White Paper

Digital Ink and the eReader

Wasn't This What They Promised When They Touted the Internet?

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Introduction

When people first started talking about the promises of the Internet, did they not say they would no longer have to print newspapers? You could get your news in real time, from anywhere around the world. Textbooks would never become obsolete and could enthrall students with multimedia content, photos, videos and links to related websites.

That didn't happen, did it? Although we are now seeing trends toward online news, one limiting factor to pervasive online book publishing has been readability. Until digital ink and small-form factor portable eReaders, there hasn't been a major rush to move publishing to strictly online formats. But with the advent of better mobile and digital ink technologies, that Internet promise could be here soon.

What Is Digital Ink And How Is An eReader Different?

Despite the advances in display technology, as the computer and consumer electronics worlds go digital, human beings still have a human body that responds to analog—from the sound waves we hear to the color and lights we see. So despite CRT, TFT, LCD, plasma, or other display technologies, humans still find it easier to read off of paper.

That is why e-paper, digital ink and eReaders were created--to reduce the eye strain inherent in back-lit or other display technologies. In fact, digital paper works nearly opposite the standard computer screen display. First, it looks more like paper and uses actual pigments. It is not backlit or refreshed. You can read an eReader outdoors or in direct sunlight, unlike a backlit display, which loses all of its readability in direct sunlight.

The digital ink technology was created by a Massachusetts company named E Ink based on research started at the MIT Media Lab. E Ink Corporation is the leading supplier of electronic paper display (EPD) technologies, a high contrast display that gives a paper-like appearance. EPDs can be used in a variety of consumer and industrial applications, from handheld devices to watches, clocks, public information or promotional signs. E Ink is currently mass manufactured in the more widely known Amazon Kindle and Sony Reader.

The principal components of electronic ink are millions of tiny microcapsules, instead of individual pixels as used in traditional LCD technology. Each microcapsule contains positively charged white particles and negatively charged black particles suspended in a viscous fluid. E Ink builds a thin piece of film with the microcapsules. The film is then glued on top of a Thin-Film-Transitor (TFT.) The TFT electrically charges the pigments causing the white or black dots of pigment to rise through the fluid to the surface to create the black-and-white images. (Currently eReaders are produced only in black-and-white, but companies are already working on the use of color in EPDs.)

E-ink does not need to be refreshed like backlit technology. The image stays in place until the next electrical charge (for example, when the reader turns a page.) So an eReader display can power down to zero, using less power overall than a display that constantly needs refreshing.

Technologies Empowering eReaders

Easier to read screens and lower power consumption are functions that are driving the acceptance of eReader technology. Other technologies and market dynamics are also converging to help empower eReader adoption. For example, the proliferation of ultra-mobile handheld devices, Wi-Fi, Bluetooth, 3G modems and power management, make Internet accessibility portable and ubiquitous. Display and silicon manufacturers are creating new solutions for the next generation. Let's see how it works.

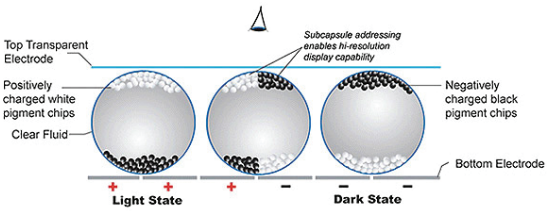
Technology Background—Frontplane—Backplane

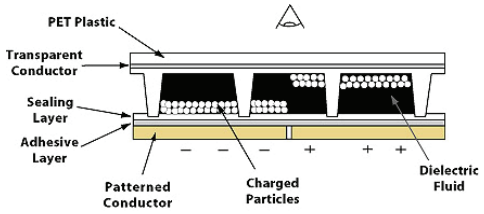
While E Ink was one of the first to commercialize e-paper, other companies like Sipix, are now jumping into the game. While e-paper technology is currently only in black-and-white, color is already being researched as well as animation. Some will take the e-paper technology and use it on plastic or create screens that will roll up (putting a fresh spin on e-scrolls to be sure!) But all this technology is referring to the frontplane.

The frontplane is the actual material, or film, that is used to hold the pigment and typically consists of tiny capsules or physical particles that move to electric charge.

Next page shows how E Ink and Sipix implement their frontplane technology.

Figure 1: (Lt. to Rt.) E Ink Frontplane Microcapsules, Sipix Frontplane Microcups, Final Thin Film Product.





