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LCD Technology

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This paper looks at the various factors that affect the display quality of liquid crystal displays (LCDs) and outlines a new standard we have designed for the evaluation of LCD display quality. Also, this paper looks at the increasingly important electromagnetic radiation interference (EMI) from LCDs and how it can be reduced.

1. Introduction

The liquid crystal display (LCD) is now a key device in multimedia equipment, and the demand for LCDs with improved performance (e.g., lighter, thinner, lower cost and power consumption, higher luminance and definition, and larger screens) is increasing. However, there are many obstacles to achieving these improvements. This paper looks at the problems of display quality and electromagnetic interference (EMI), which are particularly important in regard to the realization of a high-definition, narrow-frame, large-screen LCD. This paper also introduces some technologies for reducing the level of the EMI emitted from LCDs.

2. Display Quality

Some display factors, for example, color cromaticity, have different effects on different viewers, while others such as flicker have a common effect. Both types may be judged by the respective criteria of the users, and the items of priority differ for each user according to the conditions of usage; this is the main obstacle to optimizing the various tradeoffs. The factors that affect display quality and the factors with which they have a tradeoff relationship are listed in **Table 1**.

Table 1 shows that important factors of mobile equipment such as power consumption, weight, and size have close relations with display

Table 1. Factors affecting display quality and associated tradeoff factors.

Item	General description	Tradeoff factors
Luminance	Screen brightness	Power consumption, weight
Uniformity	Evenness over screen	Weight, size
Flicker	Periodic variation in screen brightness	—
Color reproducibility	Number of colors	Luminance, power consumption, weight
Color cromaticity	Balance of red, blue, and green	Luminance (in some cases)
Dot pitch	Screen resolution	Power consumption, weight, size
Contrast	Screen sharpness	Response speed
Surface reflection	Reflection of glare	Luminance, power consumption, weight
Viewing angle	Variation in image according to viewing angle	Luminance, power consumption, weight
Response speed	Afterimage	Contrast
Glare	Luminance unevenness within small area	Surface reflection
Crosstalk	Tail-shape unevenness on display	—
Afterimage	Afterimage lasting for hours	—

quality.

Also, as mentioned above, since the priority of these factors generally depends on the individual user and the circumstances of usage, there is a possibility that display quality is overlooked because too much attention is paid to the problem of reducing the weight and power consumption. To avoid this problem and quantify display quality, which hitherto has been quantified based on sensory evaluations, we have summarized the particularly important factors regarding display quality and made them into a common standard. When making the standard, the most important point was that we should not be unrealistically strict.

To prepare the standard, first the definitions of terms were established. In the past, LCD technicians named the various problems using common idioms for their respective causes. However, we decided that as far as possible we would classify the terms to be used in the common standard according to the symptoms. We decided this because the conventional idioms were not expressions in general use and they failed to describe the nature of the problem as perceived by the user.

We considered the following three levels of development:

1) The level at which theoretically there are no problems (Level 0).
2) The level at which there is room for improvement but there are no problems in practical applications (Level 1).
3) The level at which the technology in use must be improved before there are no practical problems (Level 2).

The final target is to attain Level 0. However, in most practical situations the highest achievable level will be Level 1 or 2.

For example, the response speed of TFT type displays is at Level 1 due to inconsistencies in parts of animated images (Level 0 requires a response speed better than 33 ms). Also, the response speed of STN type displays is at Level 2 because it is too slow for animated images. Establishment of the standard is relatively easy for factors such as the response speed because they can be objectively measured. However, standardization is not so easy for subjective factors such as unevenness in luminance. The following methods were adopted to establish a common standard for objective factors.

1) Comparison of data between displays that have and do not have problems.
2) Digitization of data in 1) according to ergonomics.

One of the factors that has been standardized is uniformity (unevenness). This factor is mainly a subjective one and is a tradeoff factor, particularly in mobile equipment.

Uniformity :

Ideally there should be no variation in luminance or color on the screen. However, this is unattainable because of failings in the manufacturing process. Non-uniformity in color can, to an extent, be managed using current technology. However, non-uniformity in luminance is still unmanageable and some kind of control is necessary. Luminance non-uniformity is generally measured simply as the ratio of maximum to minimum luminance on the screen. However, this measurement is insufficient and some other kind of control of local unevenness is required. We have standardized the evaluation of local unevenness, which conventionally is done subjectively, as described below.

