

Display Week 2012 Review: Touch Technology

2012 was the year that in-cell capacitive touch became real. It didn't happen with big fanfare; in fact, you had to put together pieces from the Symposium, the Monday Technology Seminars, the Thursday Market Focus touch conference, and the exhibits to get the full picture. But it was there and it's significant.

by Geoff Walker

If you missed Display Week 2012, you missed the most important event of the year in the touch industry anywhere on the planet. The amount of concentrated information about touch available at Display Week 2012 was and will be unsurpassed by any other conference anywhere this year:

- A 4-hour Short Course on Sunday
- Two 90-minute Technology Seminars on Monday
- Three presentations at Tuesday's Investors Conference
- Six presentations at the Exhibitors Forum on Tuesday
- 12 papers in the Symposium, mostly on Wednesday
- Seven posters in Thursday's Poster Session
- 19 presentations in Thursday's Market Focus Conference
- Almost half of the 195 companies exhibiting on the show floor (including suppliers of touch screens, controllers,

touch-related materials and equipment, market research, and touch-related services such as bonding, optical enhancement, and integration)

As the likely result of projected-capacitive (p-cap) and resistive touch technologies accounting for more than 90% of the number of touch screens shipped in 2011 (according to DisplaySearch's latest 2012 data¹), the total number of touch technologies exhibited at Display Week 2012 decreased. While 12 technologies were shown in 2011, this year there were only six [p-cap, single-touch and multi-touch resistive, infrared, embedded (in-cell/on-cell/hybrid), and optical]. If you looked closely, you could find one company that sells (but wasn't exhibiting) surface acoustic wave, another that sells (but wasn't exhibiting) surface capacitive, and a third that sells (but wasn't exhibiting) electromagnetic digitizers. Bending wave (from Elo Touch-Systems and 3M) and force-sensing (*e.g.*, from F-Origin) were nowhere to be found.

Projected-Capacitive (P-Cap)

The key difference in the p-cap suppliers at Display Week this year was the number of touch-module suppliers focused specifically on meeting the needs of commercial applications in the U.S. The 15 suppliers in this group included 3M, AMT, Bergquist, Dawar, EETI, Emerging Display Technologies, Gunze USA, Mitsubishi Electric, NLT Technologies, Ocular, Panjit, RitFast, SMK, Touch

International, UICO, and Zytronic (there may be others that the author missed). Prior to Display Week, it was not unusual to hear a p-cap touch-screen prospect say, "Well, who else IS there besides Ocular and Touch International?" Several of 15 are first-time exhibitors at Display Week; others have changed their product focus from resistive to p-cap.

There's beginning to be a significant amount of product differentiation between these suppliers. Some of their differentiation points include quick-turn prototypes, large screens (*e.g.*, 17 and 22 in.), a wide range of screen sizes, cover-glass decoration (printing, shaping, drilling, light pipes, *etc.*), lamination, extended operating temperatures, working with wet hands or gloves, stylus support, a large number of simultaneous touch points, operation in rain or saltwater spray, and embedded GUI solutions.

In-Cell Touch: The Real Surprise at Display Week 2012

Prior to Display Week 2012, it seemed as though in-cell touch wasn't making any significant progress. The number of shipping products with in-cell touch could be counted on just a few fingers:

(1) The line of Samsung digital cameras that use pressed capacitive² – with a user experience significantly inferior to that of the typical smartphone.³

(2) The 21.5-in. monitors from Integrated Digital Technologies (IDTI) that use in-cell optical.^{4,5}

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(3) The Microsoft Surface 2.0 that uses Samsung's SUR40 LCD with in-cell optical – but requires severely limiting ambient light (e.g., 50-lux maximum of incandescent light) due to the touch system's very high sensitivity to ambient IR.⁶ While these products are all shipping, they cannot be seen as successful mainstream applications of in-cell touch.

What changed – and was reported in bits and pieces at Display Week 2012 – was that Synaptics made a breakthrough. Working with multiple LCD manufacturers (with the lead most likely being Sony) for the last year, Synaptics determined that the only way to create a smartphone-like touch experience with in-cell touch is to use the same mutual-capacitive sensor architecture that has become so successful in external touch screens, but move at least one set of electrodes into the LCD cell and find a way to significantly increase the touch system's signal-to-noise ratio (SNR).

