A Guide to **E-paper Technology** and Its Growing Range of Applications

PERVASIVE DISPLAYS

EXECUTIVE SUMMARY

Made famous by the Amazon Kindle, e-paper is an electronic display technology which mimics the appearance of paper. Using the same inks as the traditional printing industry, e-paper displays (EPDs) have tiny capsules filled with charged ink particles. When the proper charge is applied, highly detailed images can be created with the contrast ratio and readability of traditional printed material.

As a bistable display technology, e-paper can be extremely low power, allowing it to be used in devices without the power budget of a traditional LCD display. Once the text and images of an EPD have been rendered no power is needed to maintain the display. In fact, e-paper is so low power that harvested energy can be used to make updates, enabling the use of RFID or NFC devices with batteryless EPDs.

E-paper's ability to add thin, light, highly-readable displays to low power or no power devices opens up a wide range of applications across the internet of things (IoT) space, from logistics to discrete manufacturing, to retail. Batteryless, human-readable RFID tags for logistics and manufacturing, electronic shelf labels that can be monitored and updated remotely, smart badges with integrated displays; these are just a fraction of the possibilities of e-paper applications from Pervasive Displays.

TECHNOLOGY OVERVIEW

Mimicking the readability of ink and paper, e-paper combines the active-matrix TFT technology used in LCD displays with a layer of electronic ink. The ink layer consists of millions of tiny capsules with electrically charged pigment particles suspended between a transparent top electrode and bottom electrode. As the appropriate charges are applied, highly detailed images are formed with the contrast and readability of traditional printed material.

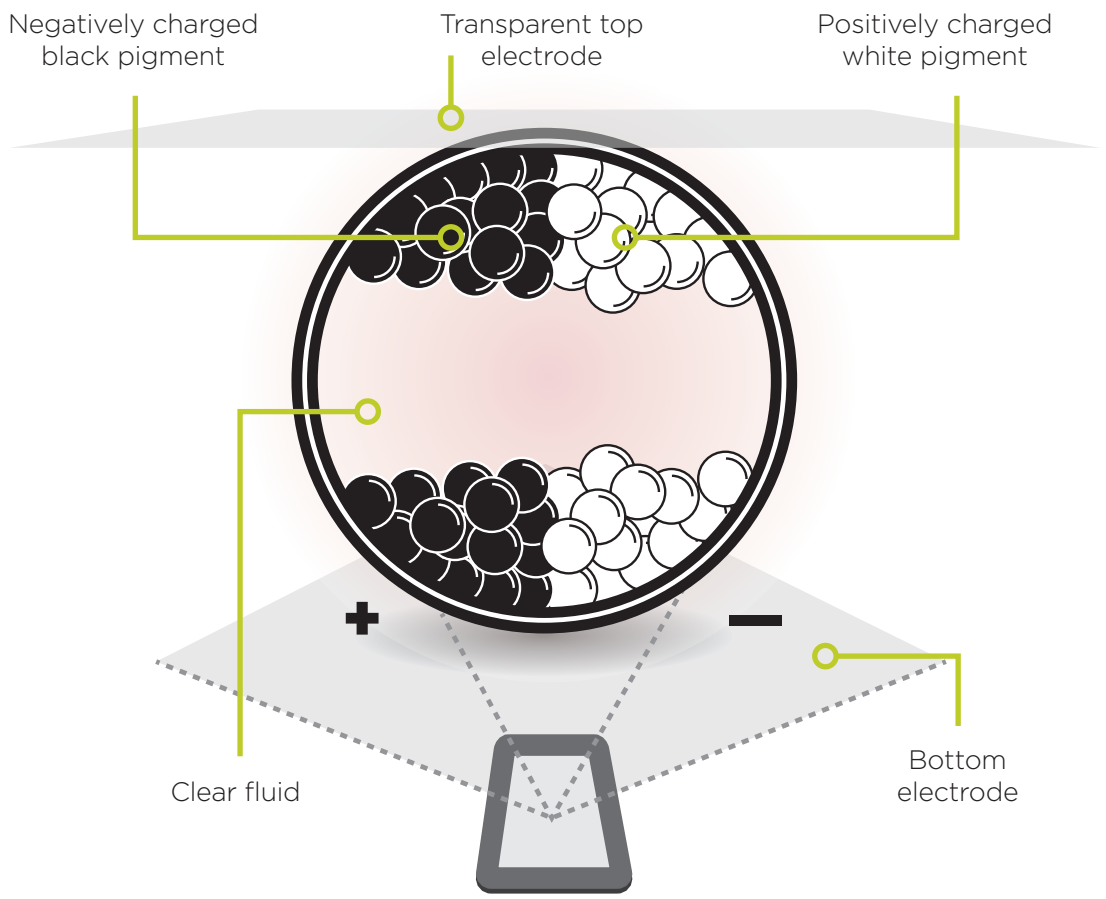


Fig 1. E-paper rotates electrically-charged particles to display black and white colors. (Source: E Ink)

