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ELECTRONIC PAPER DISPLAY

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Abstract: E-paper displays aims to mimic real paper with high reflectance and low power consumption similar to original paper. Here we intend to study working principle of several E-paper technologies, driving schemes with hardware and software implementations to solve challenges in E-paper ecosystem. We found that understanding different E-paper displays will help us to pursue novel display research to find new materials governed by laws of physics and to propose New Driving methods. Comparative studies on E-paper technologies help us to propose new research and development on E-paper Displays. We claim that; study on E- paper displays like CH-LCD (Cholestric Liquid crystal Display) enables us to visualize information effectively. We also speculate next generation contender for E-paper displays. This paper suggests developments in Physical Implementations for creating High quality displays involving Low cost and Low Power consumption.

INTRODUCTION

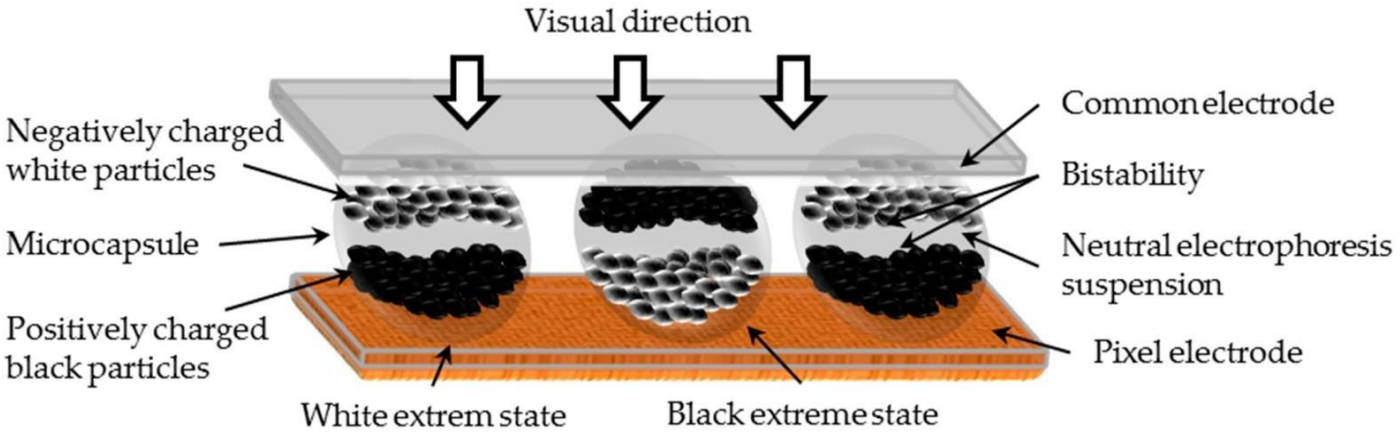
An Electronic display is a converter of electronic information for recognition by brain via vision. Software and hardware components of Electronic Display (E-Display) enable us to visualize data. E-displays aims to represent the maximum variance in Human perception while perceiving information with physical and environmental considerations. Recent developments in E-Display systems like Liquid crystal display (LCD) and Organic light emitting diode(OLED) helps to realize the information effectively.
Several issues such as wide viewing angle, Low power consumption is solved by OLED while LCD is still cost-effective. Though, there exist a well-known problem to mimic hard copy type printed Paper.

1. E- PAPER TECHNOLOGIES

Below mentioned three mainstream E-paper technologies which are successful in making E-paper displays.

