Electronic Displays

TEXAS INSTRUMENTS ELECTRONIC SERIES

Electronic Displays

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Preface

Digital electronics has become pervasive as a result of its extremely low cost. Displays for digital systems allow direct indication and reading of numbers, letters, and symbols. They can present more data in less space than the obsolescent analog meters.

This book about the application of digital displays is for the practicing engineer. It is written to answer recurring questions that arise, and its purpose is to bridge the interface between the display designer and manufacturer in the middle and between the prospective user (or user engineer) on one side and the circuit designer on the other. To the extent that this book is an aid to this task, it will be successful in its purpose.

The book first covers general display considerations, such as font, legibility, size, and comparison methods. It then explores several display types—such as the gas discharge, visible light-emitting diode, vacuum fluorescent, and liquid crystal displays—at some length. Mentioned briefly are the incandescent and cathode-ray-tube displays.

The dc gas discharge and liquid crystal displays are difficult to drive; their operating conditions are explored in somewhat greater detail than those for the more easily driven displays. An attempt has also been made to give the practicing engineer a feel for the important approaches to specifying the user interface.

Acknowledgments: Years of interaction with internal and external Texas Instruments customers have led to the viewpoints expressed in this book; the continuing help of these customers is acknowledged. The optoelectronics marketing department in the persons of Michael S. Bender and Carroll E. Smith supplied advice and references.

The continuing support of Carroll E. Nelson, John W. Vance, and Harold L. Woody is also appreciated. The typing was carefully done by Margaret Grigg, who was of great assistance. Finally, any errors are solely the author's.

E. G. Bylander

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Introduction to Electronic Displays

1.1 INTRODUCTION

The digital era has led to the obsolescence of the analog art. Historical analog applications of sensing and control are now digital. While much design emphasis is concentrated on the microprocessor [the arithmetic logic unit (ALU) or central processor unit (CPU)], its peripheral input and output requirements must be met as well. That is, digital means must be provided to communicate with the digital system sensors or analog sensors; and analog-to-digital (A–D) converters and digital or alphanumeric displays, printers, and terminals are required. To aid digital design, the selection criteria and application techniques for the electronic display portion of the digital system are described here.

Chapter 1 describes display choices, typical applications, and fonts. Chapter 2 is concerned with general display principles and applications, and Chapter 3 deals with viewing or human factors considerations. Subsequent chapters take up the major display classes individually.

1.2 SURVEY OF DISPLAY TYPES

Displays may be classified by several schemes. A display family tree (Fig. 1.1) classifies displays by segmental, or dot, matrix; by number and size of characters; and by emissive or passive mechanism. A number of display types will not be further discussed, including image, analog segmental, and electromechanical. Popular emissive mechanisms used for displays are summarized in Table 1.1; absorptive processes are grouped in Table 1.2. From these classifications one can obtain, for example, the cathode-ray-tube character generator combination for alphanumeric applications, the flat-panel gas discharge display, the liquid crystal display (LCD) and the visible light-emitting diode (VLED) displays, and the dot-matrix plasma panel display. In Table 1.3 some commercial realizations of such displays are listed. These displays will be considered later in individual chapters. Additionally, a good display bibliography is given as a reference.[4]