E-paper displays are bistable. Each visual state of a capsule — black or white — can be held without power needing to be applied. This means e-paper displays only consume power when updating the screen and retain images even when the power is off.

Unlike LCD displays that depend on backlighting, e-paper displays are also reflective and can be read in ambient light or even bright sunlight, just like traditional printed material. This eliminates the need for power consuming backlights in well-lit environments, and also helps reduce eye strain.

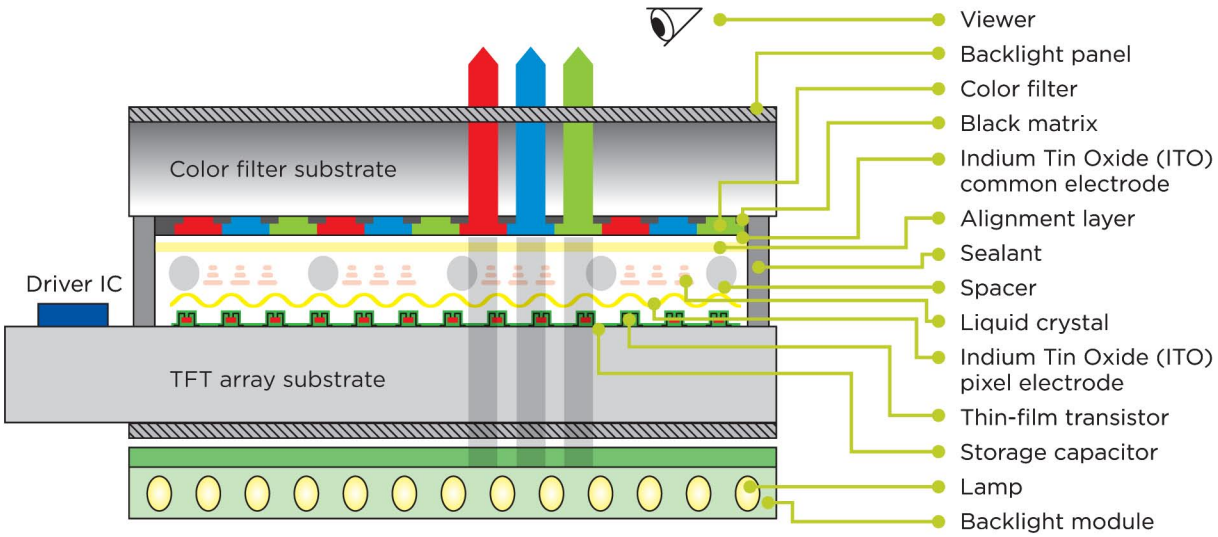


Fig 2. Cross-section of a color TFT LCD. (Source: Pervasive Displays)

EPDs are assembled by adding a film of electronic ink on top of an active-matrix TFT backplane which is then covered with a protective sheet. The panel is driven by custom chip on glass ICs and connected to an external MCU through a flexible printed circuit (FPC) cable. Depending on the e-paper module, timing control software can be located either on the driver IC itself, or run on an external microcontroller.

Due to the specific physical and electrical properties of electronic ink, the characteristics of the waveform generated by the timing control software is crucial to the visual performance, power consumption, and reliability of e-paper displays. Displays driven by proper waveforms are power efficient, and can hold visually clear, high contrast images for indefinite periods of time, while poor quality waveforms deplete battery life quickly and can cause ghosting or other unwanted visual effects.

The timing control software can be integrated into the driver IC on the EPD itself or located on an external MCU, each with its own benefits and tradeoffs. EPD modules with internal timing controllers (ITC) are simpler to integrate, but those with external timing controllers (ETC) using optimized waveforms can minimize power consumption and processor speed requirements.

BENEFITS

E-paper's remarkably low power consumption, high readability, as well as its thin and light characteristics make it a perfect display option for devices without incurring the expense of a traditional LCD display.