Luminance unevenness was previously defined using the data of nine points, which is an insufficient number of points over which to discern a local uneveness. Therefore, we started by collecting detailed data. We measured the luminance at about 800 points on problem screens and on no-problem screens, and concluded that a standard such as the one below was needed to control local unevenness.

Standard for brightness uniformity

– When the screen is divided into nine equal parts, the maximum value (IMAX) and the minimum value (IMIN) of the center luminance in each portion must satisfy the following condition:

$$\frac{IMIN}{IMAX} \times 100 > 70$$

– Luminance variation on the screen must not exceed 30% per 30 mm.

The first standard is the conventional one and the second standard has been added to control local unevenness. In human vision, when the distance between two points is large (or more exactly, when the difference in the viewing angles of two points is large), small differences in luminance between these two points are not detectable (**Figure 1**). Also, when the difference in the viewing angles of two points falls below a certain value (i.e., the limit of resolution), differences in the luminances of the points become undetectable. In brief, the rate of change of luminance over the screen is an important factor in the standardization of uniformity. The above-mentioned standard is based on this and similar observations of the various factors.

Several other factors regarding display grades were also summarized as a common standard. However, as mentioned above, few of these technical standard values have reached Level 0 and the current technology level has only been achieved through tradeoffs. Periodic review of further technical developments will be necessary.

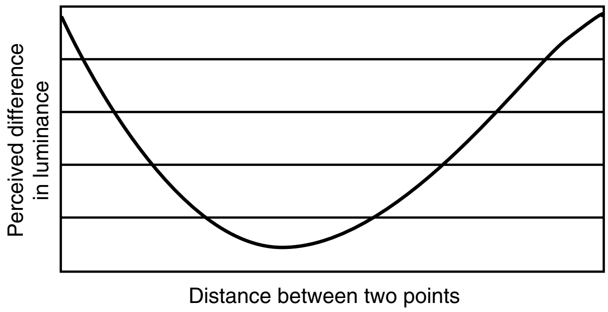

Figure 1.
Perceived difference in luminance versus distance between two points.

3. EMI

The high drive frequency (**Figure 2**) required to realize a high-definition color screen has made the problem of electromagnetic radiation leakage from the LCD interface and control base plate more serious. EMI has been reduced by modifying the LCD mounting, but for further improvements, the LCD itself must be modified at the design level. Also, since the conventional evaluation was done after the housing was completed, any countermeasures indicated by the evaluation would increase the development period and therefore tend not to be taken. To solve this problem,

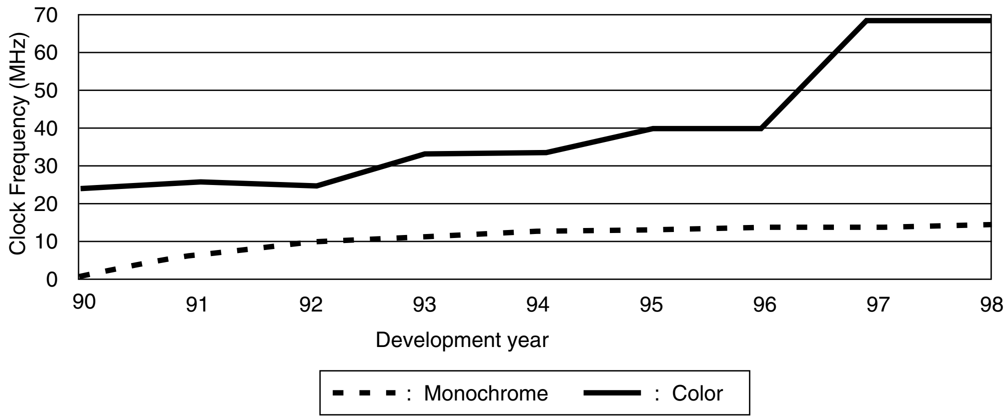

Figure 2.
Clock frequency increases.

the unit evaluation method described below was adopted.

First, we investigated a developed device in which countermeasures had already been implemented. Using the data obtained from this investigation, we determined which parts of a device mounted with an LCD could be improved by countermeasures and which parts did not need any countermeasures.

