

## What is e-paper?

It is a term that has been used rather loosely for a long time, but broadly speaking it is a display technology that has all the attributes of paper but can be written to and erased electronically. We can list some of these basic attributes as follows:

- High resolution (150dpi or better).
- High contrast, equal to that of print on paper (about 10:1 or better).
- Readable in any ambient light conditions
- Readable at any viewing angle
- Excellent ergonomic features, easy to hold, carry, and use.
- Light weight, at most comparable to an equal sized sheet of card.
- Robust, will withstand being dropped, hit, etc.
- Flexible, or at least bendable.
- Cheap, maybe not as cheap as paper, but easily affordable by everyone.
- Reasonable large area, preferably A4 (298x212mm)
- Bistable, once a display is written it will stay displayed even when power is switched off.



A display that meets all of these attributes can be referred to as an e-paper display suitable for use in an e-publication reader, since it is, in virtually all aspects, an electronic replacement for a sheet of paper. Indeed such display technologies are sometimes referred to as paper replacement technologies.

### Flexible, bendable or rigid?

Although a lot of emphasis is placed upon e-paper being either bendable or flexible these are in many ways some of the least important attributes of e-paper. However, what is important about these attributes as opposed to a rigid glass based display like an LCD panel, is that their flexibility makes them much more robust and durable.

A rigid glass substrate LCD display will break if dropped on a hard surface, trodden on, sat upon, etc. A bendable display will probably survive most of those accidents. A bendable display panel can also be made much thinner and lighter than a rigid one since it needs no strong physical support to protect it, and so if it is bent when shoved into a briefcase it will survive.

Because it needs no rigid backing a flexible display panel is thin and light weight, and hence it is both highly portable and ergonomically much easier to use.

Our potential user surveys have indicated that the majority of users will settle for a device that is slightly bendable, rather like a thick sheet of card or a thin sheet of plywood. An acceptable format would be light enough to easily hold in one hand for long periods, rigid enough to act as a writing pad for handwritten annotations using the touch sensitive surface, and yet flexible enough to survive most forms of mistreatment.

The first generation of e-paper display that are now appearing in the marketplace all use rigid glass backplanes that are basically derived from conventional LCDs, this means that they are as rigid and breakable as an LCD. From the second generation onwards all e-paper displays will at least be bendable, these displays are entering the manufacturing phase now.

### The importance of readability.

Although the information storage and distribution function of paper is increasingly being replaced by digital technology, paper still holds pre-eminence when it comes to reading that information. By and large most people still prefer to read from a sheet of paper than from a computer screen. Indeed the much heralded 'paperless age' of the personal computer has instead been an age where paper usage has been higher than ever.

The reason for this is that most people do not like reading from a computer screen, either an LCD display on a laptop, or a CRT screen on a desktop. There are several reasons for this, the most important are:

- Low contrast ratio and low resolution lead to eyestrain in long periods of continuous reading off a computer screen.
- The size, and weight of a computer screen means that the reader cannot easily position himself/herself at a proper viewing distance, leading to further eyestrain.
- Computer displays are light generative, or backlit, and often not viewable in a wide range of ambient light conditions or viewing angles, leading to further eyestrain.
- Lack of portability, even with a laptop, limits the times and places in which a document can be read off screen.
- The landscape format of a computer display contrasts to the portrait format of most printed paper documents, resulting in the need for page scrolling of documents that are formatted for print.

Although some people, especially younger computer users, are happy to read from screen for long periods, most users find that the above reasons limit the time that they can comfortably spend reading off screen. Indeed, the problem is sufficiently serious to be recognised by health authorities, and in the UK, the normal fee for eye tests can be waived for computer users.

This means that reading from a screen is usually confined to quick scan reading and searching for information, rather than careful in depth reading. Consequently most will opt for printing out a page that they wish to read carefully.

### Why E-paper offers improved readability.

In all computer displays, including e-paper, the display is made up from a number of very small picture points, or pixels, the image on the screen being formed by the pattern in which they are turned off and on. Most conventional computer displays in use today have a resolution of between 70 and 100ppi (pixels per inch). A standard laser or ink jet printer will print using a resolution of between 300 and 600ppi.

At an average viewing distance of about 60cms a screen resolution of 100ppi gives a fairly sharp image, however, at a closer distance, such as the 30cms average viewing distance when reading a printed sheet of paper, the digitisation becomes noticeable, thus reducing both the quality of the typography and the readability of small and/or serif fonts.

