TGM 2012

Geoff Walker
Senior Touch Technologist

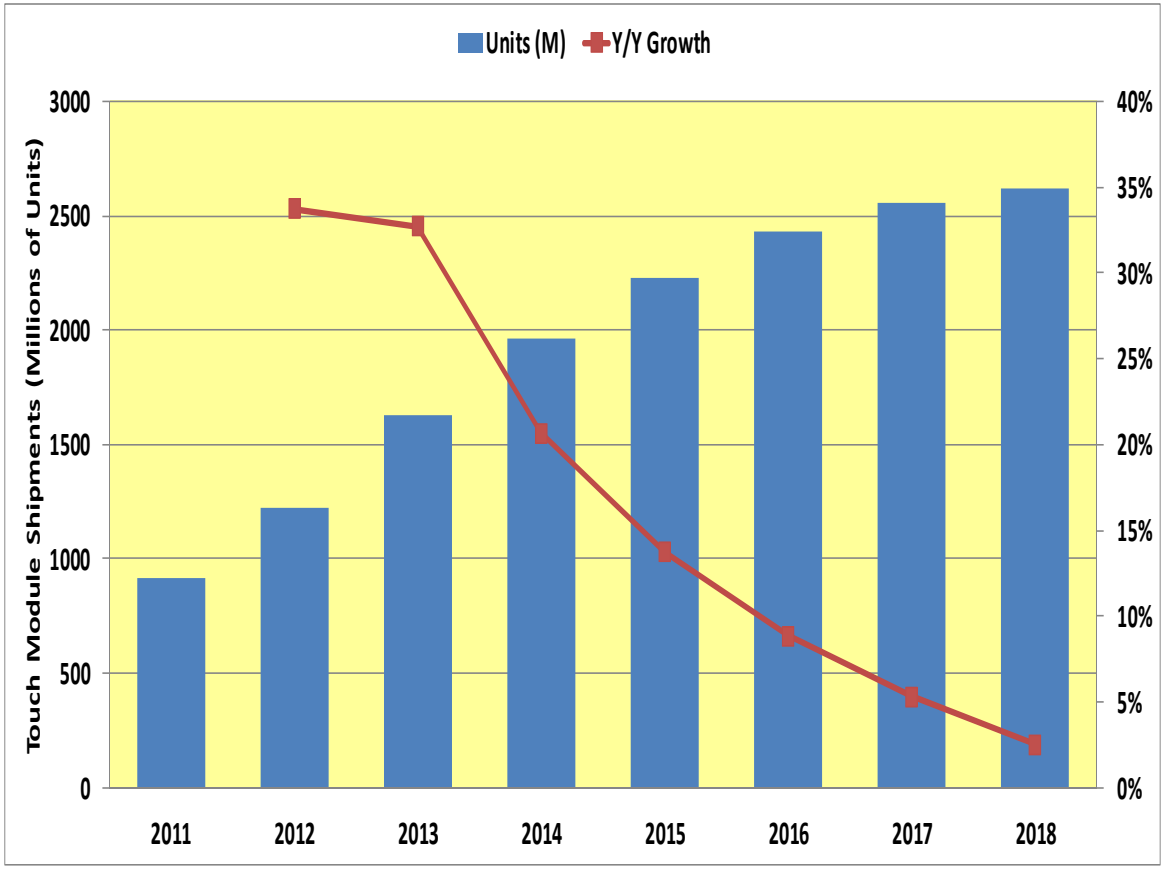
intel

The State of Projected-Capacitive Touch Technology

Topics

- Market
- Cost
- P-Cap Constructions
- ITO Replacements
- In-Cell & On-Cell Touch
- Stylus
- Interests

Market



- DisplaySearch's 4Q-2012 touch module forecast for phones, tablets, notebooks, and AiOs
  - 83% p-cap in 2012 in various forms
  - 2018 forecasted touch penetration is 95%, 100%, 37% and 23%

What About Ultrabooks?