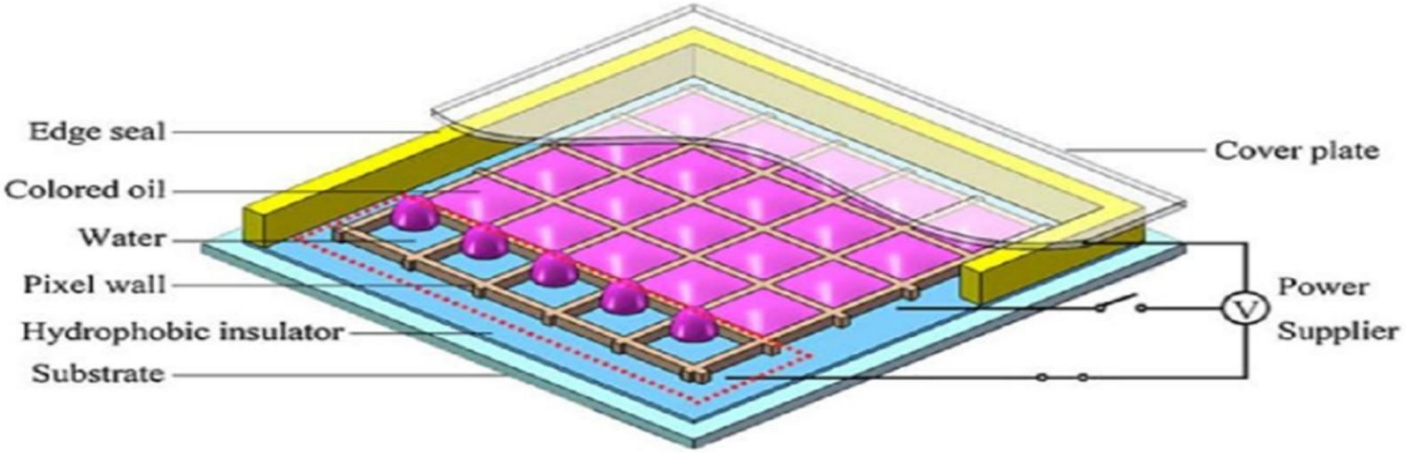
Electrophoretic Displays

Electrophoretic Ink(E-Ink) technology creates an image that looks like real printed paper from all angles and lighting condition.Fig.1 explains the working principle, the display is made up of millions of microscopic titanium oxide spheres sandwiched between electrodes within each sphere are positively charged white ink particles and negatively charged black ones. Applying a negative charge to the bottom electrode repels the black spheres to the top, making the screen appear black at that pixel. Thus, the positive charge moves the white ones to the top.



