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Printed Electrochromic Displays – Superior to Reflective Segmented LCDs?

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ABSTRACT

For several decades, reflective segmented LCDs have been the display technology of choice in many simple and low-end applications, such as calculators, fever thermometers, and household appliances. Printed electrochromic segment displays are rapidly advancing in terms of performance and mass-producibility. This presentation explores how printed electrochromic displays compare with LCDs and how they can begin to replace segment LCD screens.

1. INTRODUCTION

Reflective segment displays have historically been used in almost all types of consumer electronics that include a display module. Today, many segment displays have been replaced by more complex full-color matrix displays, when and where possible. However, there is still a significant market for reflective segment displays where a complex display is not the ideal solution. The reasons for choosing a reflective segment display instead of a matrix display include, for instance, the energy consumption, display- and system cost, and the cost and possibilities of making custom-designed solutions. When considering reflective segment displays, reflective LCDs and electrochromic displays (ECDs) are two of the top candidates.

Fig. 1 Printed Electrochromic Display Integrations

1.1 Printed Electrochromic Displays from Ynvisible

Electrochromic displays from Ynvisible Interactive Inc. are manufactured with roll-to-roll screen-printing and, in some versions, produced with completely organic materials. The simplest form of the display stack is comprised by two electrodes and an electrolyte to facilitate redox reactions of an electrochromic polymer resulting in a color change. The printed ECDs are the most energy-efficient displays for a variety of applications and are highly suitable for displaying symbols, numbers, or other simplistic visual feedback.

2. DECIDING TECHNICAL FACTORS

The most important aspects when considering a reflective segment display generally include (1) Energy Consumption, (2) Total Cost of Ownership (3) Flexibility (4) Appearance, (5) Robustness, and (6) Eco-friendliness

2.1 Energy Consumption

Low energy consumption is often crucial in most of the applications where a segment display is of interest. This is especially true for battery-driven devices, applications involving photovoltaics, as well as energy-harvesting applications (e.g. utilizing RF-reading as the power source). Certain constructs of ECDs can also double as capacitors within the electronic device, and offer display functionality otherwise not possible with LCDs.

2.2 Total Cost of Ownership

The cost per unit will always influence the decision regarding which segment display technology to use. To objectively compare costs, a segmented display with the same dimensions and segment designs has been used as basis for quotations for multiple manufacturers as well as clients.

In addition to the direct unit costs of the display component, final product owners need to also factor in indirect system level costs when choosing one display technology over the other. System level indirect costs to define Total Cost of Ownership (TCO), one needs to include cost elements such as product integration (final product design and assembly), powering and driving, as well as costs associated with after life handling.

2.3 Flexibility

Displays are no longer limited to flat surfaces. A flexible display can be integrated in an electrical device that follows its curved form factor. Flexibility is also required for applications that are inherently flexible, such as a smartcard or various labels within logistics and supply chains.

2.4 Appearance

Some applications do not have strict requirements regarding the appearance of the display assuming only that the display content is clearly visible. For other applications, appearance is one of the most important aspects. The appearance involves both optical parameters, such as contrast ratio, white reflectance, and viewing angle dependency. It also includes color options and how the display segment looks when switching between states.

2.5 Robustness

A robust display solution that can reliably work at least throughout the entire product lifetime is a critical minimum requirement. The robustness of a display can be broken down into three sub-parameters; lifetime, operation under different storage and use conditions, and ruggedness.

2.6 Eco-friendliness

Eco-friendliness is a factor is getting increasingly more important as regulations are getting stricter and consumers more enlightened. Environmental concerns are highlighted particularly in single-use applications and disposable devices, e.g. displays in pregnancy tests and point-of-care devices.

3. TECHNICAL COMPARISON

The table below summarized a technical comparison for each decision factor highlighted in section 2.

Table 1 ECD and Reflective LCD comparison.

	ECD Display	Reflective LCD
Energy (1)	1.2 μW	6.6 μW
Cost (2)	Very Low $0.2-0.5/unit	Very low $0.2-0.4/unit
Flexibility	Yes	No
Appearance	Very good appearance. Brighter display than reflective LCD. Sunlight readable, multiple color options and highly customizable at a low cost. Very thin and lightweight. Highly compatible with graphic overlays	Poor appearance. OK visibility in bright environments. Generally poor angle dependency. Thick and bulky.
Robustness	Excellent Does not break or crack, wide temperature range	Good Wide temperature range, long lifetime. Not plastic substrate.
Eco-friendliness	Excellent. Can be made with completely organic and disposable materials. ITO-free. Energy-efficient production methods.	Requires electronics recycling. Contains ITO. Energy-consuming production.

3.1 Energy comparison comment

Energy consumption calculations were based on a 2x2 cm^2 outer dimension of a 1x7 segment display, approximately equivalent to 1 cm^2 active display area. The calculations are based on 100 display updates per day.

Reflective LCDs are less complex in terms of energy consumption. According to a review of multiple reflective LCD datasheets, the average power consumption for one square centimeter active display area is 6.6 μW. This figure will not be significantly affected depending on the number of display updates that is performed.

The segment electrochromic displays have an image memory characteristic. This means that the displays will maintain the activated state of the display segment for a certain time without any power consumption. The image memory time is typically ranging from 15 minutes up 60 minutes. After this period, a small refresh pulse is required to maintain full contrast. The power consumption for the electrochromic display is therefore more dependent on the update frequency of the display, which can be calculated according to the formula below.

$$P_{ECD} = 0{,}28 + 0{,}01 \times \mathrm{n} \ \frac{\mu\mathrm{W}}{cm^2}$$

$$n = number\ of\ full\ display\ updates\ per\ day$$

3.2 Cost Comparison Comment

Cost comparison were based on a 2x2 cm^2 outer dimension of a 1x7 segment display in 100 000 displays per annum.

4. CONCLUSIONS AND DISCUSSION

The segmented electrochromic displays are a superior option to segmented LCDs when technical parameters including flexibility, appearance, and eco-friendliness are present. When only cost and energy-consumption are influencing factors, the two options for reflective segment displays are considered equal for most applications. For high-frequent display updates, the reflective LCD is the most natural choice due to the advantageous refresh rate, display lifetime, and dynamic power consumption. For infrequent display updates, such as a few times per day or week, ECDs will have a significant advantage in terms of energy consumption.