Most of the papers published – mostly by the display industry – on all forms of in-cell touch (optical, voltage sensing, pressed capacitive, and self-capacitive) have reported SNRs in the range of 10:1 (3 dB) or 20:1 (10 dB). For example, there is a touch paper from this year's Symposium that claims an SNR of 10:1 is enough to meet the needs of a smartphone. That may be acceptable in the lab, but it's certainly not acceptable in the real world. Connecting a noisy AC adapter to a smartphone can raise the system noise floor by a factor of 10, causing that touch screen to become completely inoperative. The use of a fine-tipped passive stylus – which will become much more important with the launch of Windows 8 – requires a much higher SNR. Based on Synaptics' work, a realistic minimum SNR target for an excellent user-experience in the real world is 50 dB (a little over 300:1). Even higher is better for a passive stylus.

In order to accomplish a 50-dB SNR, Synaptics concluded that (a) the basic touch architecture must be "true" mutual capacitive rather than any of the existing in-cell capacitive variations, (b) the touch controller and the LCD driver must communicate with each other, and (c) the LCD driver timing must be modified to support both a display mode and a touch mode. The Distinguished Paper entitled "An In-Cell Capable Capacitive Touchscreen Controller with High SNR and Integrated Display Driver IC for WVGA LTPS Displays" by Synaptics is the key document that describes this technique.⁷ Among other details, the

paper describes segmenting the VCOM plane in an LCD to allow dual-purpose operation as drive electrodes for "true" mutual-capacitive touch sensing while still functioning as a proper VCOM plane for display operation. Repurposing the VCOM plane as touch-screen drive electrodes also produces a highly desirable advantage: it moves the (typical) ± 10 V VCOM signal from the denominator of the SNR into the numerator; *i.e.*, instead of being considered noise that detracts from the operation of the touch screen, the VCOM signal becomes part of the touch-screen operation. Even better, higher VCOM voltages result in a higher SNR!

The sense electrodes are deposited in a single layer of ITO on top of the color-filter (CF) glass. This touch-sensor architecture is shown in Fig. 1, taken from the aforementioned Synaptics Distinguished Paper.

Note that technically this architecture is a hybrid of *in-cell* and *on-cell*, since one set of electrodes is inside the cell (the segmented VCOM plane) and one set of electrodes is outside the cell (deposited on top of the CF glass). However, the LCD industry is rapidly moving towards calling all forms of embedded touch "in-cell," on the grounds that it's all inside the LCD module. For example, Chimei Innolux announced at Display Week 2012 that it is going to brand all of its embedded touch products from now on as "Touch On Display" (TOD), intentionally obscuring the specific touch-sensor architecture that's used in a given product. After all, why should anyone care what touch-sensor architecture is used – other than the manufacturer, of course!

New Shipping In-Cell Products: The Next Piece of the Puzzle

On Monday of Display Week 2012, Bob Mackey, Synaptics's Principal Scientist, presented a Technical Seminar entitled "Innovations in Touch Sensing."⁸ This presentation described with excellent clarity all the possible touch-sensor architectures that could be used in a smartphone (see pages 20–37 of "Innovations in Touch Sensing"). In this presentation, Bob also stated that the Sony Xperia P smartphone (shown in Fig. 2) uses in-cell-touch electrodes configured as described on page 11 of the Distinguished Paper mentioned above (An In-Cell Capable Capacitive Touchscreen Controller...). In a Synaptics blog, it is stated that the HTC EVO Design 4G also uses the same in-cell configuration.⁹ Both of these smartphones use a 4-in.

960 × 540 (QHD, 275 ppi) LTPS LCD.

However, the LCDs are not actually identical; visual inspection of the phones reveals that the Sony Xperia P LCD uses RGBW pixels, while the HTC EVO Design 4G LCD uses RGB pixels.