- 140 designs currently under development, ~30% touch
- Touch in hybrids (“convertibles”) = obvious
- Touch in clamshells = less obvious
- What does it take to drive touch into clamshells?
  - Lower cost
  - Touch apps that create consumer pull
  - Touch that’s easier or more convenient than alternative input methods
  - Touch that feels natural and responds quickly
  - Touch that’s fun and satisfying
  - Windows 8

Cost…1

- Total cost of touch module installed in an Ultrabook
  - Cover glass, lamination, shielding (if needed), controller, etc.
- Walker's rule of thumb
  - **Total touch cost of <5% of BOM is a no-brainer**
  - Assuming $500 BOM for $900 13.3" Ultrabook, 5% is **$25**
  - TODAY's cost is $55 to $85 (11%-17%), depending on configuration

Cost…2

- What's going to reduce the cost of touch in an Ultrabook?
  - ITO replacements
  - Simpler/better/easier (re-workable) lamination
  - Process simplification
  - Supply-chain simplification (display integration)
  - Yield improvements at every step
  - Elimination of glass (eventually)

Cost…3

- Let's talk about yield for a moment…
  - Yield can be for a single step
  - Yield can be for an entire process (ITO deposition to final assembly)
  - Yield varies by the nature of the process
  - Yield varies by the skill & experience of the operators
  - Yield varies over time (learning curve; material & process changes)
  - Yield for exactly the same thing varies widely by company

- Consider all of this the next time you hear someone quotea yield number…

P-Cap Constructions

- P-cap sensors today exist in many different constructions, but all the variety is really only about a few things
  - Thinness
    - OGS (ITO deposited on the underside of the cover glass) = same thinness as in-cell construction
    - GF2 = ~50 microns thicker
    - GFF = ~100 microns thicker
  - Process expertise
    - A supplier tends to stay within their comfort zone
  - Cost
    - Fewer materials and simpler processes = lower cost
  - Yield…
  - IP landscape

ITO Replacements…1

- Top four materials
  - Metal mesh – **Atmel is shipping**
  - Silver nanowires – **Cambrios is shipping**
  - Carbon nanotubes (like silver nanowires, but made of carbon)
  - Conductive polymers (still striving to reach the goal…)
- It's not really about the material, it's about the process
  - All the ITO in a 42-inch TV LCD is ~$3; an Ultrabook is cents
  - ITO = vacuum deposition with photolithography on a fab
  - Metal mesh = print the entire sensor at room temperature

ITO Replacements…2

- The difficulty of new processes is lack of infrastructure
  - Supply chain has to be created from scratch
    - Silver nanowire's strategy is to stay completely compatible with the existing ITO process, but cost savings are reduced by doing patterning on a fab
  - Establishing multiple sources is difficult

- How much cost are ITO replacements going to save?
  - 30%-50% reduction in the ITO sensor cost is a good target
  - BUT, the sensor is often only 50% to 70% of the total cost, so the actual cost reduction in the installed module is 15% to 38%
    - Not enough, but a good start

In-Cell Touch…1

- **It's shipping today** in high-volume mobile-phone LCDs
  - Sony Xperia P, HTC EVO Design 4G, iPhone 5
- **All previous in-cell touch technologies failed** and should be considered dead
  - Pressed capacitive, self-capacitive, switch-sensing, light-sensing, etc.
- **The in-cell technology battle is over** (at least for mobile phones); in-cell p-cap has won
  - Invented by Sony and Synaptics
    - Use existing internal metal in groups to form drive and sense electrodes; segment the ITO static-shield on IPS displays only if necessary
    - Use VCOM as the drive signal, changing it from noise to signal
    - Cooperate with the LCD driver chip on timing

In-Cell Touch…2

- The result is a different LCD with minimal mask changes and (ideally) NO additional masks
  - The NRE required to develop this different LCD limits in-cell to high-volume applications
- Problems in expanding beyond mobile-phone size displays
  - Timing is #1
    - Larger screens have more electrodes to be sensed in less time
  - Sensing speed is #2
    - Longer electrodes have more resistance & capacitance which slow signals

In-Cell Touch…3

- Will these problems be solved?
  - Eventually, like most technical problems (in-cell required ~10 years)
  - But because of the development NRE, low-volume LCDs aren't likely to be targeted for in-cell touch

- Will the display industry eventually destroy the touch-panel industry, as suggested in the Market Focus Conference at Display Week 2012?
  - The display industry is very likely to win the revenue battle
  - BUT, the number of LCDs without in-cell touch will still far outnumber the number with in-cell touch

What About On-Cell Touch?

