Latest Advances in Touch and Display Integration for Smartphones and Tablets

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Smart Displays
Powered by Synaptics®

Introduction

Capacitive touchscreen technology has revolutionized smartphones and tablets, and is now finding its way into laptops, desktop displays, and all-in-one PCs. Because the market for these devices is fiercely competitive, vendors are constantly challenged to design systems with high display quality, ease of navigation, high performance, compact form factors, long battery life, and low cost. Because the touchscreen plays such an influential role in the user experience, the choice of its design can be a determining factor in a product's ultimate success.

The ability to turn a display into a "touch pad" requires combining these two previously distinct functions in seamless fashion. Historically, adding touch sensors to the display has been handled in an autonomous fashion by different companies supplying different layers in a laminated panel "stack-up" that is then assembled by a separate manufacturer. Recent advances in technology have made it possible to integrate the touch sensors directly into the display, as well as to integrate the Touch Controller and Display Driver functions in a single integrated circuit (IC).

This white paper outlines the touch and display integration technologies currently available[1], including a new and innovative solution that is expected to dominate designs for new devices in the foreseeable future. This white paper describes the various ways touch sensors can be integrated directly into the display; it explores integrating the touch controller and display driver into a single IC; and highlights the many advantages of fully integrating touch and display functions for device manufacturers and their partners.

[1] The focus of this white paper is exclusively on smartphones and tablets with touchscreens smaller than 8" (20 cm). While it is possible to integrate touch and display functions in a similar fashion in larger touchscreens, the differences are significant enough to warrant separate coverage.

Integrating touch sensors into the display stack-up

The integration of the touch and display functions in a touchscreen device occurs in two areas: the display panel stack-up and the ICs controlling both functions. This section describes the display panel stack-up; the next section addresses integrating the touch and display driver ICs.

Because Synaptics® supports all of these different technologies, the company is uniquely qualified to discuss each in an unbiased manner. Synaptics' engineers work closely with device and liquid crystal display (LCD) manufacturers on a regular basis to help them choose the optimal technology for each device, taking into account the product's desired functionality, pricing, and competitive differentiation, as well as the design timeframe and manufacturing considerations.

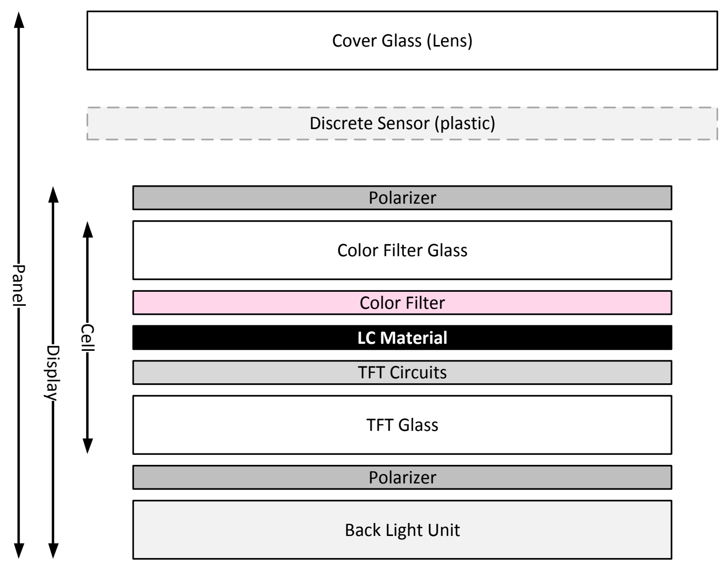

Figure 1. Touch sensors can be added to a separate layer above the display in a laminated panel stack-up, or they can be integrated directly onto one of the existing layers in the display stack-up.

Figure 1 shows the many layers in the display and panel stack-ups in a typical touchscreen. Historically, it has been common for the touch sensors to be added as a separate or discrete overlay atop the display in a laminated panel stack-up. With this design, the sensors are added either on the cover glass (CG) or in a dedicated sensor layer, typically made of plastic.

