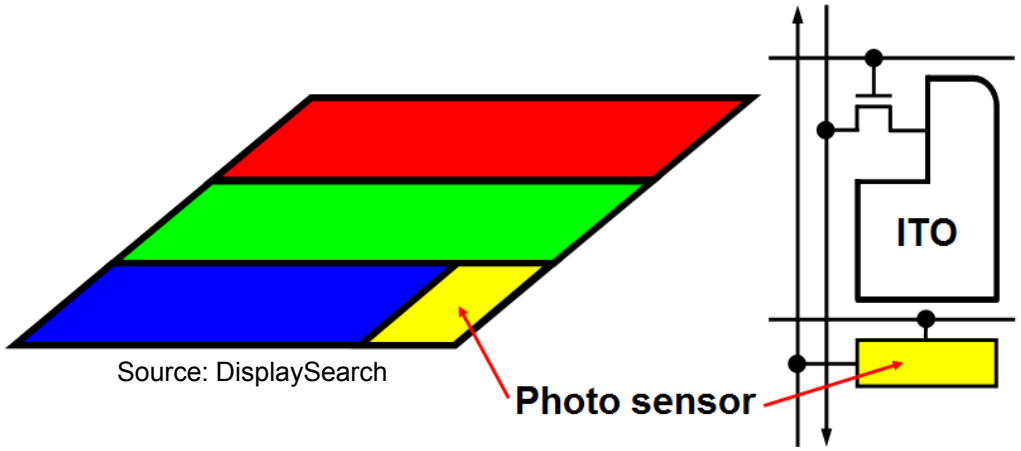
Three Different Physical Integration Methods Used In Embedded Touch

Term	Integration Method	Fab Method
In-Cell	Touch sensor is ***physically inside the LCD cell*** Touch sensor can be: • Light-sensing elements (light-sensing) • Micro-switches (voltage-sensing) • Capacitive electrodes (charge-sensing)	Addition to TFT process
On-Cell	Touch sensor is an array of ITO electrodes ***on the top surface of the color filter substrate*** • Projected capacitive • Analog resistive (voltage-sensing)(very rare)	Addition to color filter process
Hybrid (On-Cell/ In-Cell)	Touch sensor is an array of ITO electrodes ***on both surfaces of the color filter substrate***	Addition to TFT and color filter process

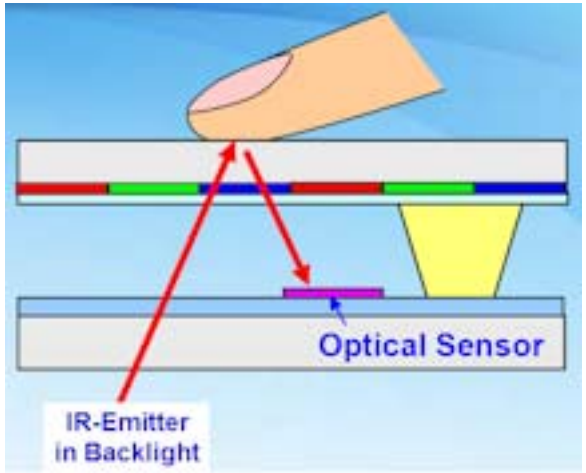
Four Different Technologies Used In Embedded Touch

- **Light-sensing or "optical"**
  - Addition of a photo-sensing element into some or all pixels
- **Voltage-sensing or "switch-sensing"**
  - Addition of micro-switches for X & Y into some or all pixels
- **Capacitive-sensing (three types)**
  - Pressed capacitive (addition of two **in-cell** mutual-capacitive electrodes per sensing element)
  - Self-capacitive (addition of one **in-cell** self-capacitive electrode per sensing element)
  - Projected capacitive (addition of two sets of **on-cell** mutual-capacitive electrodes)
- **Analog resistive**
  - Uses color filter glass as the substrate for a standard analog-resistive touch-screen (very rare)

In-Cell Light-Sensing



Source: DisplaySearch

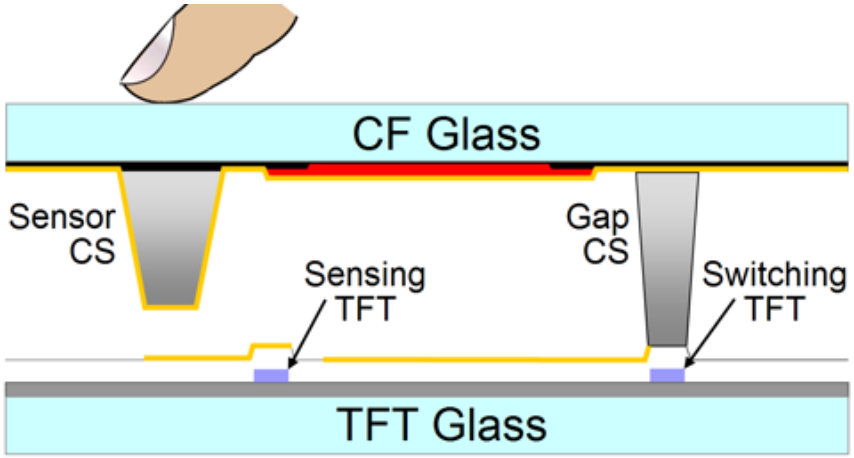


Source: Samsung

❖ Principle

- ✦ Photo-sensor in each pixel (rare) or group of pixels (4 to 16+)
  - IR sensor (aSi or aSiGe) added to TFT array
  - IR emitters added to backlight
- ✦ Works with finger or light-pen; can work as a scanner
- ✦ Adding a cover-glass to protect the surface of the LCD reduces touch sensitivity because the finger is further away from the sensors