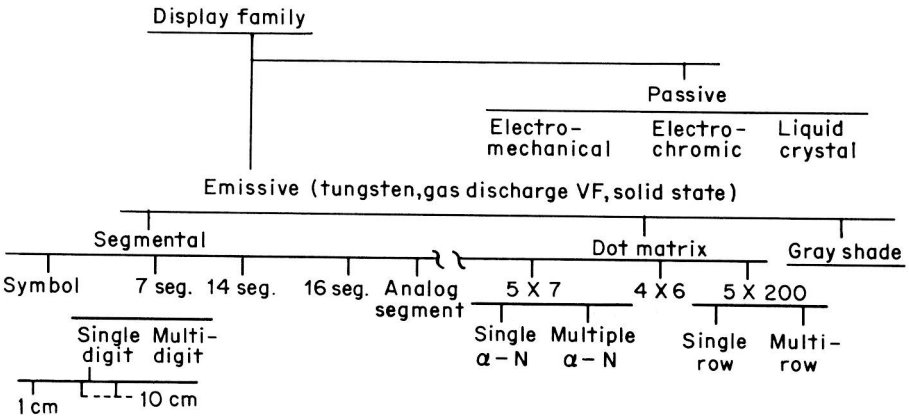


Fig. 1.1. The display family. The emissive family is listed by font. Displays with gray shade capability and analog segment displays are not considered here. The passive displays have the same font choice as the emissive ones; they are listed by type. Electromechanical displays are not considered further.

Table 1.1. Light-Emitting Processes Available for Emissive Displays

Effect	Realization
Cathodoluminescence (CL)	VF
	CRT
Photoluminescence (PL)	Colored gas discharge (UV-excited phosphor)
	Fluorescent lamp based displays
Electroluminescence (EL)	VLED
	EL-excited, polycrystalline phosphor
Plasma decay	Gas discharge panel
	Nixie* tube
	Ac gas discharge
Blackbody radiation	Tungsten filament projection

*Nixie is a registered trademark of the Burroughs Corp.

Table 1.2. Electrically Controllable Absorption Processes for Display

Process	Display realization
Dye or pigment (electrochromeric)	Electromechanical
	Electrochromic
Electropolarization	Nematic liquid crystal
	Field-effect liquid crystal
Electrophoretic	

Table 1.3. Some Commercial Displays

	Fonts	Mechanism
Gas discharge:		
Dot matrix	Alphanumeric	Dc plasma
	5 × 200 Multirow	Ac plasma*,†
Planar flat panel	Multiple 7 segment plus decimal and symbol	Dc plasma
Raised cathode	Single 7 segment and decimal	Dc plasma
	½ digit	
	3 or 4 digit stackable	
Cathodoluminescent:		
Vacuum fluorescent	Multidigit 7 segment and decimal	Hot filament in vacuum tube with phosphor-coated segments
	5 × 7, 20 character	
	14 segment, multicharacter	
CRT	Selected character shape	Electron gun in vacuum with phosphor screen
	Character generation	
Electroluminescent:		
Red GaAsP	Single- and multidigit 7-segment	Monolithic or individual diode arrays
	Alpanumeric	
Red "Super Brite," orange, and yellow GaAsP and green GaP	Single digit 7-segment	Individual diodes and light pipe
	Alphanumeric	Individual 35-diode arrays
Passive displays:		
Liquid crystal	7-segment watch	Nematic or field effect
	7-segment calculator	
Blackbody or incandescent	Individual	Hot filament(s) in vacuum
	7 segment and decimal	

*Ac plasma not generally available.
†Photoluminescent when phosphor is added for color other than neon orange.

1.3 APPLICATIONS

In general, electronic displays will be used first to replace electromechanical displays in areas such as games, registers, automobile instrument panels, gas pump dials, TV dials, adding machines, cash registers, and counters. Second, they will be used to replace analog displays in applications such as D'Arsonval meters, clock and watch dials, scale dials, and temperature scales. Finally, they will be used for communications between digital machines and their operators, such as alphanumeric displays on prompting computers and "dialed" number verification on telephones. Table 1.4 lists some consumer and business applications and representative displays; a similar listing for other economic sectors is given in Table 1.5.

1.4 THE ELECTRONIC DISPLAY SYMBOLS

A minimum number of dots or segments (bars) are required to represent a given symbol set. In addition to typical patterns (Fig. 1.2) there are 10 segments for symmetrical 1s and plus signs, and 4 × 7 and 4 × 6 dot matrices for lower-cost dot

