Flat Dot Matrix Display Module for Vehicle Instrumentation

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A flat dot matrix LCD module is one possible satisfactory solution, but it is somewhat limited in terms of response time and viewing angle.

This paper presents a review of the recent progress and projected future trends in LCD technology as it is applied to vehicle instrumentation. In addition, the paper will discuss the design methodology, electro-optical properties, and function of three types of flat dot matrix display modules which have an intermediate number of picture elements.

Sector: Automotive

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ABSTRACT

Due to the recent increase in safety and operational information supplied to vehicle operators, an important need has arisen; the development of an effective display unit which uses a minimal amount of dashboard space.

A flat dot matrix LCD module is one possible satisfactory solution, but it is somewhat limited in terms of response time and viewing angle.

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INTRODUCTION

Information now supplied to vehicle operators is in a wide range starting with the most fundamental ones such as the vehicle speed, fuel level, water temperature, warning, and trip-odo meter.

However, much additional information is also provided to monitor vehicle performance including the following; elapsed time and distance; fuel consumption rate; driving range on reserves; estimated time of arrival; instantaneous and average vehicle speeds; interior and exterior ambient temperature; air conditioning; maintenance requirement; diagnosis; and entertainment and traffic information.

Multidisplay of all such information can be performed with a CRT employed as the information center of a large number of picture elements. [1] On the other hand, there is a strong demand for information centers of small and intermediate numbers of picture elements in order to display all the information and specifically to minimize the space for the dashboard. [2]

In response to such needs, three types of display modules were developed. Among the electronic display devices currently employed in vehicles are LED (light emitting diode), VFT (vacuum fluorescent tube), LCD (Liquid Crystal Display), PDP (plasma display), CRT (cathode ray tube), and EL (Electro Luminescent display). Shown in Table 1 is a comparison of dot matrix display characteristics of the devices employed at present.

From among them we chose the multiplexing TNLCD (Twisted Nematic LCD) as the device to be used for the display module with small and intermediate numbers of picture elements, as it excels others in cost, ease of operation (low power consumption, low driving voltage) and flatness.

However, the multiplexing TNLCD gives inferior legibility compared to other devices. Therefore, its legibility must be improved if TNLCD is to be used in the module.

This report presents an outline of the design developed for the display module to improve the legibility, and the characteristics of the module.

Table. 1 Comparison of Dot Matrix Display Capability by Types of Devices

	TNLCD		CRT	EL	PDP	VFT	LED
	Multi-plexing	Active address-ing					
Display Capacity	△	○	◎	○	○	○	×
Flatness	◎	◎	×	◎	◎	○	◎
Legibility	△	◎	◎	○	○	○	×
Color	○	◎	◎	×	×	×	×
Ease of Operation	◎	◎	×	△	△	○	○
Cost	◎	×	×	×	×	△	△
Reliability	△	△	○	△	○	○	○

◎···Excellent ○···Good △···Fair ×···Poor

PROBLEMS WITH MULTIPLEXING TNLCD

In a dot matrix display, strip electrodes (column electrodes and row electrodes) are perpendicularly crisscrossed, each crossing of electrodes being considered one pixel which can be illuminated.
In operating the matrix display, a column electrode acts as a scanning line and a row electrode as a signal line. Scanning lines are signaled one line at a time. At the same time, signal lines are given a selective or non-selective signal in response to the reaction of a pixel turned on or off on a scanning line. (i.e. whether it is lit or not.) This is the method called multiplexing.

It has a shortcoming, however, in that when the number of scanning electrodes is increased, it causes a crosstalk effect (wherein the pixels are lit only half way), because a certain amount of voltage (bias voltage) is impressed upon other pixels not required to be lit up. In other words, as the number of scanning lines increases, there will occur undesirable phenomena such as the lowered brightness, less contrast narrower range of viewing angle, and slower response.

The characteristic factors of an electronic device which determine the legibility of display are as follows; [3]

i) display area
ii) resolution (number of dots)
iii) brightness, contrast
iv) color
v) afterimages created by time interval and shape of display image
vi) intermediate gradation (ie; half tone)

In the multiplexing method, as the number of scanning lines is increased, improvement is observed with regard to the display area, resolution, and the intermediate gradation, while the brightness and contrast are lowered. Therefore, in designing a module, it is important to consider the contents of the display and see how a display pattern can be formulated with the minimum number of scanning lines and with brightness and contrast as high as possible.

MODULE SPECIFICATIONS AND OBJECTIVES OF DESIGN

Specifications of three types of modules developed are given in Table 2 and their appearances in photos 1, 2, and 3.

