# Gutenberg Going Digital

The quest for the last book you'll ever need.

Benjamin Hershberg
Oregon State University

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The technology for a true digital book is only a matter of time. But we must tread with caution. The content protection problem that the music and movie industries face now could impact the publishing industry in the form of e-book piracy. For now, most of us still prefer to buy a book than download its e-book counterpart. Digital books will change that.

**Digital Evolution**

The advance of human civilization has always depended on our ability to access, distribute and record information. For centuries, books were only available to the very wealthy, the ruling elite, and the clergy. The printing press was an answer to this bottle-neck. Books became so prevalent that a new bottleneck arose: how can you efficiently sort, store, and access so much information? The digital revolution accentuated this problem. But the digital revolution has also provided us with a solution. Modern computing and the internet have not only provided us access to vast amounts of information, but more importantly, they have provided ways to search and sort that information into something meaningful.

In many ways, modern computing has provided a replacement for books. Yet, a disparity remains. A book is portable, consumes no power, and can be read without causing eyestrain. As a medium for reading text, LCD and CRT displays are still no match for paper and ink.

A truly digital book would incorporate the benefits of both a book and a digital device. It would have the physical benefits of a book, and the hidden benefits of a digital device. A digital book could hold the contents of an entire library, and display it using very little power.

**Digital Book Wannabe** – *eBook readers such as the hi310 (above) are already on the market. These devices are more an oversized PDA than a digital book.*

This potential for storage of vast amounts of information in a single digital book is significant, but I believe that the truly revolutionary improvement that digital books will bring lies in how we *access* that information. Books are an effective way of storing information, but inefficient at retrieving it. Finding a specific passage in a book can take hours; it is a task that can be performed by a computer in a matter of milliseconds. Digital books have the potential for dynamic and non-linear access. All the improvements in information searching, sorting, and processing that computers are capable of, could be merged into the traditional model of a book. You could run a keyword search on your textbook, or better yet, search the content of *every* book stored in memory.

**E-book Versus Digital Book**

The terms e-book, e-book reader, digital book, and digital print media device are often ambiguous. For the sake of clarity in this article, we will use the following definitions. An e-book is the digital version of a book. In other words, an e-book refers to the actual content. E-book readers are hardware devices that can display e-books.

Digital book and digital print media device are terms coined primarily for this article. These two terms refer to hardware that implement digital media content, and emulate the devices that they replace. This includes books, newspapers, and magazines. It is important to recognize the distinction between digital books and e-book readers. An e-book reader is similar to a tablet PC or a PDA, whereas a digital book is truly an electronic book.

The technology needed to realize Digital Books can be applied to other facets of print media. Imagine newspapers and magazines that automatically update their content wirelessly, and signs that update themselves. In fact, the first implementation of digital ink is a sign that can be updated remotely[8].

Digital Books will only be successful if the technology that implements them can meet certain requirements. The display must be thin, portable, flexible, and look similar to paper and ink. It needs to consume very little power, refresh quickly, and be viewable from any angle.

There are several technologies available today that fit most if not all of these constraints: EInk, Gyricon, EDD, MEMS, Cholesteric LCD, electrochromic, and electrowetting[3]. EInk and Gyricon have shown great promise as a realistic solution. This paper will focus primarily on the EInk and Gyricon technologies.