Electrowetting Displays

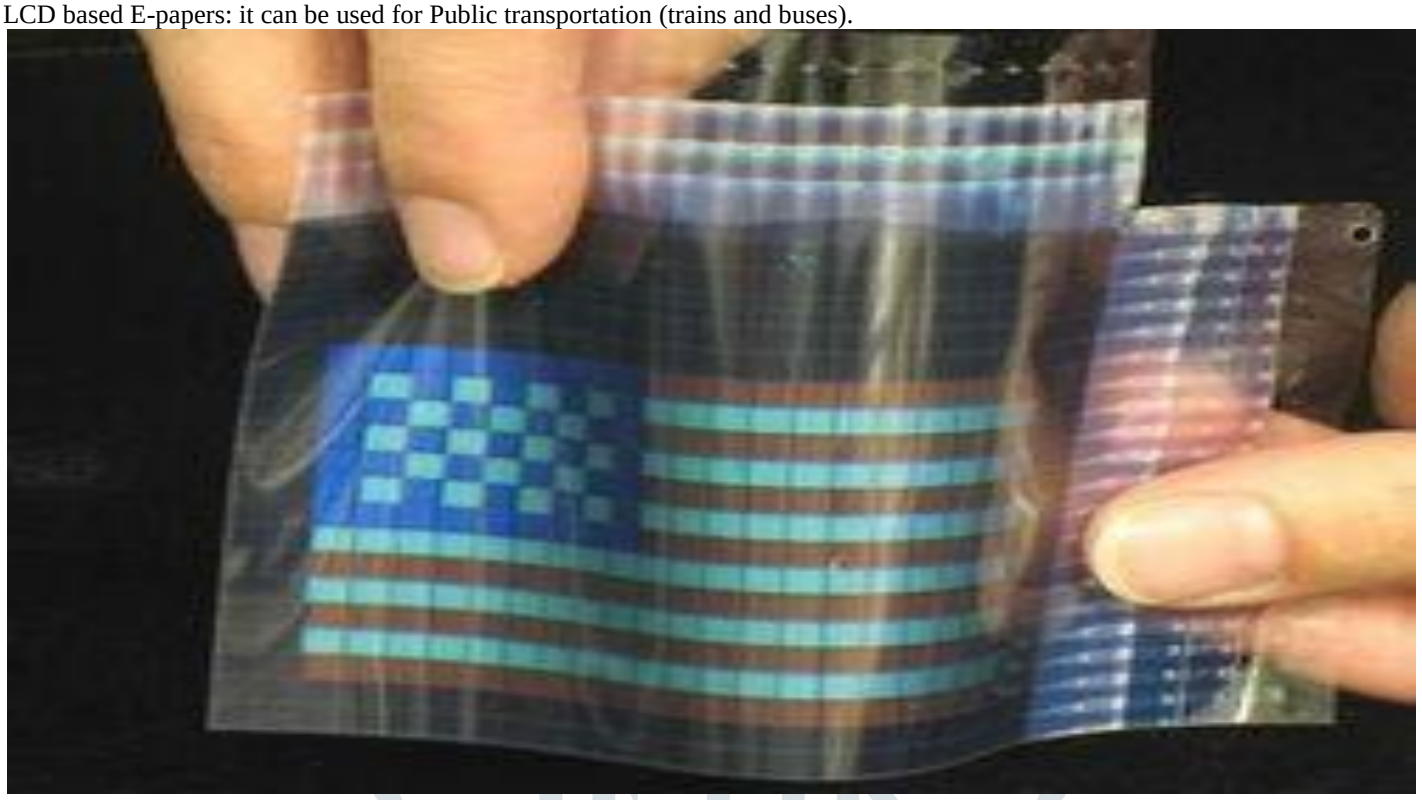
Electrowetting display is based on Electrowetting principle which uses the same underlying technology but replacing the titanium with layers of colored oil and water. Electrowetting is a micro fluidic phenomenon which modifies the surface tension of liquids on a solid surface with voltage. By applying a voltage, the wetting properties of a hydrophobic surface can be modified and the surface becomes increasingly hydrophilic (wettable). As an Electrowetting display uses colored oil, they can theoretically display up to 16 million colors. This oil and water combination also lets us to switch each pixel between a colored and a white (blank) state very quickly. Therefore, the switching speed is so fast to play video very well. This is a huge advantage over Electrophoretic displays, which switches so slowly. Its response time is 70 times better than the current reflective display. Although, Electrowetting displays has good refresh rate and suitable for video applications, still it requires high driving voltage.



Cholestric Displays

Cholestric Liquid crystal displays (CH-LCD) is a promising candidate due its impressive features. To cite, it gives better image memory retention even when power is off, with ultra-low power consumption. Manufacturing thin and lightweight CH-LCD is easy to display different colors without any color filters. Comparatively, It has good refresh speed. Finally, it is flexible and bendable which makes them well-suited for all hand-held applications like E-books and for advertisement Billboards. One example for CH-

LCD based E-papers: it can be used for Public transportation (trains and buses).



METHODOLOGY & ALGORITHM

Composition:-

1. The front plane consists of E-Ink and backplane consist of electronic circuits. To form an E-ink electronic display the ink is printed onto a plastic film that is laminated to a layer of circuit.
2. Each pixel in an E Ink display is composed of a layer of one or more (usually many) microcapsules inside of which electrically charged white-pigmented particles are suspended in a black-pigmented liquid polymer (an oil/colored pigment).
3. A layer of addressable electrodes below the microcapsule layer can apply an electric field to the microcapsule, causing the charged white pigmented particles to either move towards the electrodes (to the bottom where they are hidden by the black oil, yielding a black color to the observer) or away from the electrodes (to the top, yielding a white color).