The final frontplane product is a thin film that is flexible and can be cut into any size. The frontplane needs to be placed on top of something that can drive the bottom electrode, charging the particles and creating the color gradations and changes.

Welcome to the Backplane

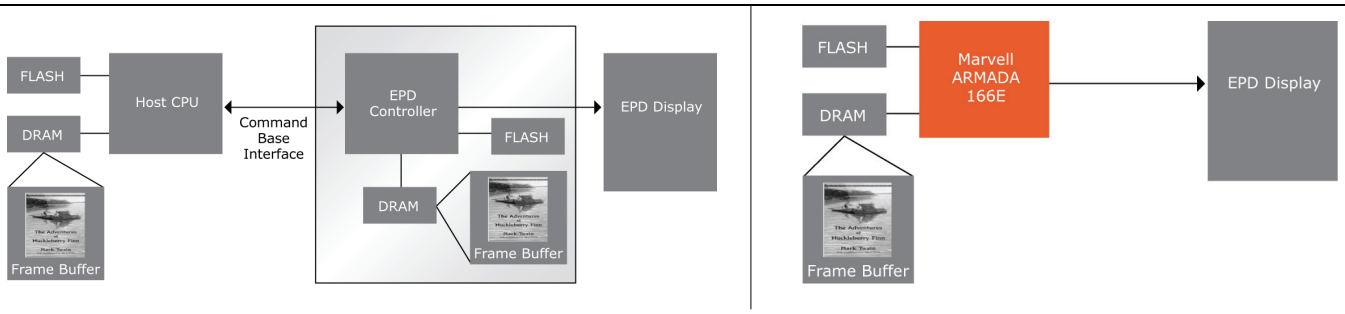
The backplane is typically a TFT display or other device that actually drives the panel. The frontplane is attached to the backplane. Currently, backplane sizes limit the e-paper sizes being offered as e-paper companies try to follow the same size as LCD manufacturers to take advantage of those TFT display backplanes made for current devices.

Backplane players include TFT-LCD manufacturers, such as Taiwan-based Prime View International (who at the time of writing this paper are in the process of acquiring E Ink); LG Displays who currently partners with E Ink and is a main supplier along with PVI; Plastic Logic (PL) which differentiates its backplane from TFT by making its backplane from plastic; AU Optronics (AUO), one of the world's largest TFT-LCD panel manufacturers, who is acquiring a major stake in Sipix.

Driving the Frontplane and Backplane Technologies

Then, there are the supporting platform technologies that drive the frontplane and the backplane technologies. For example, you need a controller. Unlike LCDs, there are no standard EPD controllers. Current device makers either use a dedicated chip that works with EPD displays or an FPGA. In addition to the controller other processors and discrete parts are needed, such as DRAM and flash memory.

Figure 2: E-Paper Display Architecture: Others vs. Marvell.