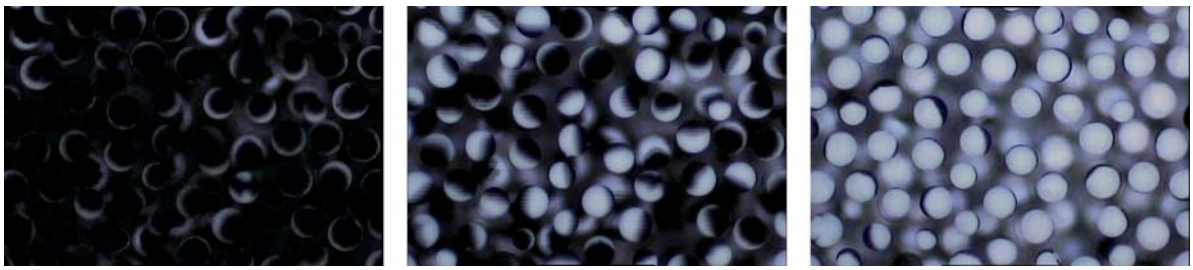
**Electronic Reusable Paper**

The concept of electronic ink began in 1978 at what was then Xerox's Palo Alto Research Center (PARC). Xerox's project to create Electronic Reusable Paper was coined Gyricon. The project really didn't heat up until the mid 90's, when wireless and web media technologies began to emerge. The new opportunities for commercialization of electronic ink brought competition with it. The MIT spin-off E-Ink was founded in 1997 and began work on its own version of Gyricon, aptly named "E-Ink."

One of Xerox's greatest weaknesses has been the failure to capitalize on PARC's innovations. PARC created the window based graphical user interface that was popularized by Microsoft and Apple. Bob Metcalfe left PARC to form 3Com, and commercialized Ethernet networking. Desktop Publishing was developed by two researchers at PARC, who later formed Adobe Systems. In similar form, Gyricon is being commercialized by the PARC spin-off, Gyricon LLC.

**The Technology**

The theory behind electronic ink technology is straightforward – giving it the potential for mass production. E-Ink is composed of microcapsules approximately the diameter of a human



**Gyricon** - *microcapsules switching from dark hemisphere to light.*

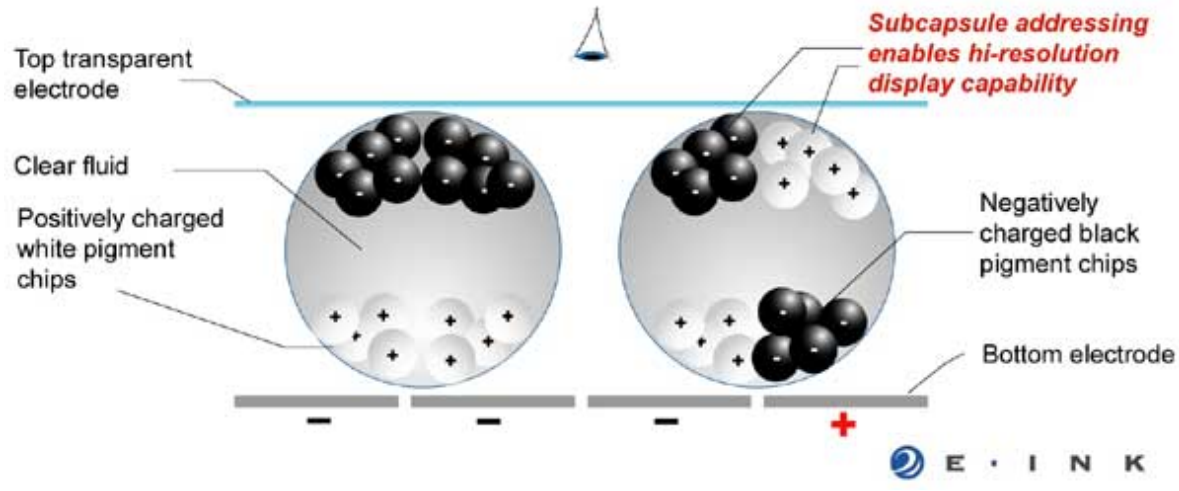
| Display Technology | White State Reflectance | Contrast Ratio |
|---|---|---|
| Transflective Mono STN LCD (common PDA with touchscreen) | 4.2% | 4.1 |
| Transflective Mono TN LCD (common eBook with touchscreen) | 4.0% | 4.6 |
| Monochrome Cholesteric (with touchscreen) | 11.5% | 3.5 |
| E Ink (with touchscreen) | 31.7% | 10.8 |
| E Ink (no touchscreen) | 41.3% | 11.5 |
| Wall Street Journal Newspaper | 64.1% | 7.0 |