Ultra-Low Power Consumption

Due to its bistable nature, e-paper is an extremely low power consumption display technology, allowing it to be used in devices without the power budget associated with a traditional LCD display, or to create devices with incredible battery life.

Item	Screen Update Current Consumption (mA)	Duration (s)	Standby (mA)	Screen Update Power Consumption (mAs)	Consumption based on 6 updates per day (mA)
2" EPD	2.33	2.32	0	5.41	32.43
2" TFT LCD	30	0.02	0.1	0.6	8,640.59

Fig 3. With 6 screen updates a day[1], a 2" e-paper display consumes 266 times less energy than a corresponding TFT LCD display.

The power consumption of an e-paper display is on a completely different level than that of an active matrix LCD display. While LCD displays need to be refreshed at 60 Hz or more, consuming power each time even to display a static image, e-paper displays only need to be refreshed when the image is changed. This makes e-paper perfectly suited for applications with infrequent screen updates, such as metering, sensing, logistics tags, ID badges, signage etc.

In addition, while backlighting is a major power consumer for LCD displays, e-paper can be read in ambient light without the need for a backlight, reducing power usage even further for many use cases. An infrequently updated 2" display running for 5 years would require the equivalent of 300 coin cell batteries using LCD technology, but an e-paper display wouldn't even consume half the energy available from a single coin cell battery over the same period.

NFC/RFID Energy-Harvesting Capability
The extremely low power consumption of e-paper makes it suitable for using the energy harvested from NFC/RFID readers. The same RF field that energizes an NFC or RFID antenna to read data from a device carries enough power to update an EPD. This enables "no-power" e-paper displays powered purely from RF energy, without the need for an internal battery.

High Readability - Even Outdoors
Using the same pigments as the printing industry, e-paper's contrast, viewing angles and readability are similar to traditional ink and paper. Readability is superb in both ambient light and bright sunlight, making e-paper suitable for outdoor applications that would challenge LCD displays such as signage.

Thin and Lightweight
E-paper technology is thinner and lighter than LCDs. A 2.0 inch" e-paper module is 1.1 millimeter in thickness and weighs just 2.6g, while a corresponding TFT LCD display is roughly double the thickness and weight. Devices using e-paper can thus be made thinner and lighter, perfectly fitting the requirements of many IoT applications.

[1] This calculation assumes the TFT LCD has a standby mode available to reduce the backlight brightness when there is no pixel change, otherwise the difference in power consumption would be even greater.

CURRENT AND FUTURE APPLICATIONS

There is a growing shift in the marketplace from consumer devices with large power and processing budgets designed for multimedia, towards smaller, interconnected, power-constrained devices designed to sense, compute, and communicate business information. This is the Internet of Things, driven by industrial applications.

E-paper's ability to add thin, light, highly-readable displays to these extremely power-constrained devices is opening up a wide range of new applications across the IoT space, from logistics to discrete manufacturing, to retail.

Electronic Shelf Labels Enable Dynamic Pricing for Retailers

Electronic shelf labelling (ESL) is changing the retail space, reducing price management costs and making dynamic pricing possible.

Whereas traditional price tags require staff to constantly replace and update shelf labels as prices change, ESL labels are wirelessly connected, allowing for remote, central management of all the price labels at a single or even multiple retail location.

ESL also allows for dynamic pricing, letting retailers adjust prices faster to respond to changing market conditions and inventory levels. For grocery stores, for instance, being able to turn over slow moving or perishable inventory through promotional pricing, or increase prices to account for a sudden increase in produce costs is essential to profitability.

Retail shelf labels have high readability challenges as they must be both human and machine readable. Good contrast across various lighting conditions and wide viewing angles are key, as customers must be able to read prices at a glance, and barcode readers must be able to scan codes easily.

Battery life is another key requirement as, with hundreds of ESL devices commonly deployed at a single retail location, frequent recharging is out of the question.

Fig 4. This Electronic Shelf Label powered by a Pervasive Display EPD has excellent readability and a 5 year battery life (Source: SES-imagotag)

For ESL, e-paper is the perfect technology, providing high contrast images easily readable by 2D and 3D barcode readers in a variety of lighting conditions, and consisting of a bistable display which only consumes power when updated.

Fig 5. In addition to black and white displays, three pigment displays (black white and red, or black white and yellow) are now available with e-paper. (Source: Pervasive Displays)

For retail applications, the latest e-paper modules feature three pigments: white, black and red ink, allowing for more dynamic shelf labeling excellent for highlighting promotions. E-paper modules from Pervasive Displays also feature health monitoring technologies which detects screen breakage or problems powering up the display, helping to make sure pricing labels across a retail location are working reliably.