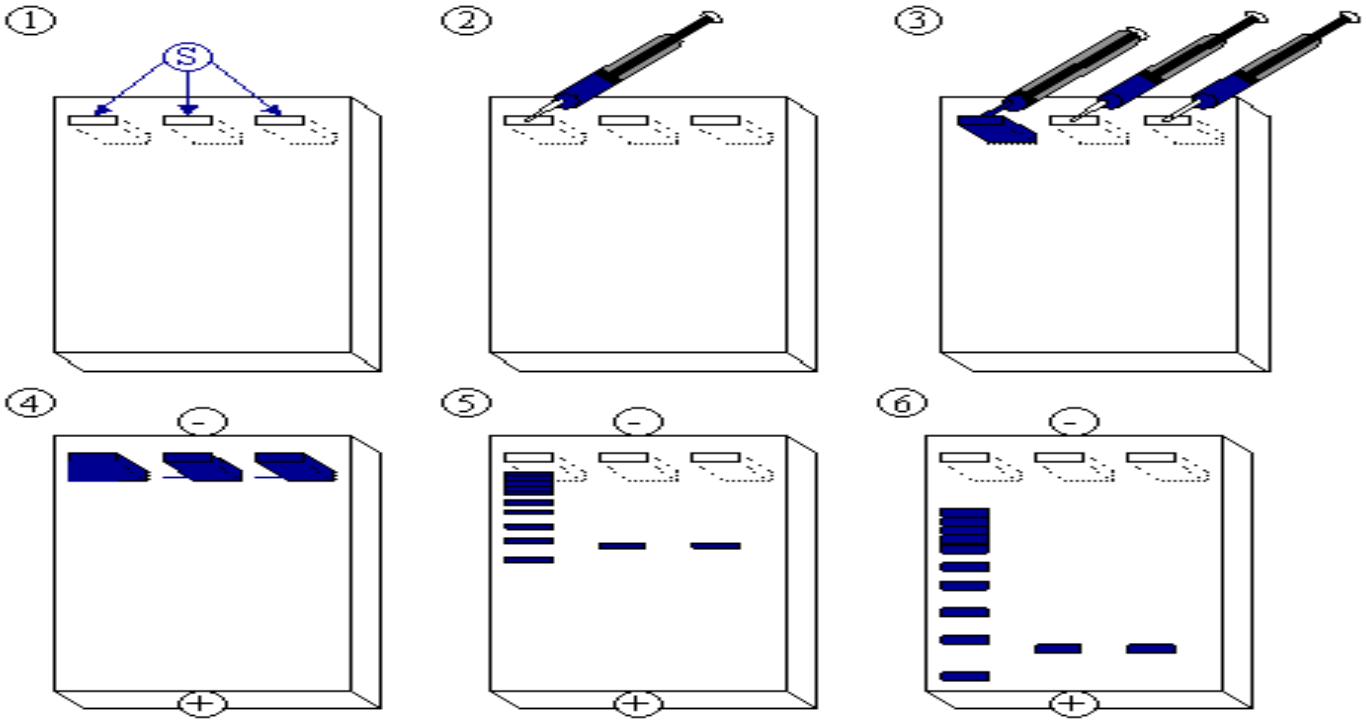
WORKING PROCESS AND TECHNOLOGY

Process:-

- Electrophoresis is a process, which enables separating molecules according to their size and electrical charge by applying an electric current.

What is Electrophoresis process?

Electrophoresis is an electro kinetic process which separates charged particles in a fluid using a field of electrical charge.