**Just the right angle** – *electronic ink's visual properties are close to that of real ink and paper.*

hair. These microcapsules are filled with a clear fluid. In addition to the fluid, there are positively charged white pigment chips, and negatively charged black chips. The microcapsules are suspended in a fluid "carrier medium", and printed onto a flexible plastic film. The film is placed on a thin film transistor (TFT) backplane, which is controlled by a display driver.

The carrier medium that the microcapsules are suspended in allows E-Ink to be printed using existing screen printing technologies. That means that E-Ink can be printed onto virtually any surface including glass, plastic, and fabric. This new potential for display devices on flexible surfaces can make display devices far more ubiquitous than they will ever be with current rigid display technologies.

Gyricon differs from the E-Ink technology in a few ways. Gyricon also consists of microcapsules with black and white charged pigment. However, the pigment is applied to the surface of the microcapsule. One hemisphere is white, and the other is black. Depending on the charge in the TFT array, the visible area of the microcapsule will either be black or white. When the charge transitions, the microcapsules rotate 180 degrees to reveal the other color.




**EInk** – *A thin film of microcapsules is applied to TFT array, to create an active matrix display. Microcapsules only change state when re-addressed. This means that power consumption depends on how often the display is updated, not how long it is active.*

**Applications of E-Ink and Gyricon**

While this paper is mainly concerned with Digital Books, it is important to note that the applicability of EInk and Gyricon is by no means limited to Digital Print Media devices. Electronic Ink technology can be applied in emerging markets such as Smart Card Technology and Wearable computing[3].

More conventional displays such as the LCDs used in cell phones, could adopt the electronic ink technology as a way to reduce power consumption. EInk is currently working with Motorola to implement electronic ink into several of Motorola's products[20].

Electronic Ink displays are very well suited for wearable computing applications because of their low power consumption, always-on display, and flexibility. In fact, E-Ink displays are surprisingly flexible. Yu Chen, a principal engineer at Kovio Inc and former chief scientist at E-Ink, published an article in the British Journal *Nature* in May of 2003 about ultra thin, ultra flexible electronic ink displays. The paper illustrated an electronic ink display technology that is the thickness of three human hairs, viewable from any angle, and can be rolled into a tube 4 millimeters in diameter without damaging the display[3].

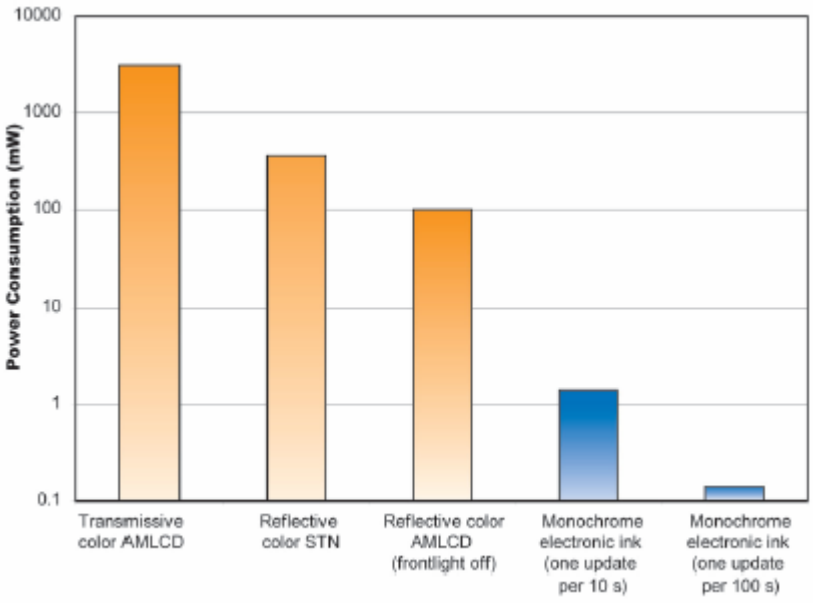
Such a rugged display technology opens up many opportunities for wearable computing. Electronic Reusable Paper could be sewn into clothing, laminated onto walls, and printed on Smart Cards. Electronic Ink can bring us much closer to information, whenever and wherever we are.