Retailers such as Carrefour, Media Saturn and Edeka are already starting to use the current generation of e-paper based ESL devices which allow retailers to control prices dynamically and lower labor costs through centralized price management. But the potential of retail ESL devices is only just being explored, and future ESL devices are positioned to improve operational efficiencies and retail profits even further.

E-paper + RFID/NFC Provide Immediate Visibility Throughout the Supply Chain

Fig 6. This Toppan smart tag combines NFC technology with an e-paper display (Source: Toppan)

E-paper works phenomenally well as a complementary technology for RFID or NFC as it has the ability to visibly display information these RF-based technologies cannot. A properly designed e-paper display has minimal impact on a RFID or NFC device's battery life and can even use harvested energy from the tag reader just like a passive NFC/RFID device. The combination of wireless asset tracking capabilities with the immediate visibility of e-paper has profound implications for industries ranging from logistics, manufacturing and distribution, to medicine, and construction.

RFID and NFC tags, which are available in either battery powered or batteryless forms, are wireless devices that provide asset tracking and identification functionality similar to barcodes. Unlike barcodes, they can be accessed wirelessly and the data they store can be updated as well.

RFID/NFC technology has huge benefits for many industries, but logistics and manufacturing in particular. Assets entering or leaving a warehouse, being loaded on a truck, warehouse shelf, or factory bin can all be automatically logged and tracked, and their internal status can also be updated as needed. The increased visibility and automation made possible by these technologies has huge benefits for the entire supply chain.

Despite the advantages of RFID/NFC, it isn't possible for RFID tags to fully replace paper labels and barcodes yet. This is because a paper label has both a scannable barcode and information which can be read with the naked eye. Unless they are part of a printed label, RFID tags can't be read with the naked eye and require a specialized scanner to access and update data - this makes paper labels an essential requirement for many applications.

The need for a specialized scanner when using RF technology has slowed its adoption and meant paper labels are still widely used in many industries such as logistics, which would otherwise benefit heavily from the increased automation and visibility made possible by the use of RF technology.

E-paper solves the need for a specialized scanner perfectly, giving immediate at a glance visibility into tag data. In addition, e-paper's low power requirements would allow it to be energized by an RF field, like a regular RF tag in order to update the displayed information.