Table 1.4. Business and Consumer Display Applications

Application	Typical display
Appliance applications (washer, dryer, range, ovens, air conditioners)	
Time/time cycle Temperature/cycle	4 digit/Gas discharge, VLED
Commerce (adding machines, cash registers, scales)	
Totalizer/status Weight/unit cost	Multidigit with status indicator/VF, gas discharge, Tungsten filament
Automotive (clock, radio, instruments)	
Engine: Water temperature/oil pressure/vacuum Peripheral: Time/frequency of radio, CB channel Navigation: Gasoline remaining/mpg Distance remaining, distance to/travel distance Diagnostic readouts	Gas discharge, VF, VLED
Personal consumer	
Watch Calculator TV, CB, radio	4 digit plus colon; VLED, LCD 8 to 12 digit; VLED, LCD, VF 2 to 4 digit; VLED, LCD, CRT

matrix displays. Sometimes a second small horizontal crossbar is supplied, which increases the 7-segment character to 8. Some typical character sets are shown in Fig. 1.2. Figure 1.3 shows some additional symbol sets available with the 7-segment display that may be useful as status indicators. Figure 1.4 shows a symbol set generated with 7-bit logic and a 5 × 7 display.

Table 1.5. Industrial, Medical, and Military Display Applications

	Typical display
Medical:	
Digital thermometer	VLED
Sphygmomanometer, pulse rate, patient monitors	—
Industrial electronics:	
Meters, positioners	VLED, tungsten filament
Test equipment, gages	Gas discharge
Military:	
Situation indicators	Traditional
Miscellaneous:	
Computer peripherals	VLED
ALU status	VLED

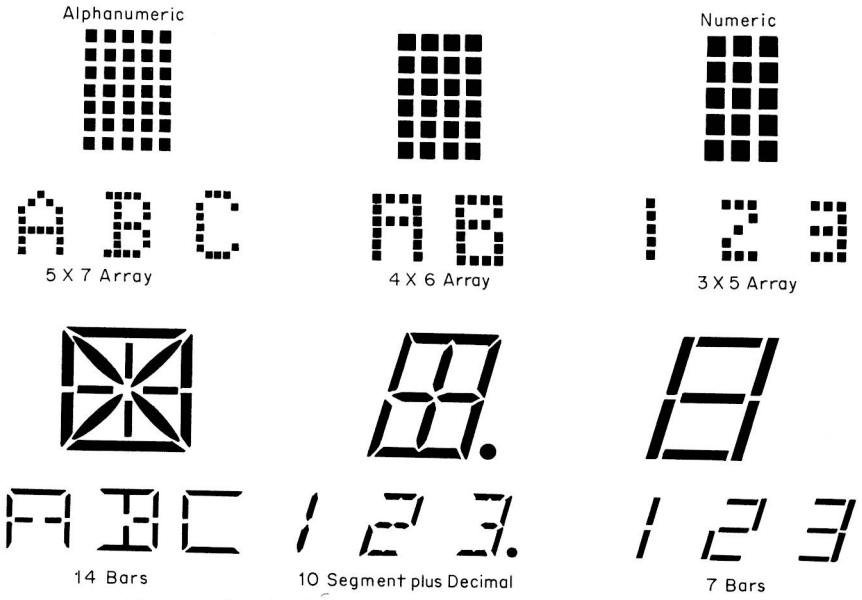


Fig. 1.2. Symbolic array geometries. *(After Ref. 1, in part.)*

Manufacturers may select characteristic fonts. Examples include square corner, round corner, and mitered corner (Fig. 1.5). Also shown in the figure is the standard segment identification method: segments are lettered from *a* through *g* and sometimes *h*. Characters may be upright or slanted; a ten-degree slant is common. Use of the slant has the advantage of allowing the decimal point to fit in the character space.

An additional font requirement is the aspect ratio, which is the ratio of height to width of either the character or the segment. For example, segment aspect ratios might be 5:1 for a vacuum fluorescent display and would result from phosphor deposition requirements. For a gas discharge display the segment aspect might be 10:1 or 20:1, where the display would be expected to appear crisper or sharper because of the higher aspect ratio. Character aspect ratios are in the neighborhood of 2:1; values smaller than 2:1 are often used in conjunction with a small aspect ratio or "fat" segments, and values larger than this are useful where multidigit space is at a premium.