These two shipping products use separate (but linked) touch controller and LCD driver ICs. Synaptics has announced that it has started manufacturing a single IC that includes both functions for 864 × 480 (WVGA) LCDs; it has named this new product TDDI (Touch and Display Driver IC). This integration reduces component cost, of course, but it also creates an IC that is unique for a particular LCD. If another LCD manufacturer wants the same functionality but is using an LCD with a slightly different resolution (there are no standards for LCD resolution in the smartphone market like there are in the PC market), then it requires a new custom IC. This problem was pointed out in a presentation entitled "Challenges and Opportunities in Touch Controller Semiconductors" made by Randy Lawson, a Senior Principal Analyst at IHS, during Thursday's Market Focus touch conference.¹⁰

In-Cell Touch in IPS-LCDs

In an IPS-LCD, the VCOM plane is located in the TFT array, and it's already segmented by design. Without changing the various metal

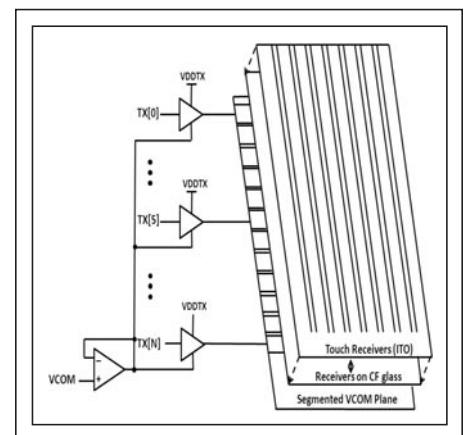


Fig. 1: Synaptics's "true" mutual-capacitive LCD in-cell touch-sensor architecture incorporates a VCOM plane that is segmented to allow dual-purpose operation as drive electrodes for touch sensing while still functioning as a proper VCOM plane for display operation. Sense electrodes are deposited on top of the color-filter glass. Source: Synaptics.



Fig. 2: The Sony Xperia P smartphone uses Synaptics's "true" mutual-capacitive in-cell touch-sensor architecture as described in the company's Distinguished Paper. Like most current mobile devices, this smartphone uses an IPS-LCD; the touch sensor is therefore configured as shown in Fig. 3. Image source: Sony.

and ITO masks used to create the VCOM plane, the VCOM segments can be grouped differently to form touch-sensing drive electrodes. In most IPS-LCDs there is also a grounded layer of ITO on top of the CF glass that functions as a shield and anti-static device; this layer can be segmented into sense electrodes. Since all sense electrodes except the one being sensed at any given moment are grounded, the ITO layer still performs its original function even though it's been segmented. The touch-sensor architecture of an IPS-LCD is illustrated in Fig. 3.

Adding in-cell touch to an IPS-LCD as described in the previous paragraph is sometimes referred to as "no cost" because it may require no mask changes. The author dis-

agrees with this viewpoint, since it is likely that we are actually talking about creating a new display with embedded touch, which represents a new development cost that must be amortized. The reason it's a new display is that the existing non-touch display is unlikely to be made obsolete since the LCD maker probably has OEM customers buying it that use discrete or one-glass solution (OGS) touch-screen construction. In-cell touch in general is likely to add new products to an LCD maker's product line rather than replacing existing products. The management of this expanded product line adds yet another implicit cost.

The new development costs to be amortized include not only a new set of masks for the TFT array, but also the customization of the combined touch-controller and LCD driver (TTDI) IC and firmware to match the particular display resolution being used. Non-recurring engineering (NRE) costs such as the latter can be justified by the reduction in component cost achieved by the TTDI IC, but the primary factor that justifies the development of a new display with embedded touch is very high sales volume. In the author's opinion, it therefore seems unlikely that in-cell touch is going to spread into every LCD in an LCD maker's product line; it's more likely that it will be used only in the highest-volume models – at least in the next several years. Over the long term, as the overall penetration of touch increases, it is possible that the majority of mobile LCDs could include in-cell touch. Usable in-cell capacitive touch in

larger-than-mobile LCDs is still under development; ITO-replacement materials such as micro-scale metal mesh or silver nanowires are probably the most significant enabler.