It is likely that electronic ink will become a ubiquitous part of our society in more than one way. It will be interesting to see what markets assimilate Electronic Ink technology. Perhaps E-Ink's greatest potential for ubiquitous computing lies in wearable computing.

**Drawbacks and Limitations**

Electronic ink has many advantages over conventional display technologies, but that's not to say that it doesn't have its share of weaknesses too. The three biggest issues right now are refresh rate, resolution, and lifespan.

LCD displays have refresh rates far beyond electronic ink. This is a serious limitation for E-Ink acceptance. A typical electronic ink display has a refresh time between 250 to 1000 milliseconds. That is not nearly fast enough to display video motion. A change of state in an electronic ink display is a physical process; and that takes time. For instance, for a Gyricon microcapsule to change states, it must physically rotate 180 degrees.



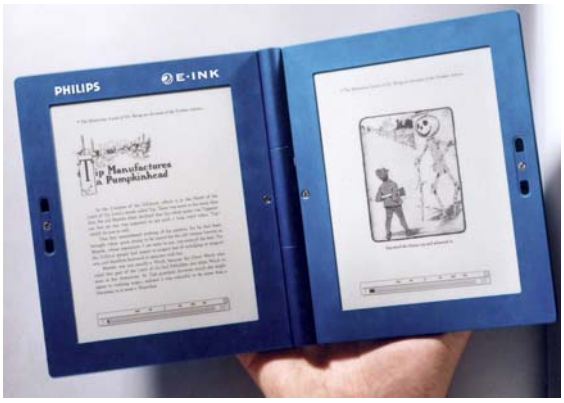

**Comparison of Display Power Consumption** - *Electronic Ink and LCD technologies for two different display formats.*

EInk and Phillips Electronics released a prototype Digital Book last year. The first major prototype had a lifespan of about 4,000 hours. Last May, they released a prototype with a lifespan of 30,000 hours[21]. This equates to about three and a half years, which is a pretty big improvement. But a Digital Book must live up to higher standards than an LCD: books can last hundreds of years, not three and a half.

EInk was able to increase the lifespan by tightening the specs on their materials, such as the carbon black and titanium oxide pigment chips. They have also built a custom display driver IC designed specifically for electronic ink applications.

The resolution of an EInk active matrix display is good enough to read, but is not yet print quality. Current products have a resolution of 160 pixels per inch (ppi)[21], but that number will rise with time.

While the drawbacks of EInk present some serious limitations, many of the problems can be overcome. Most products are still in the prototype phase. Within a few years, the technology will be much more mature. Yu Chen believes that someday electronic ink could even be applied to televisions. But for now, electronic ink's applicability will have some limitations.




**Once Upon A Time** – *EInk and Phillips Electronics' prototype Digital Book. All electronic ink products and prototypes to date have been monochromatic. However, color is in the future.*

**The Hardware Gap**

So far, the current e-book implementation has been a failure. Barnes and Noble has abandoned the sale of e-books entirely, and most e-book sites have gone out of business[23].

The problem is that there is nothing better about an e-book over a regular book. In fact, a regular book is probably better. The E-book readers that have been released are little more than bloated PDAs that must be recharged every 10 hours. E-books cost about as much as a paperback, and rarely offer any additional content.

Richard Wan, chief executive of E-Book systems furthers this point. "E-book reader devices were once lauded as the answer to a problem that wasn't really much of a problem to begin with. Paper books are light, don't need batteries and a volume published in the last 200 years has a better resolution than an LCD screen."