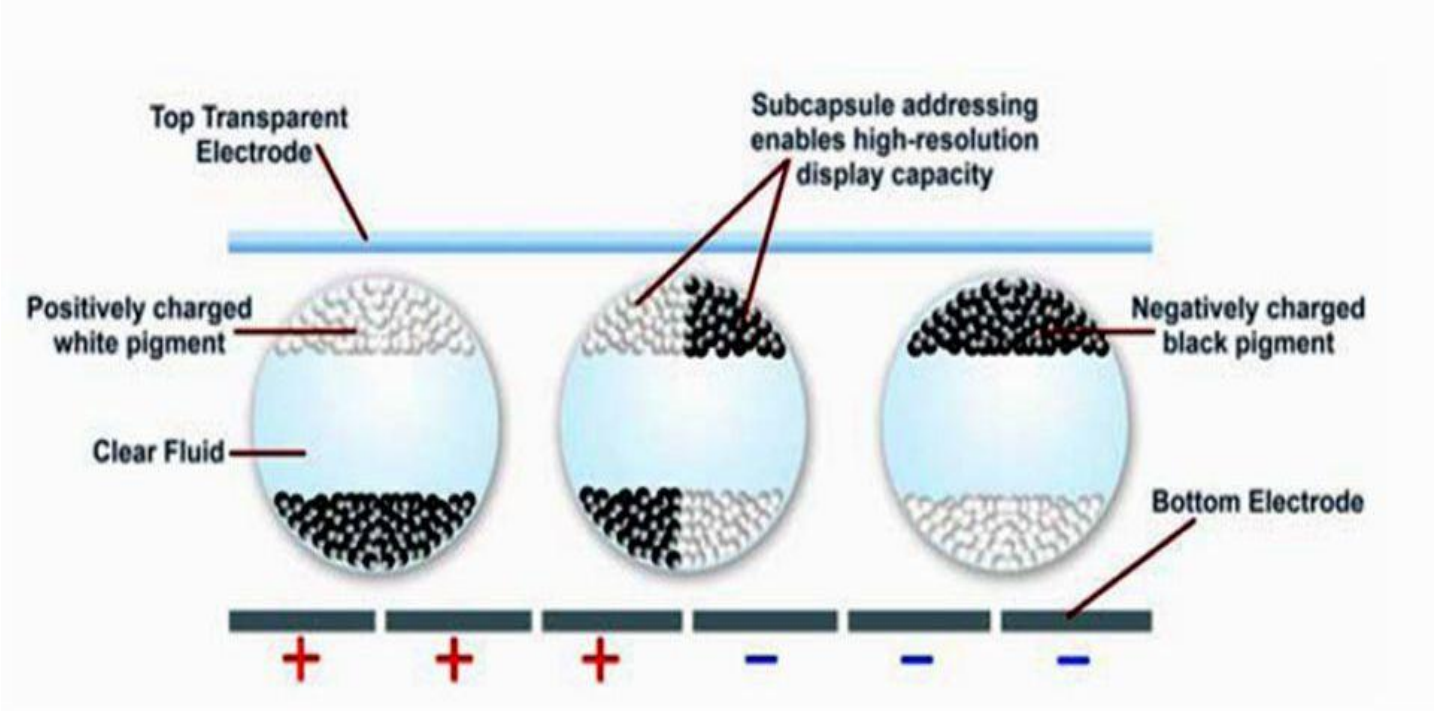
Implementation:-

- In an electrophoretic front plane, small charges submicron particles are suspended in a dielectric fluid that is enclosed into a sub-pixel size cell or microcapsule.
- When an electric filed is applied across the cell or capsule, the ink particles will move towards the electrode with the opposite charge.
- With a transparent electrode, the cell or capsule takes in the color of the ink when current is applied. The contrast is improved by using opposite colored particles such as black and white- and charging them with opposite polarities.
- When current is applied, all the black particles will migrate to one side, and all the white to the other. Switch the field, and the capsule will change color. This enables switching between all black particles and all White particles on the transparent front electrode of the cell or microcapsule.
- This is how the high contrast ratio of electrophoretic display is created.