Display size depends critically on the display technology (Fig. 1.6); various technologies are restricted to particular size ranges. Commonly used sizes are

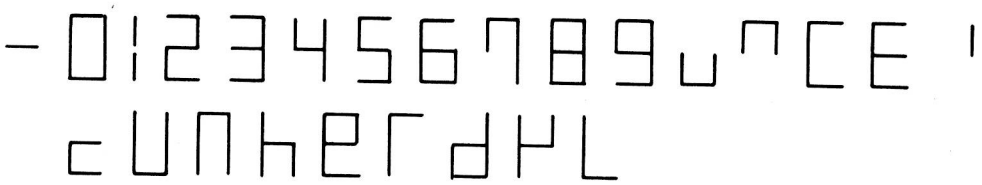
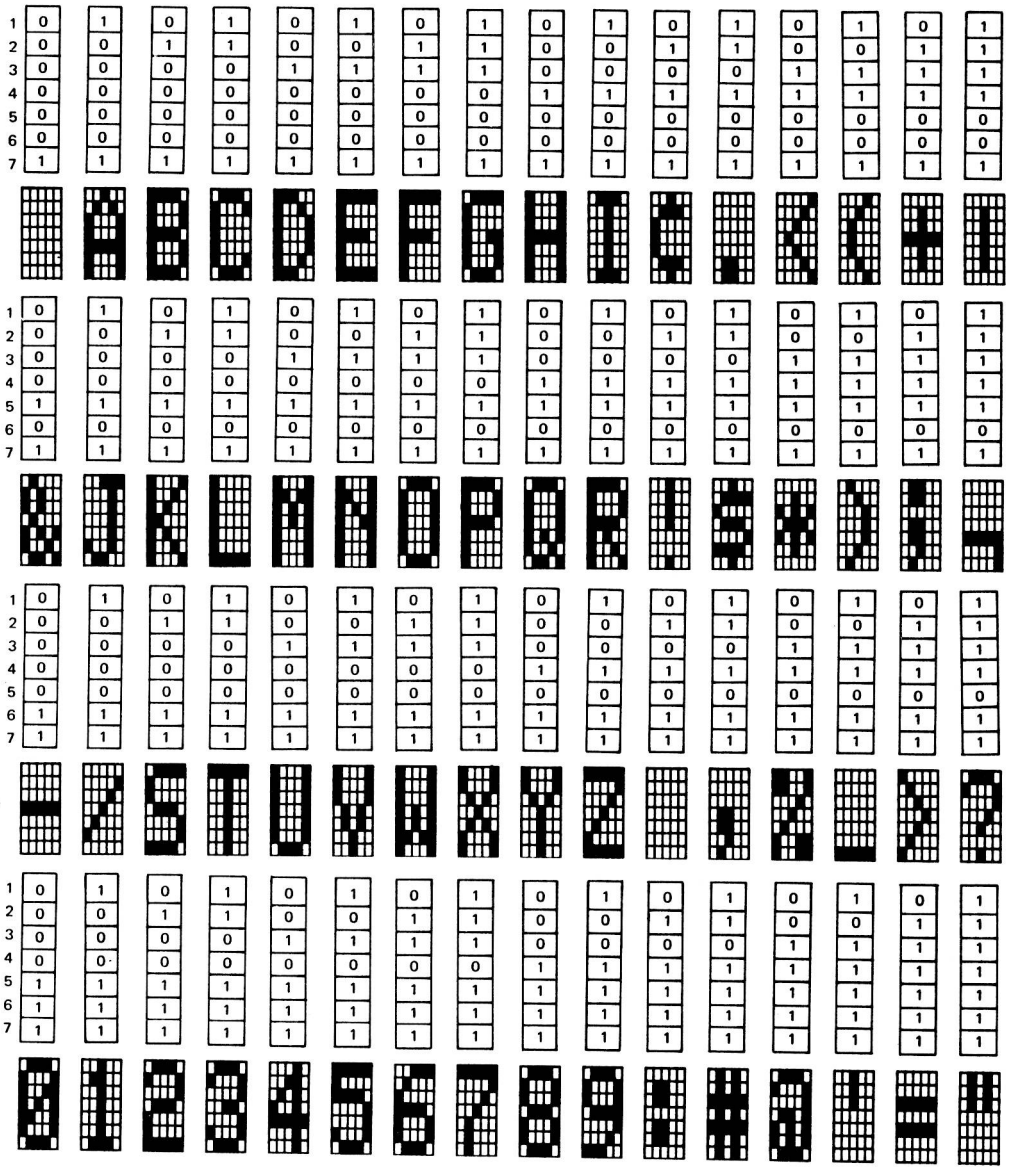