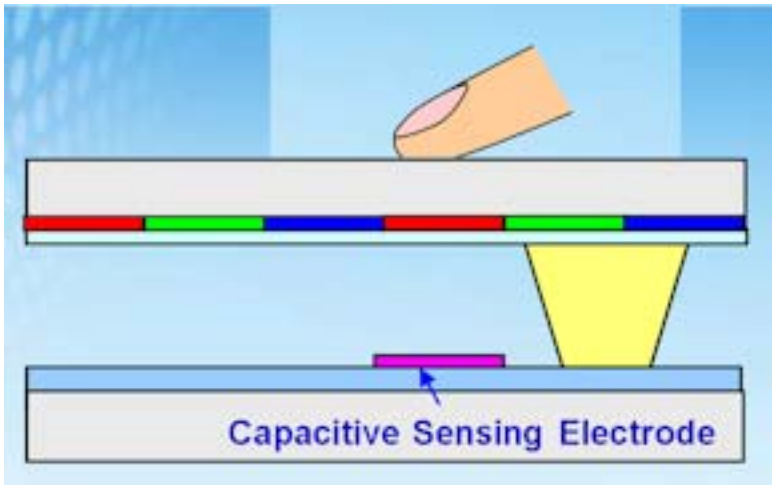
In-Cell Pressed Capacitive



Source: LG Display

- **Principle**
  - Pressing the LCD changes the dielectric constant of the liquid crystal, which changes the capacitance between the conductive column spacer (CS) and the flat electrode in the TFT array. Electrode pairs can be in one pixel or in a group of pixels.
  - Works with any touch object within damage limits of top polarizer; human body capacitance and dimensional change between electrodes are not relevant factors
  - Requires deflecting the LCD surface (cannot add a cover glass)

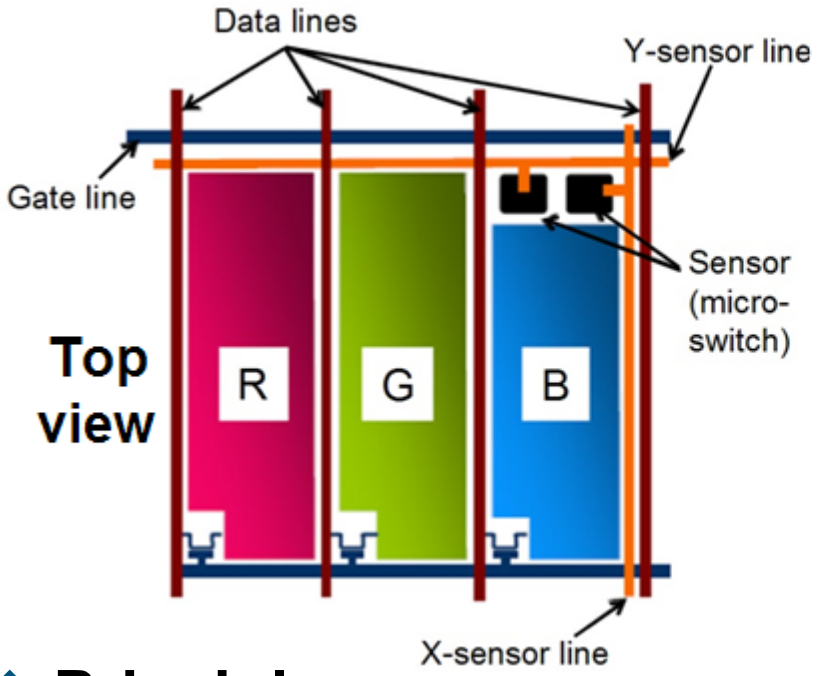
In-Cell Self-Capacitive

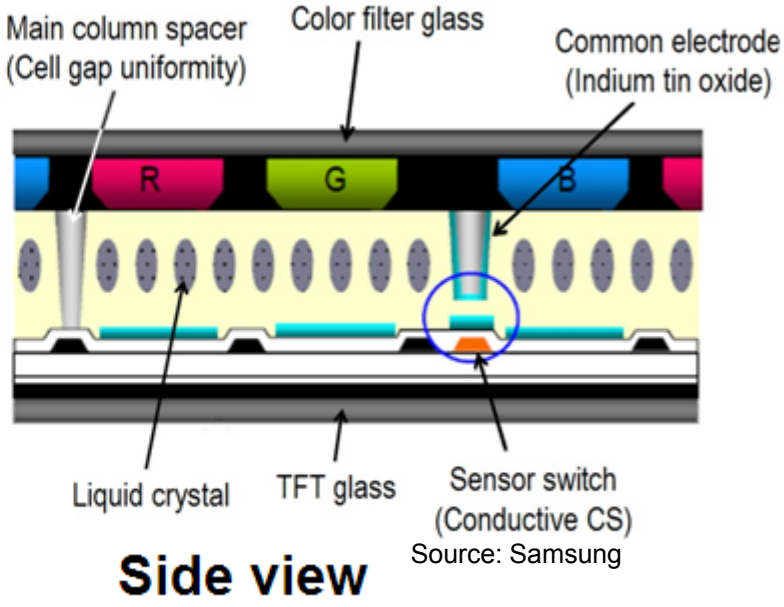


Source:
Drawing = Samsung & Author;
Information = Toshiba Mobile Display

- **Principle**
  - A single electrode per sensing element in the TFT array is connected to a reference capacitor. When a finger touches the LCD, the voltage at the electrode changes due to the capacitive coupling of the user's body-capacitance to ground.
  - Works only with finger; no pressure is required
  - Adding a cover glass reduces touch sensitivity; reduction in SNR may make touch non-functional in noisy environments

In-Cell Voltage-Sensing

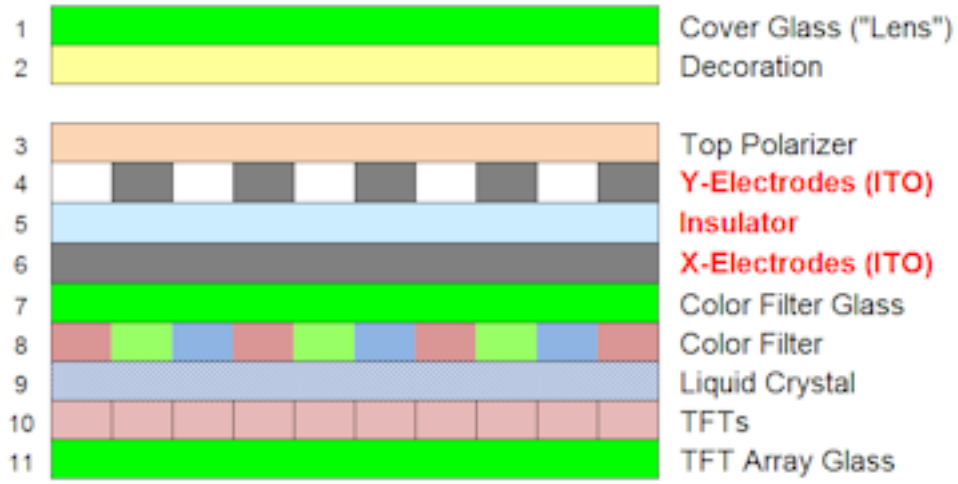




Source: Samsung

- **Principle**
  - Pressing LCD surface closes X & Y micro-switches in each pixel or group of pixels
  - Requires deflecting the LCD surface (cannot add a cover glass)
  - Works with any touch object within damage limits of top polarizer