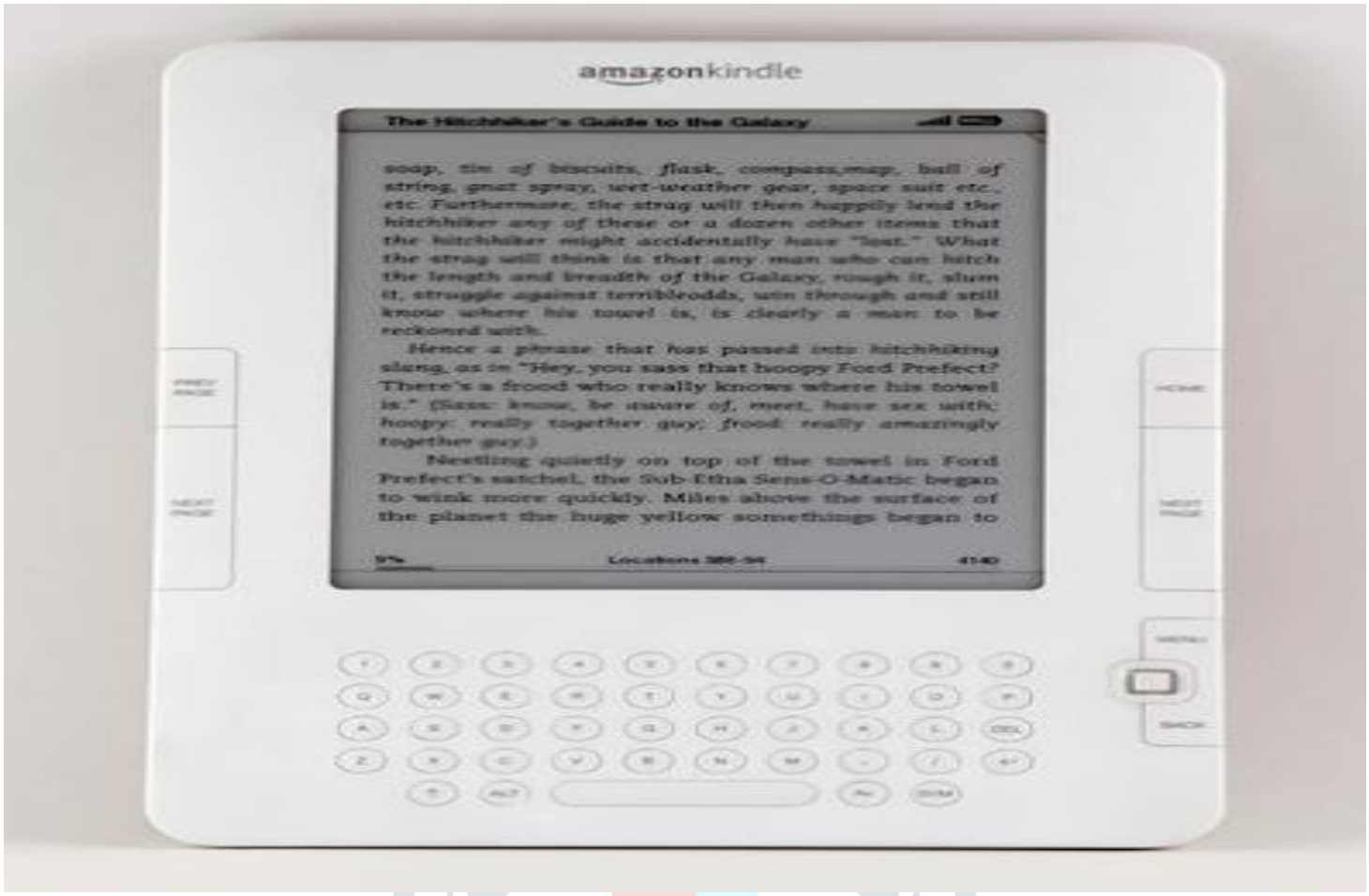
FINALLY

The electrophoretic technology used by E-ink is the most widely known and used form of E-paper. Known as electronic ink, it is a proprietary material that is made into a film for incorporation ink a paper-like display.

ELECTROPHORETIC DISPLAY PROCESS



ELECTROPHORETIC DISPLAY



COMPONENTS

- EPD Cells
- Power
- Circuits
- Color film
- LCD/LED
- Storage chip
- After the LCD, Plasma and LED displays, we have reached in the era of flexible and bendable displays. It is in this display technology, you can bend the screen as your wish.
- E-paper is a revolutionary material (sometime called radio paper or just electronic) that can be used to make electronic displays.
- It is portable, reusable storage and display medium, electrically writable and erasable and can be re-used 1000s of times.