Fig. 1.3. Some symbols available from the 7-segment character.



positive logic: 1 = H = 2 V to 5.5 V
0 = L = 0 V to 0.8 V

Fig. 1.4. 5 × 7 alphanumeric display type TIL305. Resultant displays using TMS4179JC or TMS4179NC chips with EBDIC coded inputs. *(From Ref. 2.)*

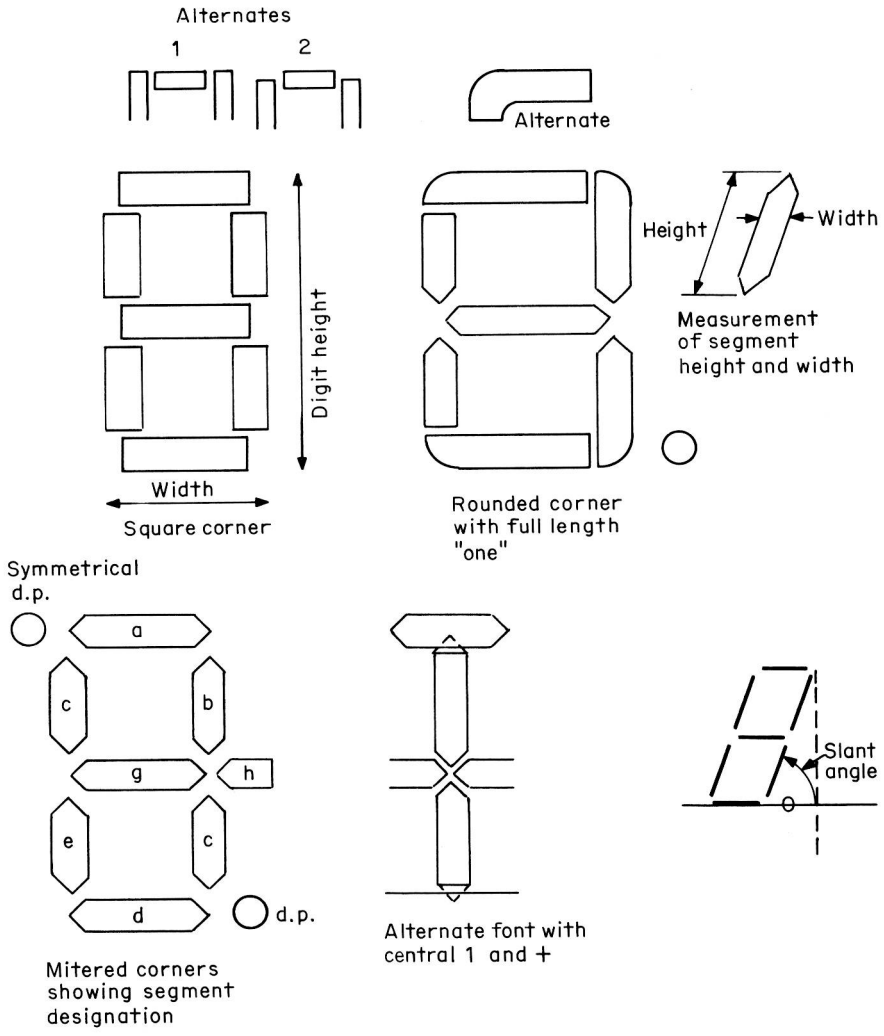


Fig. 1.5. Various fonts for seven-segment displays.