Table. 3 Principal Objectives and Principal Related Factors

Principal objectives	Principal related factors
1. Display patterns	1. Development of CRT display simulation program
2. Color matching	1. Development of CRT display simulation program 2. (Selection of color filters)[4][5][6][7]
3. Expansion of viewing angle dependency of contrast ratio characteristics	1. Selection of polarizer 2. Reduction of number of scanning lines 3. (Selection of LCD materials)[8][9]
4. Improved response time at low temperature	1. Reduction of number of scanning lines 2. Development of heating unit 3. (Selection of LCD materials)

Shown in table 3 is the relationship between the principal objectives and the principal related factors of the three module designes using a multiplexing TNLCD.

This paper describes four of the six principal factors required to achieve an improved design.

Table. 2 Module—3 Types

Module Type	Type 1	Type 2	Type 3
Usage	Message display	Symbol display, Warning or maintenance	Graphic display, for gauges, air conditioner, etc
Form of Display	Numerals, English alphabet, Kanji, and Hiragana	Numerals, English alphabet, Kanji, and ISO symbols	Numerals, English alphabet, Kanji, ISO symbols, and Graphics
Contents of Display	13 Warning messages 3 maintenance instructions 8 gear-shift instructions Greetings, Time-piece	13 Warning symbols 3 maintenance instructions 8 gear-shift instructions Time-piece	6 Warning symbols Gauge indication (fuel, water temperature) Gear-shift instructions Air conditioning Speed
Mode	Negative, transreflective type	Negative, transreflective type	Negative, transparent type
Colors	Monochrome (yellow, black)	Monochrome (yellow, black)	3 colors (yellow, red, green, black)
Dots	Dot size 0.55×0.55(mm) Pitch 0.7(mm) Number of dots 16×160 dots	1.0×1.0(mm) 1.3(mm) 32×30 dots	Lateral/longitudinal 0.76 0.37(mm) 0.80 0.40(mm) 48×200 dots
Driving Duly	1/16 duty 1/5bias	1/8 duty 1/4 bias	1/12, 1/24 duty ···shifted 1/5 bias ···common to both

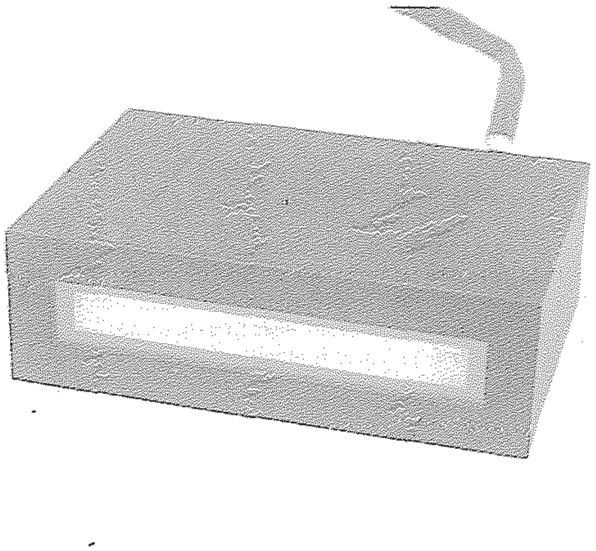


Photo 1 Type I Module

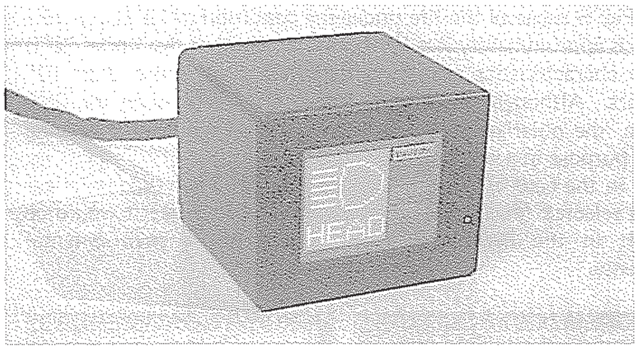


Photo 2 Type 2 Module

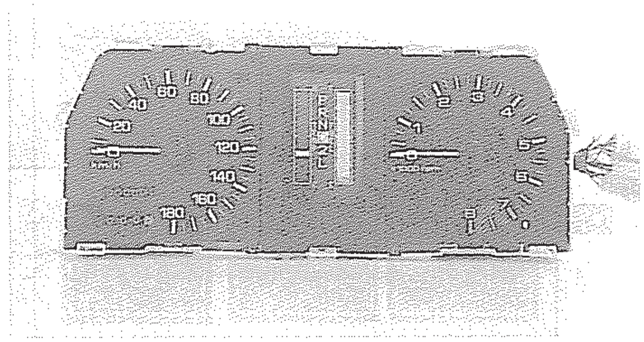


Photo 3 Type 3 Module, Built into the Instrumentation Panel

METHODOLOGY

DETERMINATION OF DOT FORMS AND COLOR ARRANGEMENT BY DEVELOPMENT OF CRT DISPLAY SIMULATION PROGRAM – While electrodes in a dot matrix are of simple composition, there is a great number of items for which the most appropriate condition would have to be sought in order to provide the best possible display within a limited number of dots, such as the form of dots (size, number, and pitch) and the selection of color filters. We therefore developed a software program for a CRT display simulation system comprising designs of liquid crystal display elements, and studied the feasibility of the desired display patterns.