On-Cell Projected Capacitive

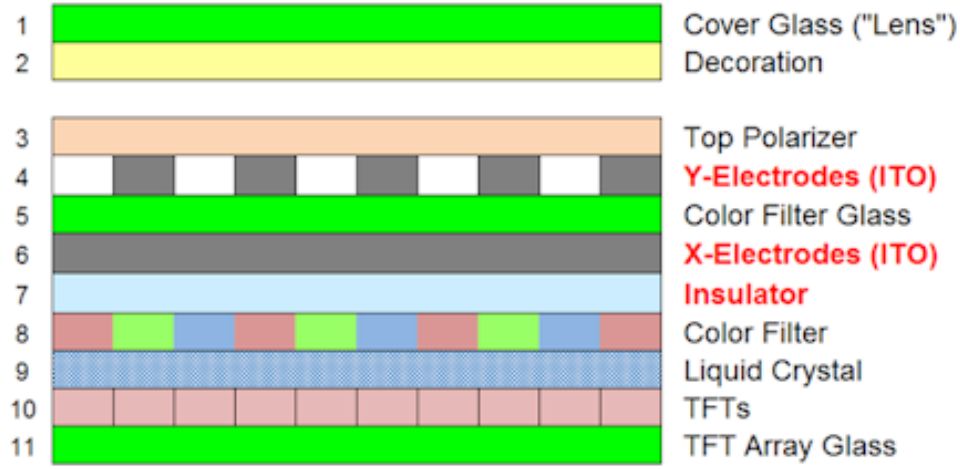


Source: Author

❖ Principle

- ✦ Projected-capacitive X-Y electrode array is deposited on top of the color filter glass, under the top polarizer
  - Exactly the same function as discrete (standalone) p-cap
- ✦ Works only with finger; no pressure is required; human body capacitance changes mutual capacitance between electrodes
- ✦ Cover-glass (typically 0.5 to 1.0 mm) can be added on top of polarizer to protect LCD surface

Hybrid On-Cell/In-Cell Projected Capacitive (Synaptics)

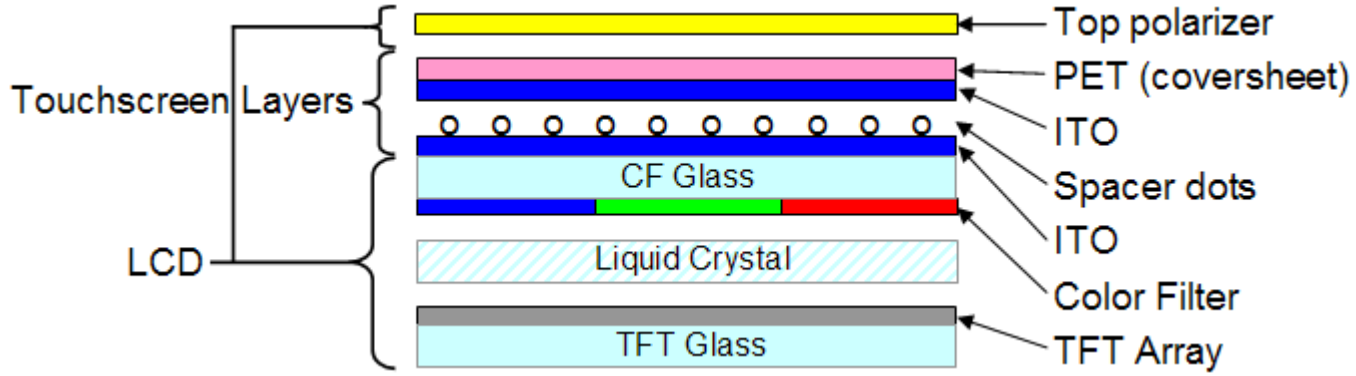


Source: Author

❖ Principle

- ✦ Y-electrode of projected-capacitive array is deposited on top of the color filter glass (under the top polarizer); X-electrode is deposited on the underside of the color filter glass
- ✦ Works only with finger; no pressure is required; human body capacitance changes mutual capacitance between electrodes
- ✦ Cover-glass is more problematical since X-electrodes are further away from finger

On-Cell Analog Resistive



Source: Author

Principle

- A standard analog-resistive film/glass touch-screen is added on top of the color filter glass (which acts as the touch-screen substrate), under the top polarizer
- Works with any touch object within damage limits of polarizer
- Adding a thin cover-glass (0.5 mm) on top of polarizer to protect the LCD surface works but reduces touch-screen performance

Early Products with Embedded Touch…1

- **Samsung ST10 camera with 3” 480x320 transflective TFT with in-cell pressed-capacitive touch (4/09)**
  - First use of any in-cell touch in a commercial product
  - Works with finger or stylus, but with visible pooling
  - Surface hardness = low
  - Touch-screen includes electrostatic haptic feedback
  - Camera includes MP3, PMP & text-viewer functions
  - One sensor per 8 pixels (60x40 sensing matrix)

Source: Samsung

Early Products with Embedded Touch…2

- **Excerpt from Samsung ST-700 digital camera manual**

Touching

Touch an icon to select a menu or option.

Flicking

Gently flick the touch pen across the screen.

- Do not use sharp objects, such as pens or pencils, to touch the screen. You can damage the screen.
- The touch screen may not recognize your inputs if you touch multiple items at the same time.
- The touch screen may not recognize your inputs if you touch the screen with your finger.
- When you touch or drag the screen, discolorations may occur. This is not a malfunction, but a characteristic of the touch screen. Touch or drag lightly to minimize the effect.
- The touch screen may not work properly if you use the camera in extremely humid environments.
- The touch screen may not work properly if you apply screen protection film or other accessories to the screen.

Early Products with Embedded Touch…3

- **Sharp's PC-NJ70A netbook (5/09)**
  - First use of light-sensing in-cell touch in a commercial product
  - Optical in-cell touch in 4" CG-silicon 854x480 touchpad LCD (245 dpi)
    - 1 sensor per 9 pixels
    - LED backlight
    - Stylus & 2-finger multi-touch
    - Scanning (shape recognition)
    - Touch surface = ??
    - Japan-only; $815
  - Problems
    - Had to add IR emitters to backlight
    - **S L O W** (25% of typical touchpad speed)
    - Short battery life

Source: Sharp

Early Products with Embedded Touch…4

- **LGD's 13.3" 1280x800 on-cell charge-sensing LCD (10/09)**
  - Largest on-cell LCD
    - 1 sensor per 4x4 pixels
    - 10 gF activation force
  - Win-7 Touch Logo 2/10
  - Positioning
    - High optical quality
    - Sunlight readability (AR?)
    - Preserving thinness
    - Two-touch multi-touch
  - Targeted at notebooks
  - Production in 2H-2010 (?)
  - Added price for touch function = ??