What are common challenges for the design of small screen devices?

For me, if there are too many things we want to put in one screen.

- ❖ First to think the solutions.
- ❖ Second, we need to think the strategy (like, Okay let's try and test this one, if it doesn't work, we will take that out.).
- ❖ Third, we need to talk with empathy with the stakeholders, we should (yes, we should) educate, give them understanding from the design side.

So I think the common challenge for the design of small screen devices is how to design if we have many things to display in a one single screen.

Challenges:-

- ❖ Compact size.
- ❖ Easy to access.
- ❖ Low power consumption.
- ❖ Load too many things in one screen.
- ❖ Long life of device & battery.
- ❖ No visual distraction.

- ❖ Alignment.
- ❖ Reasonable price.
- ❖ Device based on customer requirement and market survey.
- ❖ Light weight.
- ❖ Full fill with advanced technology.

Power Consumption Relatable To Battery Life.

If this were true, it would create a significant logistical headache for anyone operating large numbers of battery powered e-paper kit, such as tags or labels. Happily, in most cases, an annual battery change is highly unlikely.

Granted, exactly how long the battery in a tag or label will last depends on a range of factors: type of battery used, how often the display is updated, how that information is sent to the tag or label, and what other components it contains.

Even though e-paper uses relatively little power, devices with e-paper displays still typically require a battery change every 12 months (Approx).

When the battery runs out, you lose what's shown on an e-paper display.

Unlike traditional TFT LCDs, which require a constant power source to display anything, once an e-paper display is showing an image, it will remain there and consume no power. In other words, even if you remove the power source, whatever is on the display will remain visible.

That's because e-paper utilizes "bistable technology."

What is "Bistable technology"?

Bistable technology refers to the fact that an image on an E Ink screen will be retained even when all power sources are removed.

Why Choose Modern Bi-stable Display?

- Much like e-paper screens, our modern bi-stable displays are also readable in sunlight and have excellent viewing angles.
- They also remain on after the power is switched off and only require more power when the image needs refreshing.
- One major advantage, however, is that bi-stable screens are able to display fixed print colours and can also operate in a wider temperature range.

Many existing barcode or QR-code scanners can't read an e-paper display.

When you display a barcode on an LCD, not all scanners can read it.

As a result, there's a misconception that barcodes or QR codes shown on e-paper displays will produce the same result. In fact, the way e-paper technology creates an image is fundamentally different from LCDs, meaning the majority of existing scanners can read barcodes and QR codes shown on an e-paper display.

E-paper displays create a visible image by reflecting ambient light off the white particles (and not reflecting it off the black ones), in exactly the same way that a printed barcode is visible to the eye or a scanner. LCDs, by contrast, aren't reflective. They work by passing light through a layer of liquid crystal, so certain types of scanner may not be able to determine the difference between areas our eyes perceive as dark and light.

Duration, durability, and duality: how e-paper is challenging compromise.

- ❖ Laptops, tablets and smartwatches are just a handful of the many portable devices on the market today that are plagued with limited battery life.
- ❖ Devices that integrate e-Paper displays combat this problem and provide users with greater flexibility and mobility.

<u>On reflection</u>

Beyond its battery intensive qualities, LCD and OLED displays also become virtually unreadable in bright sunlight. This is because they rely on backlighting, which unfortunately can't compete with the brightness of the sun.

<u>Survival of the flaxiest</u>

In addition to the lacklustre battery life and its highly reflective qualities, glass displays are also highly fragile. Its molecular structure is composed of tetrahedral crystals, making it prone to shattering, scratches and breakage.

You can't make an e-paper touchscreen.