[centimeters (inches)]: 0.076(0.03), 0.15(0.06), 0.38(0.15), 0.46(0.18), 0.51(0.2), 0.76(0.3), 1.0(0.4), 1.22(0.5), 2.0(0.8), 2.54(1.0), 5.1(2.0), and 10.2(4.0).

A display may be limited to a single character, or it may use stackable combinations of single characters to form a larger number of characters. Stacking is common practice for VLEDs and raised cathode gas discharge displays. Other technologies with large fixed-cost packages find it more economical to fabricate large-character-number displays as a single package. Also, quantity applications invite the same procedure for the VLED technology. Some multidigit forms are 3½ and 4½ digit (where the ½ digit is a ±1). Other styles are 8 digit(d), 9d, 10d, 11d, 12d, 13d, and 14d, where the last odd-numbered character is generally used as a status flag. Other special symbols are shown in Fig. 1.7. Figure 1.8 shows a clock display. Morning or

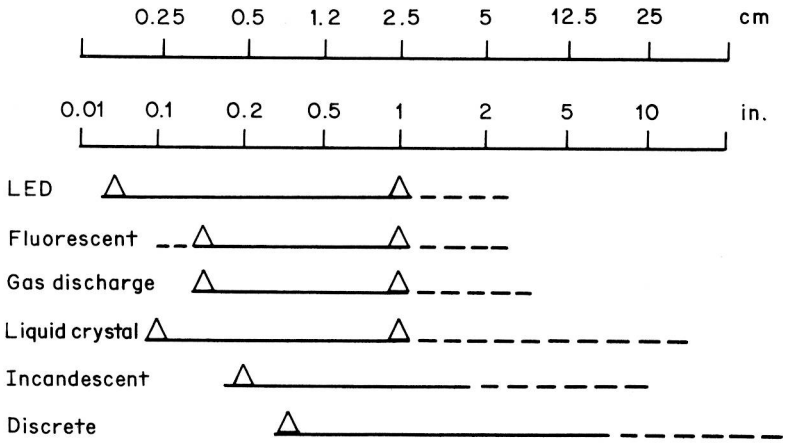


Fig. 1.6. Comparison of character sizes by display. *(After Ref. 3.)*

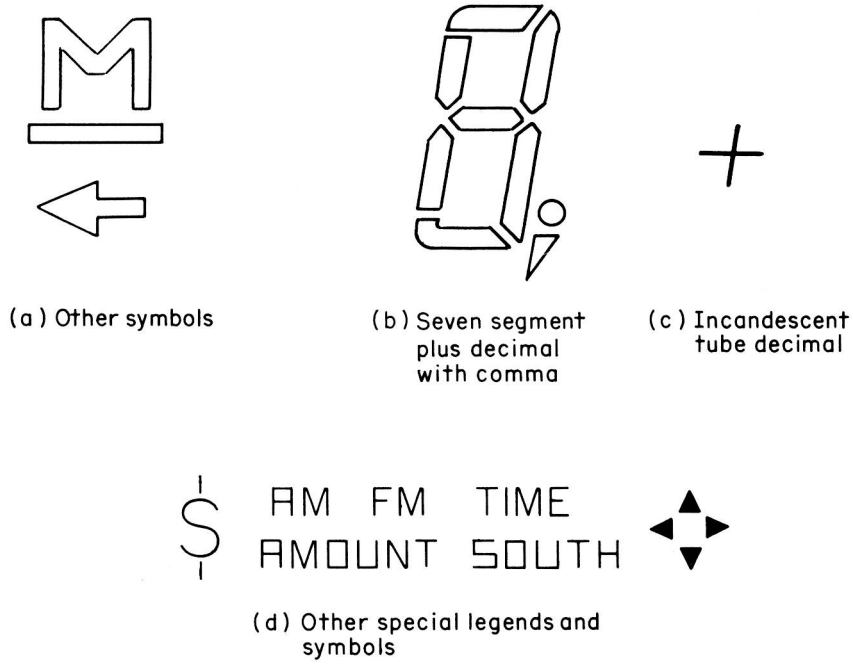


Fig. 1.7. Special display symbols.