Source: LG Displays

Prototype of same screen at SID 2009

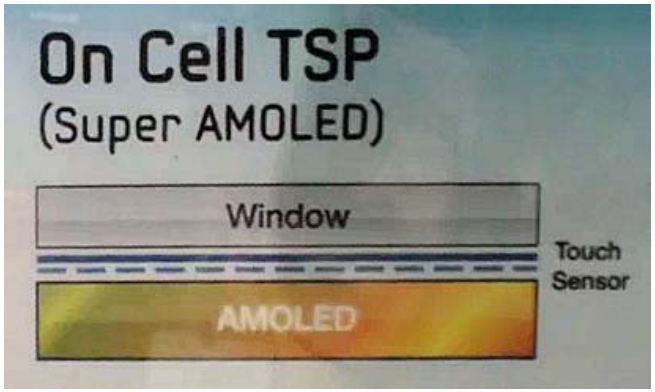
Source: Photo by Geoff Walker

Early Products with Embedded Touch…5

- **Samsung S8500 Wave mobile phone with Super OLED on-cell charge-sensing touch (2/10)**
  - 3.3-inch 800x480 (283 ppi) AMOLED
  - "Super OLED" is Samsung's (weak) branding for on-cell touch
  - Sunlight readable
    - AR coating & no touchscreen overlay

Source: Samsung

"Window" here refers to the cover glass that's laminated on top of the display



Source: Samsung booth graphic at Mobile World Congress 2010

Early Products with Embedded Touch…6

- **Special case: Integrated Digital Technologies, Inc.**

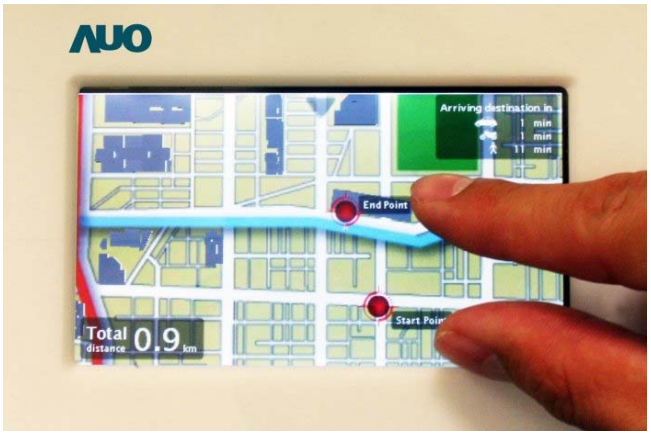
Source: IDTI

Source: Photo by author

- 21.5” light-sensing in-cell monitor with **IR light-pen**
- Supports two-touch with two pens
- Backplane by HannStar

Embedded Touch Characteristics…1

- **Advantages (summary)**
  - Integration, size, thickness, weight, ID (touch is “invisible”)
  - Unlimited multi-touch (controller-dependent)
  - Conceptually high performance
    - Low parallax error (assuming no cover glass)
    - Very accurate & linear touch-point data
    - Potentially higher resolution than LCD
  - Lower manufacturing cost



Source: AUO

Embedded Touch Characteristics…2

- **Disadvantages (summary)**
  - **Standard LCD polarizer is too soft for normal touch usage**
  - **Successful integration can be very difficult due to LCD noise (reduced signal-to-noise ratio)**
  - The sensor consumes too much of the pixel aperture
  - Liquid-crystal pooling can be visually distracting
  - The amount of processing power required by the touch function may result in high power consumption in a mobile device
  - IR light-sensing: Sensitivity to ambient IR makes usage outdoors impractical
  - Visible light-sensing: Touching a black image doesn't work; can't reliably detect touch over the full range of ambient
  - Voltage-sensing: Unstable microswitch contact at the edge of the screen

Embedded Touch Characteristics…3

- **Variations**
  - Number of pixels per sensing element
- **Size range**
  - 3” to 40”
- **Controller**
  - Proprietary/unique; potentially dead-end?
- **Applications**
  - Mobile (cellphones, tablets, notebooks, cameras, etc.)
- **Market share**
  - Just starting
- **Suppliers**
  - Samsung, LGD, AUO, TMD, CMI, CPT, NEC, Sharp, Sony…

Source: Sharp

Embedded Touch Characteristics…4

- **Technology status**
  - Samsung's SUR40 demonstrates that ambient-IR sensitivity is a ***major*** problem with IR-light-sensing
  - Most development on visible light-sensing has stopped because nobody has been able to make it work reliably
  - Samsung's cameras demonstrate the impracticality of pressed-capacitive
  - Nobody is implementing self-capacitive because it's impractical *without* a cover-glass and the SNR is too low *with* a cover-glass
  - Nobody is implementing voltage-sensing (IP restriction?)
  - **On-cell capacitive is where all the action is because it's really just standard p-cap in a different location**
  - There is disagreement on whether hybrid on-cell/in-cell capacitive actually saves any manufacturing cost
  - On-cell analog resistive has been shown only in demos

Embedded Touch Characteristics…5

- **Conclusion**
  - In-cell researchers consistently seem to ignore two key issues
    - LCDs that are going to be touched ***require*** a cover-glass
    - LCD touch systems ***require*** a high signal-to-noise ratio to work reliably in the real world
  - There is little public discussion of the business issues that would arise from in-cell touch destroying the touch-module business
    - Suppliers such as TPK are ***not*** going to go "quietly into the night"
    - There are also product-management issues on the LCD side

The author's opinion: In-cell touch is unlikely to succeed as a mainstream touch technology as currently envisioned