Putting the sensors on the cover glass lens is sometimes referred to as Sensor-on-Lens (SoL) or as a One Glass Solution (OGS) because it eliminates the need for a separate sensor layer. Designs with a separate sensor layer are known as Glass-Film (GF) or Glass-Film-Film (GFF), depending on whether the transmitting and receiving touch functions are implemented in one or two layers, respectively, of the sensor film. These designs are called "discrete" to emphasize the fact that the touch function exists separately as an overlay on the display.

Advanced touch features

Touch sensors and controllers are being enhanced to deliver advanced user features such as:

- Touch wake-up gestures
- Pen support down to a 1 mm tip
- Concurrent finger and pen operation
- Proximity and finger hover
- Glove and fingernail support
- Ability to operate in moist environments

Discrete touch sensor overlays have the advantage of being proven, low-risk technologies with short time-to-market, and some LCD manufacturers (LCMs) also value their ability to leverage existing manufacturing set-ups in the plant and equipment. They have the disadvantage, however, of making the panel stack-up thicker, dimmer, and more expensive.

Recent technological advances enable LCMs to integrate the touch sensors directly into one or more layers in the display stack-up itself. This integration can occur either on or in the display's cell: an On-Cell integration or an In-Cell integration.

Situating the touch sensor matrix on top of the color filter glass is called an *On-Cell* integration because the sensor is built on top of the display's cell. The sensor transmit and receive grids (a diamond pattern or a bars-and-stripes pattern) can be electrically isolated with jumpers or laid out in a special arrangement that enables them to be implemented without jumpers. This latter technology, referred to as *Single-Layer-On-Cell* (SLOC), results in lower costs and higher yields.

On-Cell technology is a simple, dependable way to add touch to a display. It is often the best choice for use with active matrix organic light-emitting diode (AMOLED) displays. Jumperless, metal-mesh sensors also make On-Cell integration a good choice for larger display sizes as well as curved or flexible displays.

As shown in Figure 1, the display cell extends vertically from the bottom of the thin-film transistor (TFT) glass to the top of the color filter glass and includes the TFT circuitry, the LC material, and the color filter. In-Cell sensors use existing display layers to construct the touch sensor matrix, typically leveraging the common electrode (or V_{COM} layer) as the touch sensor matrix and the metal layers as interconnects to the matrix. For today's in plane switching (IPS) panels, these layers all exist on the TFT glass.

One other type of In-Cell integration is a hybrid design in which the transmitting layer of the touch sensor is In-Cell on the TFT glass while the receiving layer is On-Cell on the color filter glass. This is referred to as a *Hybrid In-Cell* design. The term *Full In-Cell* means that the transmitting and receiving touch sensor layers are both within the cell. Both types of In-Cell are shown in Figure 2.