The contents of the program software are shown in Table 4.

The size and number of dots for the module were determined using this simulation system.

Comparisons of the actual CRT and LCD displays are given in photos 4 and 5.

Type 3 module has a more complex design of display than the other two. Furthermore it is necessary to provide either a red or green filter at each pixel within the liquid crystal cell, since three colors are used for the display, namely red (R), green (G), and yellow (Y).
Therefore, the arrangement of these two colors was studied first.

The arrangement of these two color comes in two types, longitudinal and skew.

In the case of a linear display in longitudinal and lateral directions the longitudinal stripes will give clear edges, but when expressing diagonal lines or circles the skew stripes can provide a better looking design. Here the longitudinally striped arrangement has been chosen, since module displays carry many ISO symbols and the ISO symbols themselves are generally comparatively linear in shape. Results of study on the CRT display is shown in photo 6.

Furthermore in order to determine the color dot size, it is necessary to check the possibility of producing a yellow colored display by means of red and green dots. In general, the following Equation (1) will express the condition under which two color dots are mixed and observed as one dot.

Table. 4 Programming for Patterns

Display Patterns
1) Messages, letters, numerals
2) ISO symbols, warnings
3) Various indicator displays
4) Graphic displays

⇔

LCD Cell Electrodes
1) Dot size, shape, and space
2) Number of colors, color arrangement, hue
3) Dimensions of display area, aspect ratio

⇑

CRT Simulation Program
16 bit, 640 × 400 dots display
Display in 16 colors out of 4096

1) Capability to select the number of display pixels
2) Capability to select the number of dots composing the pixel
3) Capability to select the color filter for each dot composing the pixel
4) Selection of dot sizes
5) Capability to select the ON-OFF display color in intermediate gradation
6) Arrangement and selection of color filters
7) Capability of formulating, storing and correcting the designs

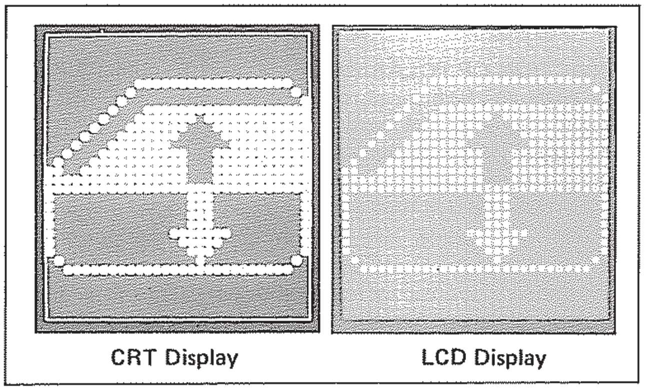


Photo 4 Type 2 Module Simulation

$$y = a/\tan(1/60 \cdot e) \quad \ldots\ldots\ldots\ldots (1)$$

y: distance at which two dots are recognized as one dot.
a: dot pitch.
e: visual acuity.

If the distance between the dashboard and the operator is 1000mm, and the visual acuity is e = 1.0, then it will give a = 0.3mm.