If e-books want to become successful, they need to offer something that a real book can't. Companies such as Singapore based E-Book Systems believe that e-books should be embedded with audio and video content.

I believe that while adding multimedia content to e-books will contribute to their value, the missing keystone is a Digital Book technology. There is still no solid hardware solution for viewing e-books, and few people are willing to read a book on their computer screen. That's where products that implement electronic ink come in. When true Digital Books do come, the hardware gap will be bridged.

**The Content Protection Problem**

When Digital Books are successful, then a very serious problem will arise. How will we control e-book piracy?

Compared to the file sharing crisis facing the recording and movie industries right now, e-book piracy receives little attention. After all, the entire e-book industry only generated a paltry $10 million of revenue in 2002[19] compared to the $12.6 billion in US music CD sales (which was actually a $1.02 billion drop in sales from 2001) and $8.7 billion in US DVD sales.

E-book sales may be at $10 million, but overall US books sales in 2002 were $26.8 billion. If e-book sales become a larger share of that overall market, then it's easy to see how e-book piracy could become a very big deal, very fast.

When the hardware gap is bridged, and Digital Books become affordable, then people will want content to load onto their Digital Book. As Digital Print Media devices become more and more ubiquitous, I believe that the piracy problem will increase. The more people use e-books, the more hackers will be motivated to develop applications to pirate them.

At the National Institute of Standards and Technology's (NIST) Electronic Book Conference and Trade Show, Martin Eberhard addressed the inherent problems of securing e-books. First, he made the important point that piracy doesn't require skill, just a good application. "One does not have to be a skilled hacker to remove encryption from protected content. Only one skilled hacker is needed to write a software utility to automate this process. Any average computer user can then download this software from the web and become just as powerful to defeat the copyright protection system."

The content protection problem is something of a paradox. Legitimate users must be able to access their files without inconvenience. This puts serious limitations on authentication of files via a remote server. Encryption has traditionally been the assumed solution. But in the case of encrypted media files, the cyphertext and decryption key are both located on the end user's machine, most likely in the file itself, or in the software that views it. Thus, the size of the key, and the level of encryption doesn't matter. The key can be discovered simply by searching for the key on the hard disk. In a sense, there is nothing to stop someone from hacking their own computer.

This same weakness is inherent in encrypted music and video formats. Eberhard quoted an article posted at Microsoft's website, saying, "Content providers can remain confident that their media files will stay protected no matter how widely they are distributed ... Windows Media technology uses one of the strongest DRM encryption schemes available. It would take days of supercomputer time to decode."

Eberhard refuted this by cracking an encrypted Windows Media Audio (wma) file, during his presentation. He launched a cracking application that he had downloaded to his laptop and dragged and dropped the file into the program window. A minute later he had a cracked version. Eberhard teased, "So, I mean, days of supercomputer time indeed! In fact, this is so easy to do that it doesn't even really feel like stealing." And that's the problem. Piracy is all about convenience and anonymity. If it's low enough risk, and easier and cheaper than buying a legal copy, people will do it.

**Preemptive strike**

The false start of e-books has given the publishing industry valuable time to address the content protection problem before it spirals out of control. An effective plan to limit digital print media piracy must be developed if the publishing industry is to support e-books. If the music and DVD piracy situation scares the publishing industry enough to boycott e-books, Digital Print Media devices will never realize their potential.

The publishing industry must use the advantage of time to develop anti-piracy measures. Piracy can't be stopped, but it can be limited.

Digital Print Media devices have the potential to become a fully ubiquitous part of our society. When asked about the future of Digital Books, Yu Chen of Koyo Inc replied, "E-paper is coming. When the time comes, throw your paperbacks in the recycle bin, break down your psychological barrier, buy a Digital Book and keep it with you all the time. It will be the last book you will ever need." It looks like Gutenberg is ready for an upgrade.

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