In-Cell Touch in VA-LCDs

The differences in touch-sensing architecture between an IPS-LCD and a VA-LCD are minor. The main difference is the location of the VCOM electrode. In a VA-LCD, the VCOM signal is applied to the ITO on the inner surface of the CF glass. Again, the ITO mask used to create the VCOM plane is changed so that the VCOM segments can be grouped differently to form drive electrodes. Since the inner surface of the CF glass and the top surface of the TFT array are only a few microns apart, there is little functional difference between the VA and IPS configurations.

VA-LCDs do not use a shield layer on top of the CF glass, so one additional ITO mask is required in order to deposit a layer of segmented ITO to form sense electrodes on top of the CF glass. The position of the drive electrodes in a VA-LCD is fixed by the VCOM mask, while the position of the drive electrodes in an IPS-LCD is determined by the LCD drive electronics. The touch-sensor architecture of a VA-LCD is illustrated in Fig. 4.

Chimei Innolux's In-Cell Prototype: The Final Piece of the Puzzle

The final piece of the puzzle came from the author talking with several company represen-

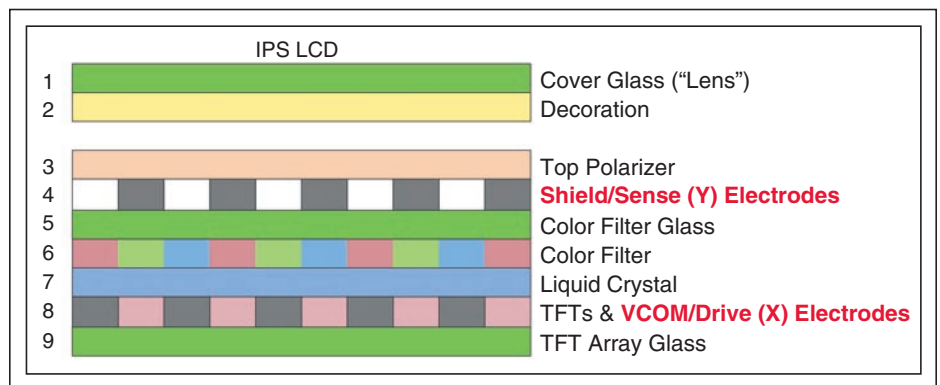


Fig. 3: Synaptics's touch-sensor architecture for IPS-LCDs uses an ITO shield layer on top of the CF glass (row 4 in the graphic). The shield layer is segmented to form sense electrodes while still retaining its function as a shield. Similarly, the segments of the VCOM plane in the TFT array (row 8 in the graphic) are grouped differently to form drive electrodes when the display is operating in touch-sensing mode. Source: Geoff Walker.

tatives in Chimei Innolux’s booth on the show floor. The Chimei representatives said that they have recently prototyped in-cell touch in one of their IPS-LCDs using Synaptics’s touch-sensor architecture and an early sample of Synaptics’s integrated touch controller and LCD driver (TDDI) IC. The Chimei representatives said that their drive electrodes (VCOM segments) use existing traces on the TFT array; this is possible because the Synaptics TDDI IC allows each row and column of the LCD to be addressed individually. They also said that they had not yet measured the SNR of their prototype, but that they expected the value to be similar to that reported by Synaptics.

Other Chimei Innolux Embedded Touch Architectures

Chimei had the most extensive display of embedded touch products on the show floor. In addition to the IPS in-cell touch mentioned in the previous paragraph, the company was also showing or talking about the following:

- A self-capacitive set of electrodes on top of the CF glass, in a diamond pattern with true multi-touch (and as many as 300 pads!). A VP at Chimei told the author that they had started this project a long time ago when Chimei had a restricted manufacturing capacity. They did not want to add more machines to do multiple layers, so they challenged their engineering team to add touch using the existing equipment. From such challenges innovation is born.
- Standard on-cell mutual capacitive, which Chimei calls OTS (on-cell touch screen). This is a single layer of ITO with bridges, using the standard Synaptics controller. This configuration is not in volume production yet at Chimei because the yield is only 60–70% due to the “double-sided problem”; *i.e.*, whatever you do to one side of the CF glass is likely to damage or affect the other side. For example, if you do the CF side first, it can use organic material; when you anneal the ITO on the touch side, the high temperature damages the organic CF material.
- One-glass solution (OGS), which Chimei calls “window integrated sensor.” (By the way, the term “OGS” seems to be slowly taking hold in the touch industry; more than a few booths on the show floor were using it.) Chimei’s yield with