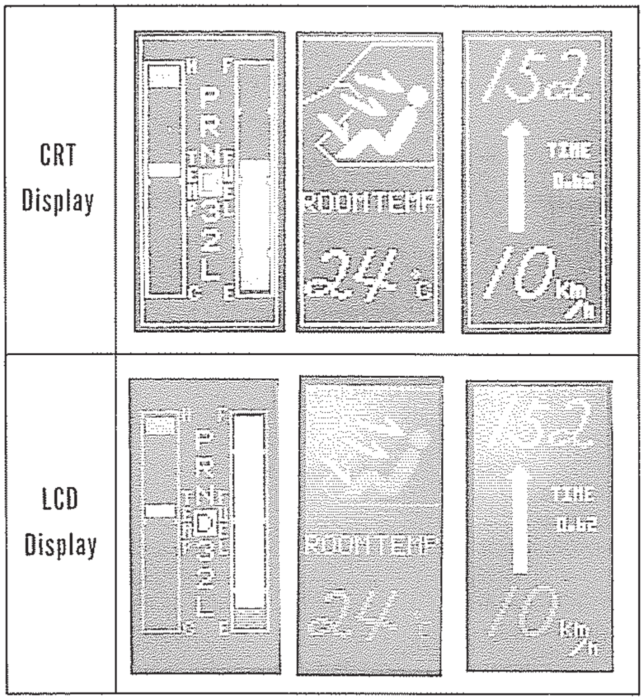


Photo 5 Type 3 Module Simulation

However, other elements of module design such as the size of the display area and the number of scanning lines will not permit the formulation of dots at such a pitch. Therefore, tests were carried out on a CRT display to ascertain the possibility of color mixing at dots of 0.8x0.4mm, which is closest to the mixing pitch. In fact, color mixing at this dot pitch was possible on an actually prepared LCD.

Shown in Table 2 are the dot specifications finalized for the three types of modules.

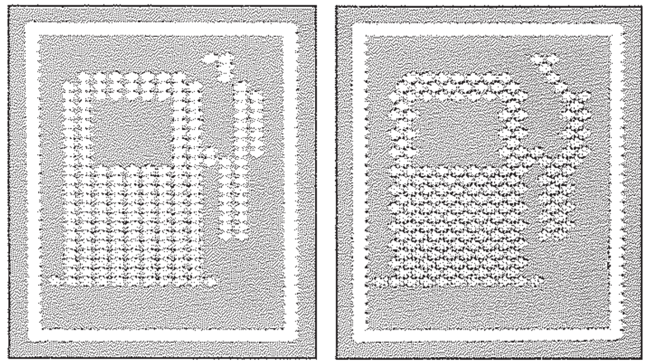
SELECTION OF POLARIZER – In order to obtain a wide viewing angle and high speed response, it is important, first of all, to select liquid crystal material of superior quality. [8] [9] But the viewing angle dependency of contrast ratio characteristics hinges largely on the polarizer. Polarizers come in two types, the dichroic dye type and the iodine type. For vehicle instruments the dichroic dye type polarizer is normally used because of its durability against environmental stresses. However, the iodine type polarizer has superior optical characteristics (polarization and transmission). Fig. 1 illustrates the effect of viewing angle enlargement with an iodine type polarizer.

The recent improvement in substrate has given the iodine type polarizer a greater durability against environmental stresses. An evaluation test has been carried out on the improved iodine type polarizer, which has become available.

Fig.s 2,3,4 illustrate the color difference, polarization, and variation of trans mission of a single polarizer under the environment of 60°C and 90% relative humidity.

From the test results the variation at color difference ΔE^*_{uv}=5 is judged to be the life of the polarizer. The Arrhenius plot at Fig. 5 suggests the life under the condition of 25°C and 90% RH is approximately 2×10^4 hours. In another test under 90°C the characteristics could be maintained for more than 10^3 hours. Although it will be necessary to also consider the field data, the polarizer seems to have a high probability of serving the purpose in a vehicle.

In the case of the Type 3 module, the iodine type polarizer was selected for evaluation in the dashboard, since it would be built in the dashboard and protected from environmental stresses.



a) longitudinal stripes b) skew stripes

Photo 6 Color Arrangement on CRT Display

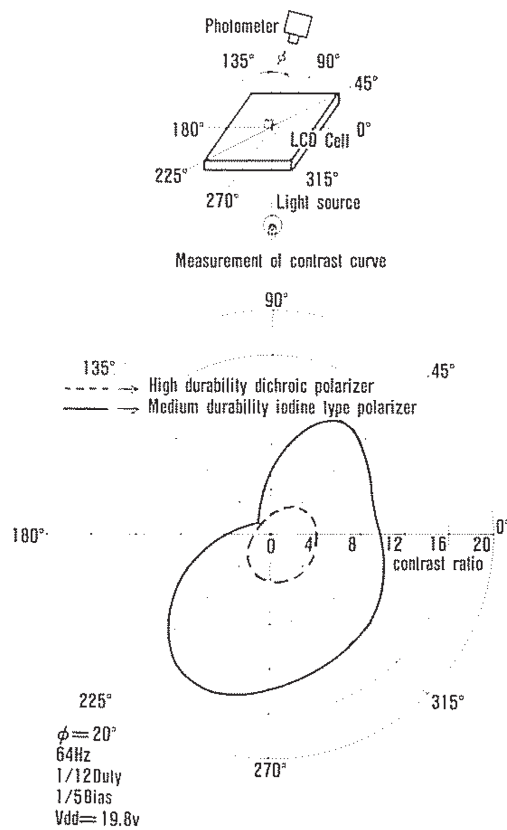


Fig. 1 Contrast Curve at ϕ = Constant

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