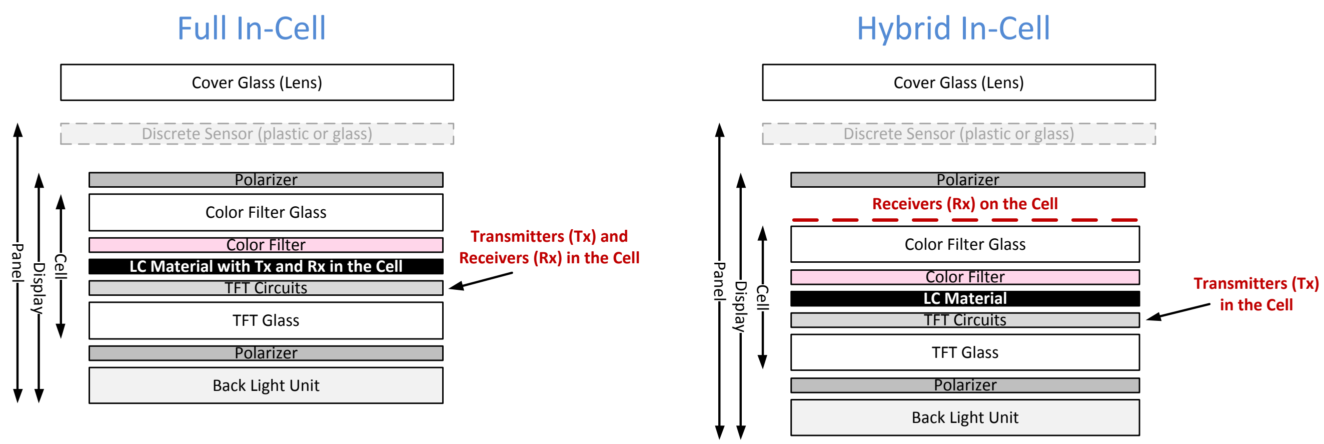

Figure 2. The type of In-Cell integration is determined by the location of the touch sensor's transmitting and receiving layers.

Integrating the touch controller and display driver ICs

The ICs that control the touch and display functions have historically been provided by separate suppliers. While integrating these separate ICs is possible with discrete panel stack-ups and On-Cell displays, the benefits are limited and the effort is more complicated when multiple suppliers are involved. With In-Cell integration, by contrast, integrating the Touch Controller and the Display Driver into a single IC is both easier and substantially more beneficial.

Synaptics touchscreen ICs

The Synaptics® ClearPad® portfolio offers the industry's broadest and most advanced line of clear capacitive touch controller solutions, while the Synaptics family of liquid crystal display drivers offers advanced image processing to meet the needs of today's mobile devices.

Synaptics brings these technologies together to lead the adoption of touch and display driver integration (TDDI) solutions for mobile markets.

The display functions in existing smartphones and tablets are likely to be controlled by a single Display Driver IC (DDIC) and the touch functions are likely to be controlled by a separate Touch Controller IC. In designs that use an On-Cell display, the DDIC is always located on the TFT glass itself, referred to as *Chip-On-Glass* (COG), while the Touch Controller IC is usually located on a flexible printed circuit (FPC or flex), referred to as *Chip-On-Flex* (COF). In such designs, there are usually two FPCs from the host to the panel: one for the DDIC on the TFT glass and the other for the Touch Controller.

Smartphones and tablets designed with a Full In-Cell display require only a *single* FPC for interfacing with both the display and the touch sensor. Having a single FPC makes a compelling case for integrating the touch controller and the display driver into a single IC (*Touch and Display Driver Integration* otherwise known as TDDI).[2] Because the IC itself has a CPU (for touch signal processing) and is mounted on the TFT glass, the integrated solution is sometimes referred to as a smart display that is powered by TDDI.