Then, we located the origins of the EMI emitted from the LCD using an antenna array of near-field magnetic probes. **Figure 3** shows the results of an example measurement. This investigation indicated that:

1) Particular care is needed to prevent radiation from the interface for LCDs having a resolution better than XGA (e.g., VGA, SVGA).
2) Care is needed in the design of connections (e.g., connectors, jumpers) of power supply lines inside the LCD.
3) Buffers and similar devices provided inside the LCD should be used if possible to avoid the need to increase the clock and data speeds.
4) The EMI generated by a mounted LCD should be at least 35 dB below the standard-

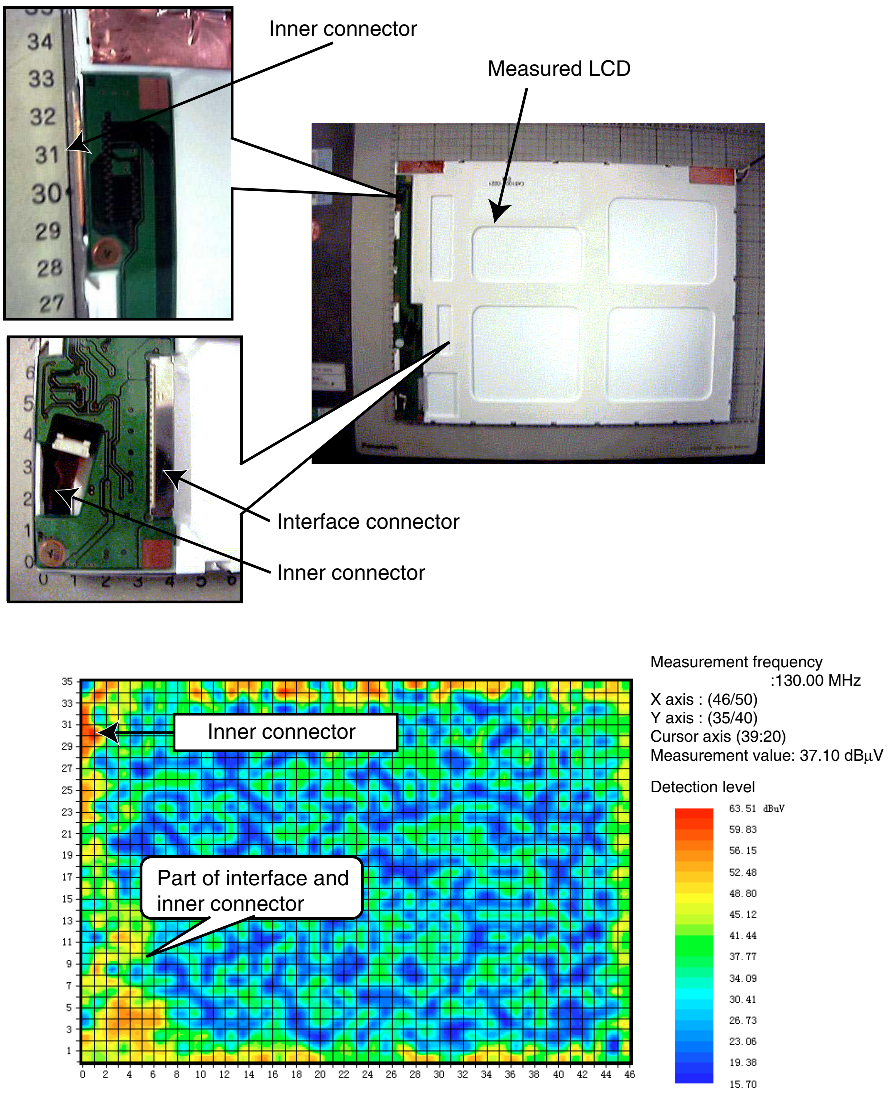

Figure 3.
LCD measurement results.

value.

We achieved effective countermeasures for 1) by adopting a new interface that uses low-amplitude differential signals (Figure 3).

Effective countermeasures were found and measurements were made for 3) and 4) at the initial design stage (before the device housing was completed).

We intend to establish measures to prevent the occurrence of problems instead of just coping with the ones that already exist. To do this, we are preparing design guidelines so that problems are handled as close to their origins as possible.

4. Conclusion

This paper described the various factors that affect LCD display quality and introduced a new standard for its evaluation. Also, this paper briefly looked at the problem of LCD EMI and suggested several ways in which it can be reduced. By implementing the findings of our work in this area, we have achieved substantial improvements in various notebook personal computers. Many LCD problems similar to those outlined in this paper remain, the solutions to which must be found in the early stages of product design.

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