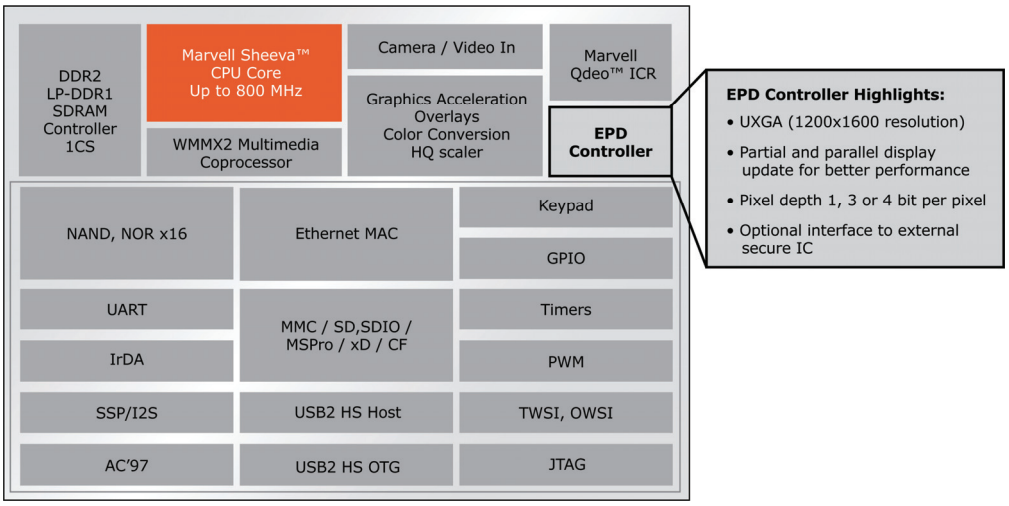


Marvell has designed a new eReader hardware platform solution to help original equipment manufacturers (OEMs) rapidly release next-generation eReaders. Marvell has introduced its Marvell ARMADA 166E application processor, which integrates a high-performance eReader processor and state-of-the-art EPD controller on a single chip. The ARMADA 166E with the integrated EPD controller is designed to offer OEMs ultra fast renderings of high-resolution PDF documents and support for the latest e-paper technologies, plus extended battery life in new smaller, slimmer form factors.

Marvell's solution makes the hardware design easier creating a total platform solution, which also includes Marvell key technologies such as Wi-Fi, Bluetooth, 3G modem, video and power management. The company also offers OEMs a developer's kit and turnkey reference design for a highly integrated, low-cost solution. This way, OEMs can focus on custom and unique applications, which they can get to market more quickly. Marvell's platform reduces the number of discreet components and therefore, the cost. In addition, it supports Window CE, Google Android and Linux operating systems.

Next page shows the Marvell ARMADA 166E with integrated EPD.

Figure 3: Marvell ARMADA 166E with Integrated EPD.



Highlights of the EPD controller from Marvell include:

- UXGA (1200x1600 resolution)
- Partial and parallel display update for better performance
- Pixel depth 1, 3 or 4 bit per pixel
- Optional interface to external secure IC

Included in the board design is the Marvell ARMADA 166E with 800 MHz CPU and Sheeva PJ1 CPU core and WMMX2 Multimedia coprocessor. The ARMADA 166E includes ARMv5/XScale technology capabilities, with built-in 32Kb L1 cache and 128KB L2 cache. See specs for memory, LCD controller, graphics, video, peripherals and process/package specifics at http://www.marvell.com/products/armada.

In addition to its processing core, is Marvell's patented Qdeo video processing technology, plus memory, DDR1/2 SDRAM controller, graphics acceleration overlays, color conversion, HQ scaler, EPD display interface, connectivity and all else needed for a flexible and robust eReader package. More integration means lower cost and ease of hardware design.

Markets and Applications:

As the technology develops, the eReader industry landscape begins to unfold. The diagram below shows the ecosystem developing to support the eReader industry including: eReader OEMs already in the market, the e-paper display OEMs that manufacture the frontplane, e-paper ODMs, content aggregators and distributors that will sell the books and content owners that will publish. Other players that will influence and grow the market include the government (by developing or mandating things like e-textbooks), wireless carriers, device manufacturers and software companies. Globally, as countries begin to manage their limited resources and embark on green lower-energy initiatives, eReaders may come to the forefront to help reduce paper and waste.

Figure 4: eReader Industry Landscape

e-Book OEMs	e-Paper ODMs	e-Paper Display OEMs	Other Players	Content Aggregator & Distributor	Content Owners
• Amazon • Sony • Plastic Logic • Hanwang • Jinke (Hanling) • First Paper • Entourage • Asus • 15+ other	• Ensky • Foxconn • IAC • etc.	• E Ink - PVI • Sipix - AUO • Other startups	• Government (e-textbooks) • Wireless carriers • Google, Adobe	• Amazon • Barnes & Noble • First Paper • Others	• Book publishers • Newspapers -NYT, WSJ, etc • Magazines – Time, Fortune, etc • Textbook publishers • Business documents

Since eReaders are easy to use and easier on the eyes and now combine a number of technologies, they offer several advantages for consumers including:

Easier Access: eReader formats, including eReaders, e-newspapers, e-magazines, e-textbooks, e-learning and e-documents, will save time, because content will be available via Wi-Fi and 3G. Services are being created that will automatically update newspapers, magazines, comics, book lists, even text books on a monthly, hourly or real-time basis. You would be able to pick up the Wall Street Journal, New York Times, your favorite local or international paper anytime and newspaper publishing houses will not have to worry about driving to the 5:00 p.m. deadline for news.

Easier on the environment: There will be less need to print or waste paper with eReaders. In a way, e-paper continually recycles. In addition, because it does not need to be refreshed, as soon as the reader turns the page, the power can be turned off. That means there is less battery drain and less need for electrical recharges.