Other Touch Technologies

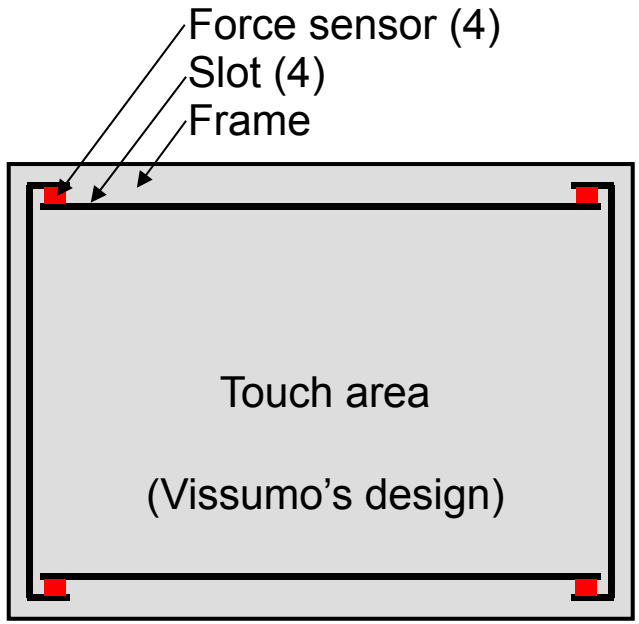
- Force-Sensing
- Electromagnetic Resonance (EMR)

Source: Vissumo

Force Sensing

Force Sensing…1

- **Principle**
  - Suspend the touch-screen from force-sensors (strain gauges or piezos) such that movement is constrained to only the z-axis
- **Variations**
  - **IBM "TouchSelect":** Strain gauges (early 1990s, unsuccessful)
  - **Vissumo:** "Beam-mounted" sensors (ran out of money in 2009)
  - **F-Origin:** "Spring-arm mounted" sensors (recovered after shrinking to just one person)
  - **FloatingTouch:** "Flexible adhesive pad" sensors (just starting up)
- **Size range**
  - 5"-48"



Force Sensing…2

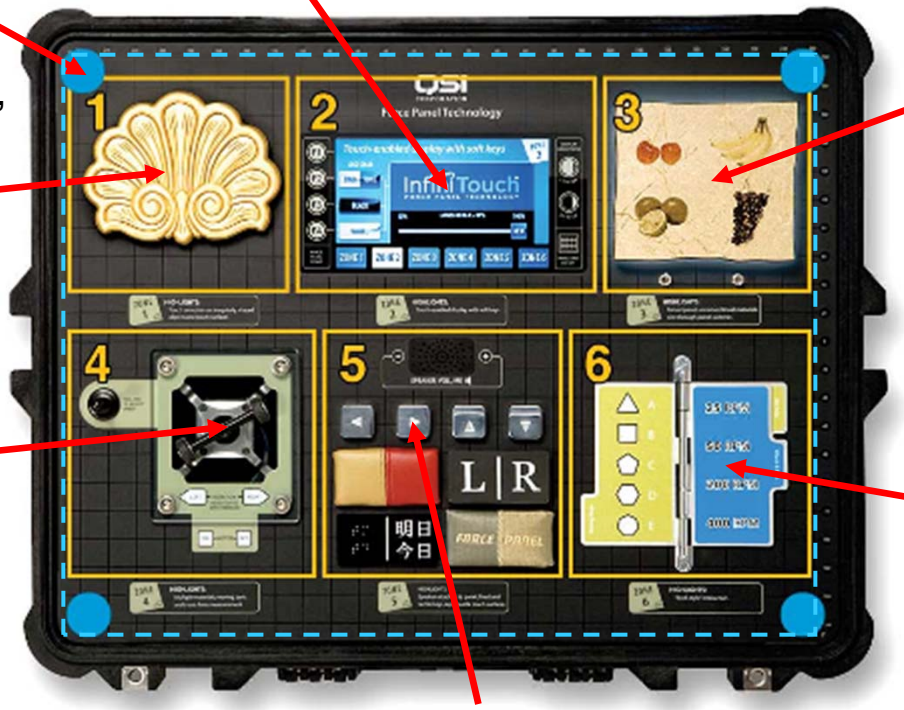
Vissumo's Amazing Demo Box

4 strain gauges supporting one touch panel

Glass-covered LCD integrated into touch panel with "soft keys" printed on back of glass

Irregularly shaped, raised, textured, wooden touch surface

Motor attached to and penetrating touch panel with printed speed control keys and push-pull control lever



Raised, marble touch surface with toggle switches penetrating touch panel

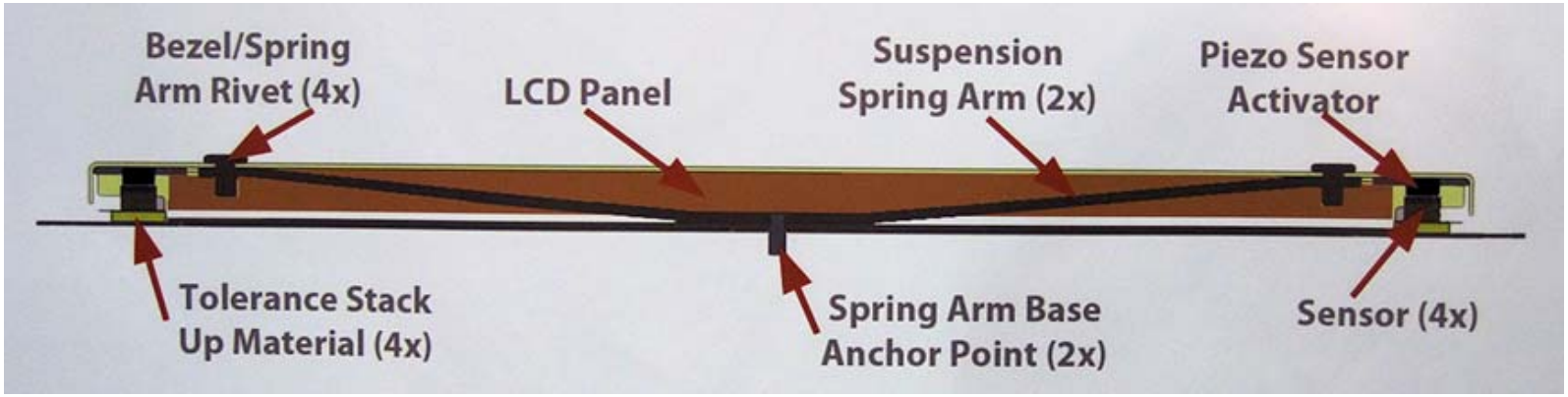
Multi-page "book" with touchable & movable metal pages

"Snap-dome" keys attached to touch panel; removable padded and textured keys; speaker attached with holes through the touch panel.