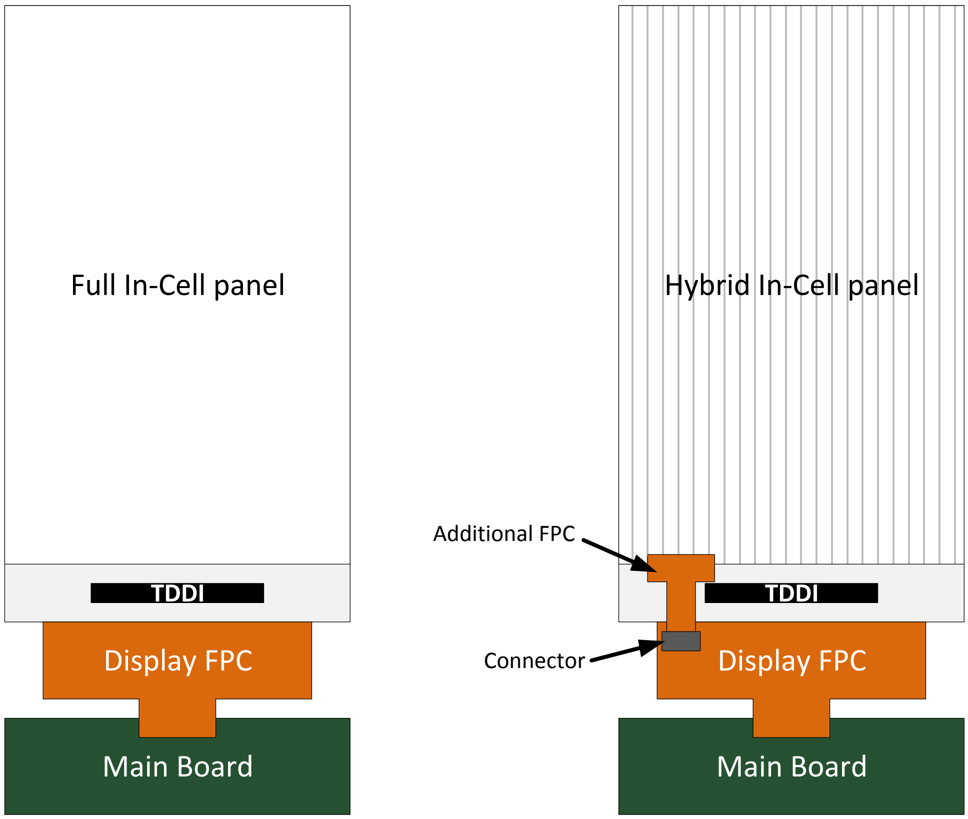

Figure 3. With Hybrid In-Cell designs, an additional FPC is needed.

The architectural design and implementation of TDDI solutions is not trivial. For advanced display noise management and improved capacitive sensing performance, Synaptics TDsync™ technology coordinates and synchronizes the touch and display functions.

The resulting solution overcomes the limitations associated with discrete panel stack-ups and On-Cell displays, where touch and display functions typically operate independently from one another.

[2] TDDI can also be used for Hybrid In-Cell implementations. In this configuration, a second FPC is usually used to route the receiver pins (from the TDDI chip on the TFT glass) to the receiver electrodes on top of the color filter glass as shown in Figure 3. This second FPC only contains the routing signals and does not have any active components on it.

Advantages of In-Cell TDDI solutions

Some significant advantages can be derived from integrating the touch and display functions in both In-Cell displays and the ICs. These advantages can be divided into two categories: those that benefit engineering, manufacturing, and support activities; and those that enhance the design of the smartphone or tablet.

Engineering, manufacturing, and support advantages

Integrating touch and display functions in both the display stack-up and the IC simplify the design effort, helping to accelerate the time-to-market for new devices — giving device manufacturers a distinct competitive advantage.

Manufacturing costs are minimized based on a combination of fewer components and a more efficient supply chain. There is one less FPC with Full In-Cell integration, and one less IC. The display panels ship from the LCD manufacturer (LCM) with fully integrated touch capabilities, virtually eliminating yield loss from a separate sensor lamination process. With fewer components and suppliers, there are fewer assembly steps and problems, and the devices require less work-in-process manufacturing time.

Engineering, manufacturing, and especially ongoing support all benefit from the streamlined supply chain that affords “one-stop-shopping” with a single supplier who is responsible for the entire touchscreen display panel subassembly—edge-to-edge and top-to-bottom. By having a single supplier fully responsible for both the touch and display functions, troubleshooting efforts are also streamlined.

Device design advantages

The elegance and simplicity of integrating both the touch and display functions in both the display glass and the IC results in a sleeker, more functional device. With full In-Cell displays, the panel is thinner compared to discrete designs. The display also has narrower borders because there is no need for external routing on the sides or top of the display panel. Thinner panels result in thinner form factors or provide more space for other features, such as additional memory or battery capacity, while the narrower borders support the narrow bezels needed to produce full size, edge to edge displays.

The combination of In-Cell and TDDI also improves performance because the display is more responsive to touch control owing to synchronized scanning, as Synaptics does with TDsync. In addition, synchronizing the touch and display functions virtually eliminates electrical display noise from interfering with touch sensing, which can cause operational problems when not properly mitigated. And as shown in Figure 4, with no separate touch sensor layer to attenuate light, In-Cell displays are about 10 percent brighter or, alternatively, can provide the same brightness with less backlight, resulting in longer battery life.