- On-cell touch has become the standard for OLED, yet it hasn't become very popular with LCD makers
  - It may not solve enough problems on LCDs
    - It's still basically like putting a discrete touchscreen on top of the color filter; connectivity is messy with a separate flex and controller
    - Double-sided processing of the color filter/touch sensor is still a problem
  - Some experimentation is in progress with ITO-replacement based touch sensors

Stylus…1

- In 2007, Steve Jobs famously said, “Stylus, yeeecchh!”
- In 2008, Microsoft decided to emphasize the finger in Windows-7 touch over the stylus from the (perceived) failed Tablet PC
- The result is that for the last six years, we’ve been in an artificially pro-finger-touch world
  - Remember the stylus on the Palm PDA and the Handspring Trio?
    - Stylus has been around a LONG time and it’s NOT going away
- Windows 8 may cause stylus to re-emerge and become important again

Stylus…2

- Stylus use cases
  - Quick sketching
  - Artistic drawing
  - Taking notes that are converted into searchable text in the background
  - Precision pointing device for legacy Windows apps
  - Annotation of existing documents

Stylus…3

- Stylus types for use with p-cap touchscreens
  - "**Artificial finger**", what most consumers think of as a stylus today
    - $10 at Amazon with a 7 mm conductive-rubber tip and a very poor UX
  - **Passive metal stylus** with 2 mm tip
    - Latest generation of touch controllers with high SNR supports these, but none are shipping yet
  - **Active stylus** with <1 mm tip ➔ most likely to be successful
    - N-trig is the most mature supplier
    - Atmel, Synaptics, Cypress and other p-cap controller suppliers all have them but aren't shipping yet
    - Wacom (used in the Samsung Galaxy notes) is legacy technology that requires an additional behind-the-LCD sensor

Interests: Hover & Haptics

- **Finger-hover** (mouseover) is shipping in the Sony Xperia Sola mobile phone, implemented only in the browser and on the home screen
  - If you have ideas or desires about using finger-hover, I'd love to speak with you!

- **Haptics** doesn't really exist to any significant extent in tablets or notebooks
  - If you'd like to cooperate in developing a tablet or notebook haptics-application reference platform, I'd love to speak with you!

geoff.walker@intel.com
408-765-0056

Legal Disclaimer

All products, computer systems, dates, and figures specified are preliminary based on current expectations, and are subject to change without notice.

Performance tests and ratings are measured using specific computer systems and/or components and reflect the approximate performance of Intel® products as measured by those tests. Any difference in system hardware or software design or configuration may affect actual performance. Buyers should consult other sources of information to evaluate the performance of systems or components they are considering purchasing. For more information on performance tests and on the performance of Intel® products, visit Intel Performance Benchmark Limitations

Results have been estimated based on internal Intel® analysis and are provided for informational purposes only. Any difference in system hardware or software design or configuration may affect actual performance.

Results have been simulated and are provided for informational purposes only. Results were derived using simulations run on an architecture simulator or model. Any difference in system hardware or software design or configuration may affect actual performance

Intel® does not control or audit the design or implementation of third party benchmarks or Web sites referenced in this document. Intel® encourages all of its customers to visit the referenced Web sites or others where similar performance benchmarks are reported and confirm whether the referenced benchmarks are accurate and reflect performance of systems available for purchase.

Intel® processor numbers are not a measure of performance. Processor numbers differentiate features within each processor family, not across different processor families. See www.intel.com/products/processor_number for details.

Intel®, processors, chipsets, and desktop boards may contain design defects or errors known as errata, which may cause the product to deviate from published specifications. Current characterized errata are available on request.