Source: Photo by author

Force Sensing…3

- F-Origin's spring-arm suspension



Force Sensing…4

- **Advantages**
  - Complete substrate design freedom – no other touch technology can handle three-dimensional substrates with embedded moving objects
- **Disadvantages**
  - No multi-touch (TBD)
  - Mounting adds volume and cost
- **Applications**
  - Commercial applications
  - 3D architectural applications
- **Market share**
  - <<1%

Source: Vissumo

Source: F-Origin

Force Sensing…5

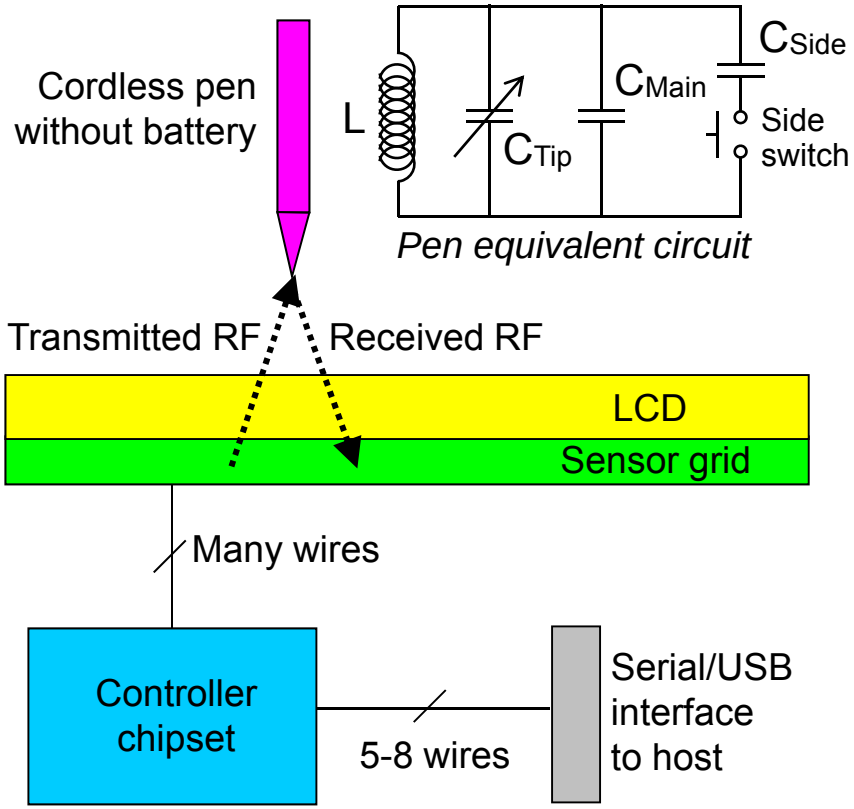
- **Market trends**
  - One re-start (F-Origin) and one new startup (FloatingTouch) are tackling this technology again
    - Don’t hold your breath…

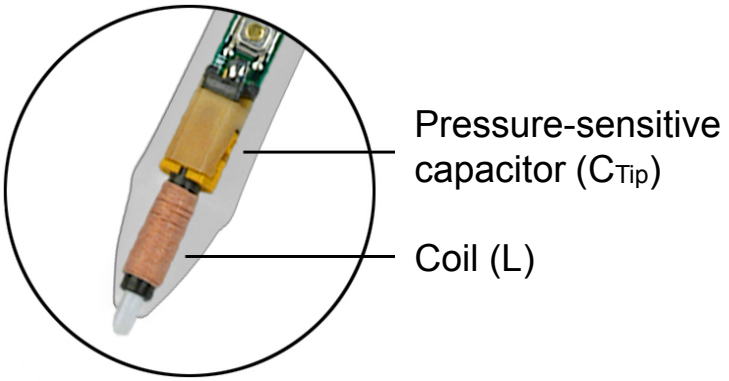
Source: Wacom

Electromagnetic Resonance (EMR) Pen Digitizer

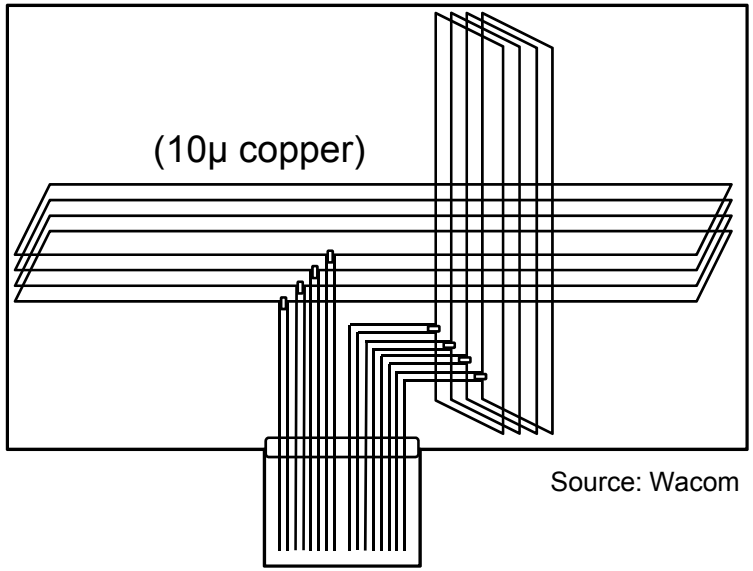
EMR Pen Digitizer…1

Source: Wacom





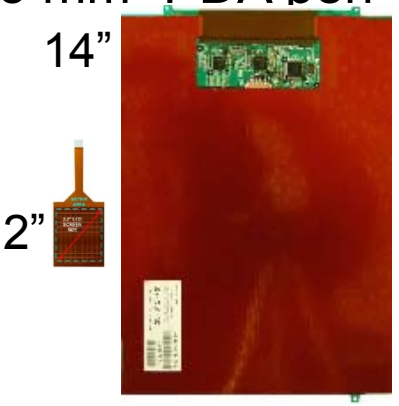
Sensor grid schematic



Source: Wacom

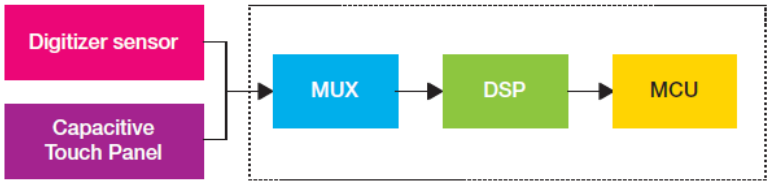
EMR Pen Digitizer…2

- **Variations**
  - Sensor substrate (rigid FR4 vs. flexible 0.3 - 0.6 mm PET)
  - Pen diameter (3.5 mm “PDA pen” to 14 mm “executive” pen)
- **Size range**
  - 2” to 14”
- **Controllers**
  - Proprietary
- **Advantages**
  - Very high resolution (1,000 dpi)
  - Pen “hover” (mouseover = move cursor without clicking)
  - Sensor is behind LCD = high durability & no optical degradation
  - Batteryless, pressure-sensitive pen