Easier on the back: eReaders will save space. No longer will book bags be needed for students to carry multiple textbooks. Business users won't have to carry multiple books, newspapers, magazines or documents; they can download all their content into one easy-to-carry device.

Easier on the billfold: Electronic books are cheaper to publish than printed versions. This will also lower the barriers to entry for new authors wanting to be published.

Easy on the eyes: As already mentioned, the screen technology is nearly as easy to read as paper, however, there are other advantages. Fonts can be increased or decreased. Before, only certain books, newspapers or magazines were available in large print—now you can change the font, increase its size or zoom images, for your personal reading comfort.

As new players enter the market, new technologies and techniques are being developed that will help drive the market and create new applications for electronic paper-based products. In fact, new processes are being developed for color e-ink, plastic screens and disposable displays. According to the CLSA Asia Pacific Market, Aug. 26, 2009 E-Paper Primer Sector Outlook, here are some current and future applications for e-paper and eReader technology:

Figure 5: Existing uses for e-paper

Existing uses for e-paper

Usage	Where	Example
Consumer electronics	E-books	Sony Reader
		Amazon *Kindle*
	Mobile phones	Secondary displays/ designs
Electronic signage	Retail	Shelf, price labels, barcodes
	Consumer	Cinema times
	Transport	Schedules
	Logistics	Warehousing and identification
Disposable electronics	Transport	Tickets
	Charge cards	Credit remaining
	Smart packaging	Pharmaceuticals/dosage details
Apparel/novelty	Jewellery	Seiko/Phosphor watches
	Clothes	Customizable clothes
	Board games	Changing patterns and text

Source: CLSA Asia-Pacific Markets

CLSA expects applications like these to drive a projected $2.8 billion dollar e-paper industry by 2015 that will include such creative uses as consumer electronics, disposable electronics, electronic signage (POP/ESL), disposable signage and apparel.

According to a May 27, 2009 Forrester E-Reading Report, new features like bigger and more flexible displays, animation, enhanced sharing, color and video, will hit the market between 2010 and 2012. This will also help spur consumer interest in eReader applications. Forrester sees the market changing from mainstream frequent book buyers in 2009 to 2011, to more mainstream business, student consumers from 2011 and beyond, when prices begin to drive down to the $99 sweet spot.

Conclusion

As the technologies come together from frontplane and backplane companies and semiconductor leaders like Marvell, the breadth of opportunities for eReaders is beginning to reach critical mass and prices will start to come down. Marvell's ARMADA 166E SoC, development kit and turnkey reference designs make it easier for manufacturers to come to market with highly integrated, lower-cost solutions so consumers can start taking advantage of the readability and portability of eReaders.

Marvell's ARMADA eReader platforms enable large or small manufacturers to quickly develop eReader systems for a wide variety of end markets, from basic book readers to subscription content devices to dedicated enterprise and educational devices. EPD panels of multiple sizes are supported and the ARMADA platform also supports LCD screens, allowing for flexible implementation. With Marvell's proven Wi-Fi/Bluetooth SoCs and HSDPA modem technology, connectivity to the WLAN or WWAN is a snap. Power management solutions from Marvell provide efficient switching regulators and power-factor correction for AC-DC adapters. Marvell also offers full development systems and turnkey reference designs, as well as Linux, Android and Windows Embedded CE board support packages (BSPs) for eReaders.

It's products and services like these from Marvell that will help make good on the early Internet promises of instant information at your fingertips.

Footnotes:

1. CLSA Asia-Pacific Markets, "EPaper Primer", by Oliver Campbell, August 26, 2009.
2. Forrester Research, "How Big is the eReader Opportunity?" by Sarah Rotman Epps for Consumer Product Strategy Professionals, May 27, 2009.

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Jack Kang is currently Director of Technical Marketing for Marvell's Application Processor Business Unit. He is responsible for multiple consumer market segments, including eReaders, gaming, and other connected consumer gadgets, and also serves as a technical expert on CPU technology. Prior to this role, Jack worked as a logic design engineer in Marvell's CPU design team. He has more than 10 patents pending in the field of CPU technology, and holds a degree in Electrical Engineering and Computer Science from the University of California, Berkeley, with an emphasis in Computer Architecture.

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