This means that paper replacement displays which will be viewed at a closer distance will need to have a resolution of at least 150ppi and preferably 200ppi for a monochrome display if it is to equal the quality of standard newsprint, and 300ppi or better if it is to equal the quality of magazine and book printing. Most e-paper technologies are well able to deliver resolutions up to 300ppi and many have already been demonstrated at 150-180ppi.

The clarity of printed text also depends upon the contrast ratio between the respective reflectivity of the paper and the ink. In newsprint the contrast ratio is typically around 10:1, though in higher quality magazines and books it can be much higher. A typical LCD display, however, will only have a contrast ratio of about 5:1. In general the higher the contrast ratio of a display the easier it is to read text based information, and the aim of any text display technology should be to aim for a contrast ratio at least equal to that of printed paper. Most e-paper technologies achieve a better than 10:1 ratio, which is about the same as that of a printed newspaper.

With colour computer displays the problem is more complex since each pixel consists of a triad of different coloured pixels, one red, one blue, and one green, the combination of these three colours together with the intensity of each will determine the resultant colour of the pixel triad. The use of such pixel triads means that the overall resolution of colour displays is usually much lower than that of monochrome displays - so, since they require three times as many pixels, a 150ppi display will require 450 colour points per inch.

However, in print, a four colour combination is used: cyan, magenta, yellow and black, which gives the high contrast black that is necessary for text, whilst at the same time offering the colour triad to generate a full colour palette. Although full colour e-paper is not yet in production, it will probably follow the four colour system used in print rather than the three colour system used in computer displays if it is to have the necessary contrast for displaying good quality text.

The readability of text, in particular the contrast between ink and paper, is also very dependent upon the ambient light conditions and the viewing angle. In a conventional CRT display, which is light generative, or a LCD display which is backlit and transmissive the display is easily 'washed out' in very bright ambient light.

However, in bright light a sheet of printed paper becomes easier to read because it is being read by reflected light. In general the human eye finds it far easier to read using reflected light than any form of light generative/backlit display. Most e-paper technologies use reflective displays, and this will probably be a major factor in their popularity since this type of display will generate considerably less eye strain.

Another readability factor where e-paper technologies will have an advantage is the viewing angle. Both CRT and LCD screens need to be viewed almost straight on, look at them from an angle and in the case of a CRT one sees reflections of the room, or in the case of LCD the contrast simply disappears. A sheet of paper can, however, be viewed at virtually any angle, the same applies to most of the e-paper technologies.

### Why E-paper offers improved usability.

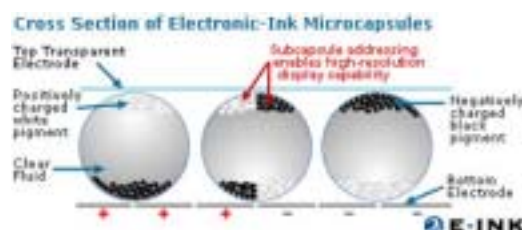
A thin lightweight display has considerable ergonomic advantages over the conventional LCD and CRT displays available today. The projected weight of an A4 e-paper display based document reader, including battery, will be under 200gms, about the same weight as a magazine like the Economist. This means that it can be comfortably held in one hand and read in any position or location that the user wishes.

The light weight of an e-paper display based reader device, coupled with the fact that it will probably be keyboardless (relying instead on a touch screen and virtual keys) also means that like a sheet of paper it can be easily used in either landscape or portrait mode. Indeed e-paper displays have another advantage in that they can be more easily manufactured in a wide range of sizes and shapes for specialist display applications.

Another ergonomic advantage of e-paper displays is that because they are reflective and offer a high contrast they can be read in any ambient light condition that will allow a paper document to be read.

The low power consumption and bistability of an e-paper display means that they can be used for long periods without recharging or replacing batteries. Manufacturers of first generation e-paper display based readers are quoting figures of 10,000 page displays on two AA batteries, or about three months of average use.

When an e-paper display is combined with a touch screen overlay the combination offers the capability of becoming an exact electronic analog of a pad of paper and a pencil. It will be possible to draw handwritten notes or diagrams onto the display, thus allowing manual annotation of printed material, note taking etc.



**Tutorial:**

1. Brainstorm different potential applications of *e-paper*.
2. Carry out a PACT analysis on one of the applications that you have come up with.