- ❖ E-paper displays don't have to be read-only. By incorporating appropriate technology, they can be used as interactive touch screens. For example, product makers have added capacitive sensors on top of their e-paper displays to provide single finger, multi-finger, and gesture control of the device.
- ❖ As a result, product designers can enjoy the benefits of e-paper, while offering their users the intuitive touch experience that they've come to expect from their Smartphone, tablets, watches, and PCs.

E-paper isn't readable in sunlight.

- ❖ LCDs become virtually unreadable in bright sunlight, because the backlight, designed to make the image in the liquid crystal visible, can't compete with the brightness of the sun.
- ❖ Conversely, e-paper displays remain perfectly usable in the sun because they're reflective.
- ❖ The image on the display remains visible in sunlight exactly like printed ink on paper: The dark areas absorb the sunlight and the light areas reflect it, thereby creating a visible image.

You have to be directly in front of an e-paper display to be able to read it.
The reflective nature of e-paper means it actually offers viewing angles close to 180° in some cases. So even if you're not able to get your eye directly in front of an e-paper display, you should still be able to read its contents.

E-paper will only work at room temperature.
Most e-paper panels are designed to be used between 0° and 50°C, meaning they're not limited to "room temperature" use cases. Indeed, there are so-called wide-temperature panels.

What is Electronic Shelf Label?

- An **electronic shelf label** (**ESL**) system is used by retailers for displaying product pricing on shelves.
- The product pricing are automatically updated whenever a price is changed from a central control server. Typically, electronic display modules are attached to the front edge of retail shelving.

ADVANTAGES
Electronic Paper offers several advantages over printed paper. For example you can use electronic bookmarks, choose you preferred level of magnification, you can also use search to find information quickly, and you have the option to print on to real paper if required.

DISADVANTAGES
A major disadvantage of electronic paper technology is very low refresh rate compared with other low-power display technologies like liquid crystal displays (LCDs). This prevents products from implementing sophisticated interactive applications (using fast moving menus, mouse pointers or scrolling) like those which are possible on handheld computers.

APPLICATIONS

- Education: Digital School Books In January 2007, the Dutch specialist in E-paper, edupaper.nl started a pilot project in a secondary school in Maastricht, using E-paper as digital school books to reduce costs and students daily burden of book.
- Wristwatches In December 2005, Seiko released their Spectrum SVRDOOITM wristwatch which has a flexible elestrophoretic display and in March 2010, Seiko released a second generation of this famous E-ink watch with an active matrix display

Addressing Schemes for E-Paper

Traditionally, there exist three addressing/driving schemes for display devices: Direct, Matrix, and Raster. The aim of each scheme is to maintain the state of a pixel to either black/white or Gray-scale level.

Discussion

We found that understanding working mechanisms of different E-paper displays will help us to pursue novel display research to find new materials governed by laws of physics. Also, Our study on E-paper Driving schemes conclude us to propose New Driving methods for High-Quality displays with Low cost and Low Power consumption. Comparative studies on E-paper technologies prove that there exist several challenges which need to be solved in E-paper ecosystem. Our study shows that different technologies are emerging from laboratories to compete next generation E-paper displays for different purposes. As an application scenario, the use of electronic paper for displaying product prices on store shelves allow us to change prices immediately, enabling stores to easily implement discounted shopping hour promotions. Thus, growth of E-paper displays lead us a new paradigm to research and develop state-of-the-art driving schemes. Although, we claimed Cholestric LCD is a low power display and making color displays is easier with compatible production process they are not well suitable for extreme temperatures. One possible solution is to add compensation circuit to adjust the temperature shift. Yet; we need confirmatory studies to conclude which technology would be the next generation contender for E-Paper Displays. Readers may criticize that E-paper displays find its way for niche application.
Nevertheless, it is important to understand its operation as it leads a new way to unanswered questions and future directions for Display of the future. Our research implies that studying E-paper displays like CH-LCD presents an effective way to propose novel driving schemes. It aims to visualize information effectively under physical and environmental considerations. Whole idea was to appreciate better Physical implementations for High quality displays involving Low cost and Low Power consumption.

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