Controller for 10.4”

Source: Wacom



Single controller can run both pen digitizer & p-cap finger touch

EMR Pen Digitizer…3

- **Disadvantages**
  - Electronic pen = disables product if lost; relatively expensive
  - Difficult integration requires lots of shielding in mobile computer
  - Sensor can't be integrated with some LCDs
  - Single-source = relatively high cost
- **Applications**
  - Tablet PCs
  - Opaque desktop graphics tablets
  - Integrated tablet (pen) monitors
  - E-book readers
  - Smartphones… but zero traction

Wacom "Bamboo" Tablet

- **Market share**
  - 100% share in Tablet PCs
    - Failed challengers: FinePoint/InPlay, Aiptek, Acecad, KYE, Synaptics, UC-Logic, Wintime
  - Majority share in graphics tablets & tablet monitors

EMR Pen Digitizer…4

- **Suppliers**
  - Wacom, Hanvon, Waltop, UC-Logic/Sunrex
- **Market trends**
  - Microsoft's significant de-emphasis of the stylus in Windows 7, and Steve Jobs' famous opposition to the stylus in the iPhone has made the last five years mostly about the finger
  - BUT, the stylus is re-emerging!
    - Samsung Galaxy Note (Wacom)
    - Atmel's & Synaptics' active & passive p-cap styli
    - Stylus for annotation in some eReaders
    - Windows 8 has <u>simultaneous</u> stylus and finger-touch

E-Ink 9.7" Prototype EMR Kit

Comparing Touch Technologies

Touch Technology vs. Application

Application	Example	Touch Technologies														
		Analog Resistive	Multi-Touch Resistive	Surface Capacitive	Projected Capacitive	SAW	Traditional IR	Waveguide IR	Optical	APR	DST	Force Sensing	LCD In-Cell (Light)	LCD In-Cell (Voltage)	LCD In-Cell (Charge)	LCD On-Cell (Charge)
Kiosk Point of Info (POI)	Museum information	O	X	O	X	O	O	X	O	O	O	X	X	X	X	X
Kiosk Commerce	Digital photo printing	O	X	O	O	O	X	X	X	O	O	X	X	X	X	X
Kiosk Ruggedized	Gas pump	X	X	O	O	O	O	X	X	X	X	O	X	X	X	X
Point of Sale (POS)	Restaurant; lottery	O	X	O	O	O	O	X	X	O	X	O	X	X	X	X
Office Automation	Office monitor	O	X	O	X	O	X	X	X	X	X	X	X	X	X	X
Industrial Control	Machine control	O	O	O	X	O	O	X	X	X	X	O	X	X	X	X
Medical Equipment	Medical devices	O	X	X	O	O	X	X	X	O	X	X	X	X	X	X
Healthcare	Patient info monitor	O	X	X	X	O	X	X	X	O	X	X	X	X	X	X
Military Fixed & Mobile	Submarine console	O	X	O	X	X	O	X	X	X	X	X	X	X	X	X
Training & Conference	Boardroom display	O	X	X	X	O	O	X	O	X	O	X	X	X	X	X
Legal Gaming	Casino machine	X	X	O	X	X	X	X	X	X	X	X	X	X	X	X
Amusement Gaming	Bar-top game	X	X	O	X	O	X	X	X	O	X	X	X	X	X	X
In-Vehicle	GPS navigation	O	X	X	O	X	X	O	X	X	X	X	X	X	X	X
ATM Machine	ATM machine	X	X	O	O	O	O	X	X	X	X	X	X	X	X	X
Mobile Device	Smartphone	O	O	X	O	X	X	O	X	O	X	O	O	O	O	O
Appliance	Refrigerator door	O	X	X	O	X	X	X	X	O	X	X	X	X	X	X
Architectural	Elevator control	X	O	X	X	X	X	X	X	X	X	O	X	X	X	X
Consumer AiO & Monitor	HP TouchSmart	O	X	X	X	O	X	X	O	X	X	X	X	X	X	X
Music Controller	Jazz Mutant	O	O	X	O	X	X	X	X	X	X	X	X	X	X	X
Digital Signage	Thru-window store	X	X	X	O	O	O	X	O	O	O	X	X	X	X	X

13 Usability Characteristics

There is…

Desirable Characteristic	Touch Technologies														
	Analog Resistive	Multi-Touch Resistive	Surface Capacitive	Projected Capacitive	SAW	Traditional IR	Waveguide IR	Optical	APR	DST	Force Sensing	LCD In-Cell (Light)	LCD In-Cell (Voltage)	LCD In-Cell (Charge)	LCD On-Cell (Charge)
Usability															
Touch with any object	H	H	L	L	M	H	H	H	H	H	H	M	M	M	L
No unintended touch	H	H	H	H	H	L	L	L	H	H	H	H	H	H	H
Multi-touch	L	H	L	H	M	M	M	M	L	L	L	H	H	H	H
Touch & hold	H	H	H	H	H	H	H	H	L	L	H	H	H	H	H
High durability	L	L	M	H	H	H	H	H	H	H	H	M	L	L	H
High sensitivity (light touch)	M	M	H	H	M	H	H	H	M	H	L	H	H	H	H
Fast response & drag	M	M	H	H	M	M	H	H	M	H	L	L	H	M	M
Stable calibration	M	H	L	H	H	H	H	H	H	H	H	H	H	H	H
Very smooth surface	L	L	H	M	M	M	M	M	M	M	M	M	L	L	M
No liquid crystal pooling	H	H	H	H	H	H	H	H	H	H	H	H	L	L	H
Resistant to contaminants	H	H	M	H	L	M	L	M	H	H	H	L	L	L	H
Works in rain, snow & ice	H	H	L	H	L	L	L	L	L	L	H	L	L	L	H
Works with scratches	L	L	M	H	H	H	H	H	M	H	H	L	L	L	H