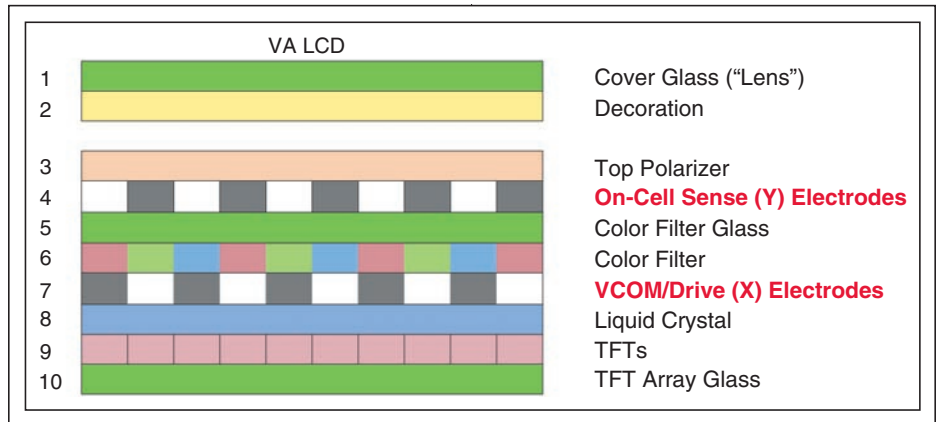


Fig. 4: Synaptics’s touch-sensor architecture for VA-LCDs incorporates an additional layer of segmented ITO (row 4 in the graphic) that is deposited to form sense electrodes on top of the CF glass. The segments of the VCOM plane underneath the CF glass (row 7 in the graphic) are grouped differently to form drive electrodes when the display is operating in touch-sensing mode. Source: Geoff Walker.

OGS is also in the 60–70% range because it’s a difficult process that the company hasn’t done before. (Other vendors with more experience doing OGS have reported higher yields.) The touch sensor is a single layer of ITO with bridges (Chimei claims that this is lower cost than two layers with an insulator). One of the difficulties is the temperature limit of the black-mask (decoration) material; if the ITO needs to be annealed, the current black-mask material cannot handle the high temperature.

Some Other Interesting Exhibits

The Display Week exhibition is so chock-full of interesting things to see that it’s almost impossible to see it all. Here is a sampling of exhibit offerings that the author found particularly interesting:

- A very clever method of having touch buttons on a display without actually using a touch screen. This is accomplished by positioning long-range proximity sensors in the bezel below the display and controlling their sensing pattern. (Azoteq)
- A Specific Absorption Rate (SAR) proximity sensor with optimization for human detection (vs. inanimate objects). This is accomplished using two capacitive proximity sensors and digital signal processing. (Semtech)
- A curved touch screen (shown in Fig. 5) built on a 50- μ m glass substrate with a

100- μ m cover glass. (Nippon Electric Glass)

- A new method of making ITO invisible by depositing the ITO on top of a 3-D “moth-eye” nanostructure. The nanostructure makes the difference between the ITO-coated and uncoated surfaces’ reflectivity (and also transmittance) almost zero. (Sony Chemical)
- A 3H hardcoat film with more abrasion resistance than an 8H hardcoat film. (Oike)
- P-cap touch screens that work well with water on the surface (several suppliers).