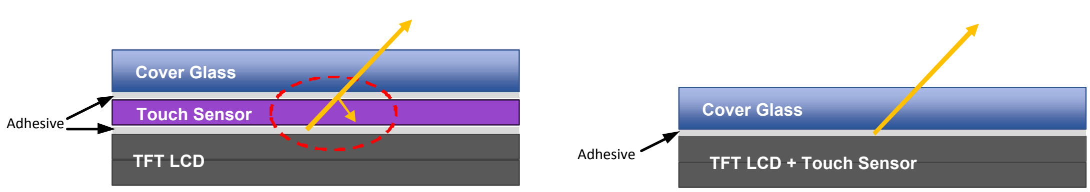

Figure 4. Integrating the touch sensors directly into the display stack-up results in a thinner, brighter display—as well as a simplified supply chain.

Because integrating the touch and display functions simplify the device's design and manufacturability, it also improves the device's overall reliability. There is no need to laminate multiple functional layers, which creates a potential cause of malfunction or failure. And if the design itself seems to be causing a problem in a laminated discrete panel stack-up, the need to involve multiple suppliers complicates the effort to resolve the issue in a timely manner.

Conclusion

Touchscreens have become the norm in smartphones and tablets, and user demand for simplicity of navigation is now making touchscreens increasingly common in laptops and all-in-one desktop PCs. Although there are now many different technologies available for incorporating touch and display functions into touchscreens, the use of an In-Cell display with TDDI is rapidly becoming the preferred choice for new devices in the mainstream mobile market.

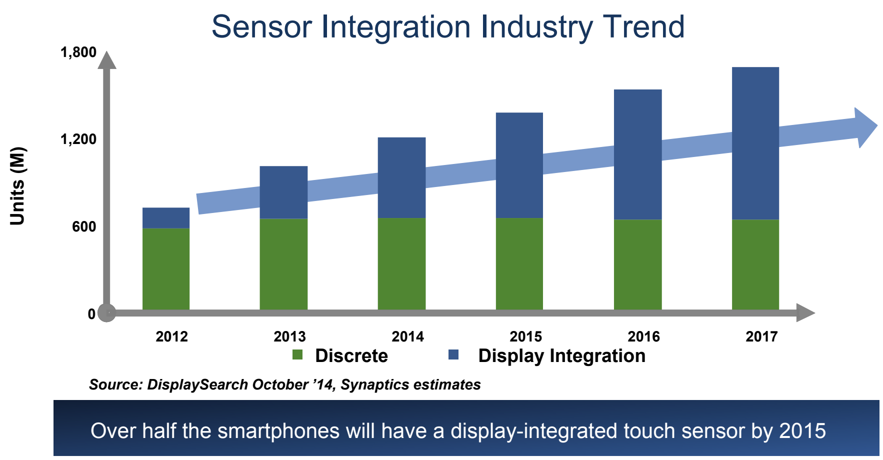

Figure 5. Discrete panel stack-ups are giving way to designs based on display integration.

The reason for its rapidly-increasing popularity is the ability of In-Cell/TDDI designs to solve a number of problems caused by the way panel stack-ups have previously been designed and manufactured, where the implementation of touch and display functions in an autonomous and asynchronous manner has resulted in more complicated designs, increased costs, and less dependable operation. By contrast, the full integration and synchronization of touch and display functions in the Synaptics ClearPad Series 4 ICs with TDsync technology solves these problems and affords some other advantages that result in better devices and, therefore, more satisfied users.

About Synaptics

Synaptics is the pioneer and leader of the human interface revolution, bringing innovative and intuitive user experiences to intelligent devices. Synaptics' broad portfolio of touch, display, and biometrics products is built on the company's rich R&D and supply chain capabilities. With solutions designed for mobile, PC and automotive industries, Synaptics combines ease of use, functionality and aesthetics to enable products that help make our digital lives more productive, secure and enjoyable. (NASDAQ: SYNA) www.synaptics.com.

Contact Synaptics

To locate the Synaptics office nearest you, please visit our website at www.synaptics.com.

Revision history

Revision	Reason for Change
A	Initial release.
B	Updated figures 3, 5, and 6.
C	Removed cost chart.
	Corrected formatting error.
D	Updated the notice and formatting.