Hyper-Threading Technology requires a computer system with a processor supporting HT Technology and an HT Technology-enabled chipset, BIOS and operating system. Performance will vary depending on the specific hardware and software you use. For more information including details on which processors support HT Technology, see http://www.intel.com/info/hyperthreading

Intel® Virtualization Technology requires a computer system with a processor, chipset, BIOS, virtual machine monitor (VMM) and applications enabled for virtualization technology. Functionality, performance or other virtualization technology benefits will vary depending on hardware and software configurations. Virtualization technology-enabled BIOS and VMM applications are currently in development.

Intel® Turbo Boost Technology requires a PC with a processor with Intel® Turbo Boost Technology capability. Intel® Turbo Boost Technology performance varies depending on hardware, software and overall system configuration. Check with your PC manufacturer on whether your system delivers Intel® Turbo Boost Technology. For more information, see http://www.intel.com/technology/turboboost.

64-bit computing on Intel® architecture requires a computer system with a processor, chipset, BIOS, operating system, device drivers and applications enabled for Intel® 64 architecture. Performance will vary depending on your hardware and software configurations. Consult with your system vendor for more information.

Lead-free: 45nm product is manufactured on a lead-free process. Lead is below 1000 PPM per EU RoHS directive (2002/95/EC, Annex A). Some EU RoHS exemptions for lead may apply to other components used in the product package.

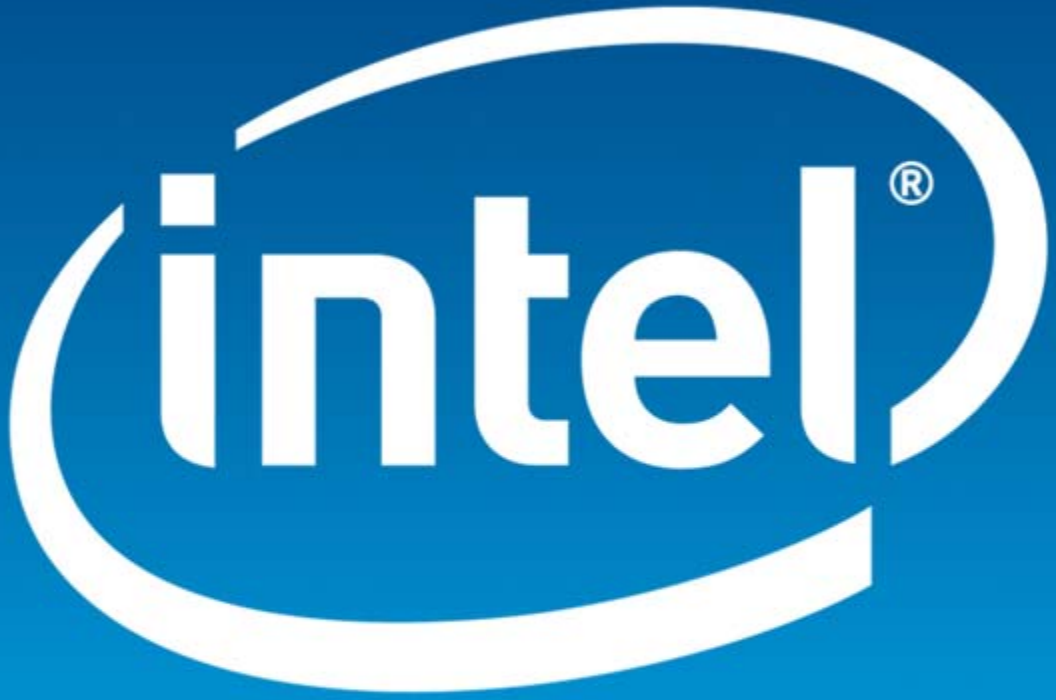
Halogen-free: Applies only to halogenated flame retardants and PVC in components. Halogens are below 900 PPM bromine and 900 PPM chlorine.

Intel®, Intel® Xeon®, Intel® Core™ microarchitecture, and the Intel® logo are trademarks or registered trademarks of Intel® Corporation or its subsidiaries in the United States and other countries.

© 2008 Standard Performance Evaluation Corporation (SPEC) logo is reprinted with permission

Roadmap not reflective of exact launch granularity and timing – please refer to ILU guidance

Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products.



Sponsors of Tomorrow.™