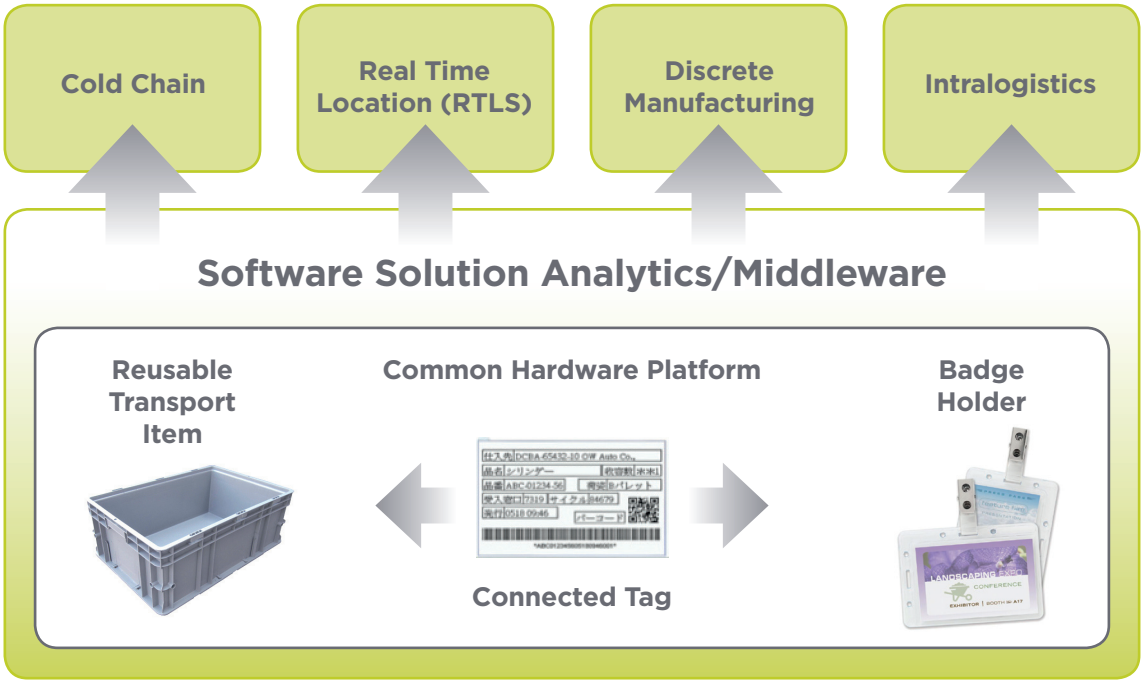


Figure 7. Connected tags with e-paper and RFID or NFC have the potential to serve a variety of markets using a common hardware platform. (Source: Pervasive Displays)

E-paper enabled RFID/NFC tags allow the automation and asset tracking capabilities of this promising technology to be fully realized without sacrificing the human-readability of paper labels, providing value throughout the supply chain, from manufacturing and shipping, to distribution.

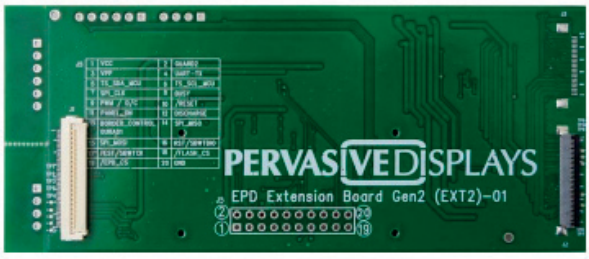
Display for Power-Constrained IoT Devices

Beyond retail and logistics, the applications of e-paper for the IoT is vast and limited only by our imagination.

Because of power constraints, many battery-powered IoT devices, such as utility meters, cold-chain temperature data loggers, environmental sensors, and blood glucose monitors forgo traditional displays and transmit data directly to the cloud where it must be read through specialized apps on network connected devices.

E-paper's ultra-low power consumption and ability to retain an image, even if the device is off, allows these low power devices to incorporate a display showing sensor data to operators. This is possible without the required equipment on hand and can work even when there are network connectivity issues. In case of device failure, error messages or device information can also be displayed on the screen and retained without power even if the device is turned off.

EPD Extension Board Gen2 (EXT2board) * 1 piece



90 degrees 20 pins header * 1 piece

Bridging cable * 1 piece

Figure 8. The EXT2 development kit from Pervasive Displays comes with a 20 pins header and a bridging cable. (Source: Pervasive Displays)

The easiest way to get started with e-paper is with a development kit from Pervasive Displays. The new EXT2 development kit is compatible with a range of evaluation boards and has direct pin-to-pin compatibility with the latest TI Launchpad evaluation boards. For other boards, or to connect with custom hardware, a 20 pin header and bridging cable is included.

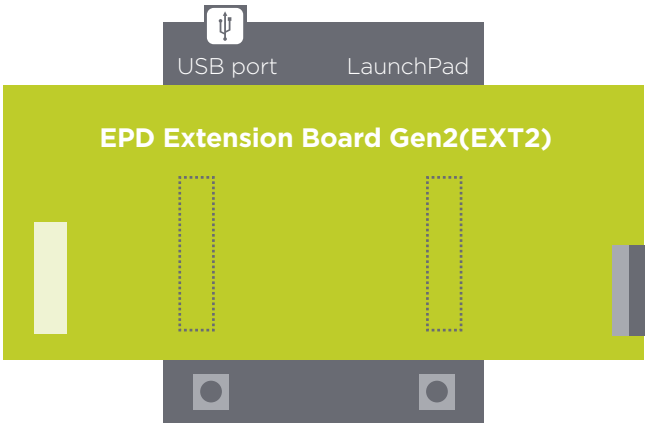


Fig 9. The EXT2 e-paper development board from Pervasive Displays has pin-to-pin compatibility and can be stacked on TI Launchpad evaluation kits. (Source: Pervasive Displays)

The kit features an onboard driving circuit to help you easily develop EPD applications for wide temperature Aurora or 3-pigment Spectra e-paper displays from 1.44" to 4.2". Both external and internal timing controller displays are supported, with driver code included.

Additional features include an on board temperature sensor used to help drive the e-paper display efficiently across a wide temperature range, as well as 8 Mb of flash memory useful for waveform, image and application storage. Capacitive touch and light guide connectors make it easy to develop touch panel applications.