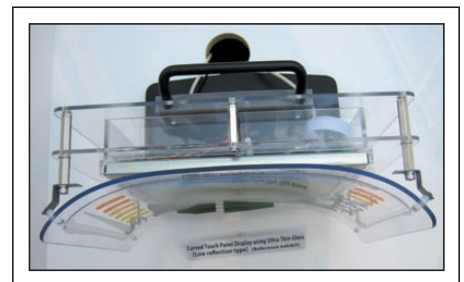


Fig. 5: Nippon Electric Glass created this 10.8-in. curved p-cap touch-screen reference design on a 50- μ m glass substrate with electrodes deposited on both sides and a 100- μ m cover glass. The minimum radius of curvature is 65 mm. Nippon Electric Glass envisions applications (with a curved display) in automotive-navigation systems, tablet PCs, and smartphones. Source: Geoff Walker.

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- Extensive parameter tunability on Baanto's latest optical touch screens. Some of the parameters include touch-area detection, minimum touch time before a new touch is recognized, and shadow touch density.
- A new laser-cutting method for aluminosilicate (toughened) glass that loses only 10% of the glass's strength. (Asahi Glass)
- A plug-in for Adobe Acrobat that allows four users to simultaneously edit the same drawing or document on a multi-user touch table. (Circle 12)
- Re-designed spacer dots in a four-wire resistive touch screen that reduce the touch-force required for activation to only 2 or 3 grams – it feels the same as p-cap! (Fujitsu Components)
- PQ Labs's "high-finger-count" infrared touch algorithms licensed to IRTouch and used in a 10-touch 22-in. IR touch screen. A representative in the IRTouch booth said that there's a lot of interest in the product, but that it's not concentrated in any one market (*i.e.*, there isn't one common application).
- Stantum's latest digital-resistive touch screen (made by Nissha Printing and shown in Fig. 6) with Peratech's "quantum tunneling" pressure-sensing material in a layer only a few microns thick between the film and the glass.
- A p-cap mutual-capacitive sensor (in 3.5-, 5-, and 7-in. sizes) that uses a single layer of ITO without bridges or metal routing traces. This is accomplished by running drive electrodes vertically down the sensor and forming individual sense pads in a column beside each drive electrode. This layout also allows the sensor to be borderless on three sides. The sensor is built on a substrate of Corning's 0.1-mm "Willow" glass and laminated to a 0.5-mm cover glass with 0.1 mm of OCA for a total stack-up of 0.7 mm. This is about the same thickness as an OGS configuration, but without the associated yield problems. (TouchTurns)
- An ordinary 7-in. p-cap touch screen (shown in Fig. 7) that works very well with a passive 2-mm-tip stylus. (Emerging Display Technologies)

Touch at Display Week is Evolving

In the beginning of this article there was a mention of the increased number of p-cap



Fig. 6: Stantum's latest digital-resistive (iVSM) touch screen uses Peratech's "quantum tunneling" pressure-sensing material in a layer only a few microns thick between the film and the glass. Note the Nissha branding; Stantum and Nissha Printing have partnered to produce a line of "Fine Touch Z" touch screens in sizes 5–12 in. Source: Geoff Walker.

module suppliers at Display Week this year that are focused specifically on meeting the needs of commercial applications in the U.S. It seems clear that the exhibition/conference portion of Display Week has become the number one place for U.S.-based commercial touch prospects to look for suppliers and new



Fig. 7: A 7-in. p-cap touch screen from Emerging Display Technologies supports a passive stylus with a 2-mm tip. The author wrote his name on the screen with palm contact; there were no spurious points recorded and the ink was noise-free with normal stair-stepping that software could easily smooth. Source: Geoff Walker.

technology. The majority of the 31 presentations on touch in the bulleted list at the beginning of this article (presentations made in the Market Focus Conference, Investors Conference, Exhibitors Forum, Technology Seminars, and Short Course) were made by American companies.

In contrast, the touch portion of the Symposium is dominated by the Asia-centric display industry. Of the 19 papers and posters on touch presented in the Symposium, 10 were written from a display-industry perspective, reflecting the very strong interest of the display industry in embedded touch; five were written from a touch-screen-industry perspective; and four were written from an "other" perspective (glass-2, bonding, and proximity sensing). While this difference between the exhibition/conference and the Symposium parts of Display Week is not necessarily a problem, the author would definitely like to encourage the touch-screen industry to write more, higher-quality papers or posters for the Symposium. In that way, the touch portion of Display Week will become all it can be.

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