13 Performance Characteristics

no perfect…

Desirable Characteristic	Touch Technologies														
	Analog Resistive	Multi-Touch Resistive	Surface Capacitive	Projected Capacitive	SAW	Traditional IR	Waveguide IR	Optical	APR	DST	Force Sensing	LCD In-Cell (Light)	LCD In-Cell (Voltage)	LCD In-Cell (Charge)	LCD On-Cell (Charge)
Performance															
High optical performance	L	L	M	M	H	H	H	H	H	H	H	H	H	H	M
High resolution	H	M	H	H	M	L	H	H	M	M	L	M	H	L	H
High linearity	H	H	M	M	M	M	H	M	M	M	H	H	H	H	M
High accuracy & repeatability	H	M	M	H	H	M	H	M	M	M	H	H	H	H	H
Low power consumption	H	H	L	M	L	L	M	M	H	L	H	H	L	M	M
Insensitive to vibration	H	H	H	H	H	H	H	H	H	M	L	H	H	H	H
Insensitive to EMI & RFI	H	H	L	L	H	H	H	H	H	H	H	L	L	L	M
Insensitive to ambient light	H	H	H	H	H	M	H	M	H	H	H	L	H	H	H
Insensitive to UV light	L	L	H	H	H	H	H	H	H	H	H	H	M	M	H
Touch-object size recognition	L	M	L	H	L	L	H	H	L	L	L	M	H	M	H
Measures Z-axis	L	L	L	M	M	L	L	L	L	L	H	L	L	L	M
Handwriting recognition	H	M	L	M	L	L	M	H	L	L	L	M	H	L	M
Works with bi-stable reflective	H	H	L	H	L	L	M	L	H	L	L	M	L	L	H

13 Integration Characteristics

touch technology!
(Burma Shave)

Desirable Characteristic	Touch Technologies														
	Analog Resistive	Multi-Touch Resistive	Surface Capacitive	Projected Capacitive	SAW	Traditional IR	Waveguide IR	Optical	APR	DST	Force Sensing	LCD In-Cell (Light)	LCD In-Cell (Voltage)	LCD In-Cell (Charge)	LCD On-Cell (Charge)
Integration															
Substrate independence	M	M	L	H	L	H	H	H	L	L	H	L	L	L	L
Scalable	M	L	M	H	M	M	L	H	H	H	H	L	L	L	L
Easy integration	H	M	L	L	M	M	M	H	L	L	M	H	H	H	H
Flush surface (low profile)	M	M	M	H	M	L	M	L	H	H	M	H	M	M	H
Narrow border width	H	M	M	H	L	L	M	L	H	H	M	H	H	H	H
Thin and light	H	H	L	H	L	L	M	L	L	L	L	H	H	H	H
Easy to seal	H	H	H	H	L	M	M	L	H	H	M	M	L	L	M
Can be vandal-proofed	L	L	M	H	H	M	M	L	H	H	H	L	L	L	L
Works on curved surface	M	M	L	H	L	L	L	L	L	L	H	H	L	L	H
Can be laminated to LCD	H	H	H	H	M	M	H	H	L	L	L	H	H	H	H
HID (Plug & Play) interface	L	L	L	L	L	L	L	H	L	H	L	L	L	L	L
Simple controller	H	M	L	L	L	L	M	M	M	L	H	L	H	M	M
Controller chip available	H	H	L	H	H	L	H	L	H	L	H	L	L	L	L

Source: CG4TV

Conclusions

There Is No Perfect Touch Technology!

Technology	Major Advantage	Major Flaw
Projected Capacitive	Multi-touch	Finger-only
Surface Capacitive	Touch sensitivity	High drift
Analog Resistive	Low cost	Low durability
Multi-Touch Analog Resistive	Multi-touch	High touch force
Surface Acoustic Wave	Durability	Soft touch object
Acoustic Pulse Recognition	Any touch-object	No touch & hold
Dispersive Signal Technology	Any touch-object	No touch & hold
Traditional Infrared	Reliability	High cost
High-Finger-Count Infrared	Multi-touch	Performance
Waveguide Infrared	Low cost	Contamination
Camera-Based Optical	Scalability	Profile height
Planar Scatter Detection	Flush surface	High cost
Vision-Based	Multi-touch	Rear projection
LCD In-Cell	Integration	Sensitivity
LCD On-Cell (P-Cap)	Integration	Finger-only
Force-Sensing	3D substrate	Multi-touch
Electromagnetic Resonance	High resolution	Pen-only

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

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

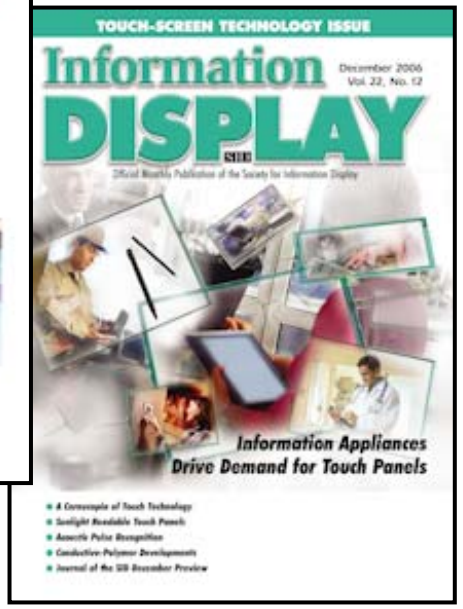
Suggested Reading on Touch

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

March 2011

March 2010

December 2007



December 2006

September 2012

Suggested Conferences and Shows on Touch & Interactivity

- **SID's Display Week** YOU ARE HERE
  - Exhibits, Symposium, Sunday Short Course, Monday Technology Seminar, Market-Focus Touch Conference, Exhibitors' Forum
- **SID's International Display Workshop (ITW - Japan)**
- **Computex (Taipei - consumer products)**
- **InfoComm (Large-format products)**
- **DisplaySearch Emerging Display Technologies**
- **FPD International (Japan)**
- **China Touchscreen (Shenzhen, China)**
- **ACM's Interactive Tabletops & Surfaces (ITS)**
- **ACM's SIGGRAPH**

Suggested Conferences and Shows on Touch & Interactivity…2

- **Shows with commercial touch applications**
  - National Retail Federation (NRF)
  - Healthcare Information Management Systems Society (HIMSS)
  - Global Gaming Expo (G2E-USA & G2E-Asia)
  - Digital Signage Expo (DSE)
  - Customer Engagement Technology World (CETW) (Formerly "KioskCom")
  - Integrated Systems Europe (ISE)

Thank You!

PDF File Download: *www.walkermobile.com/SID_2012_Short_Course_S3.pdf*

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