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|---|---|
| Document in this file | Electronics World, February 1969, Article about digital readouts |
| Display devices in this document | different devices |

# Electronics World

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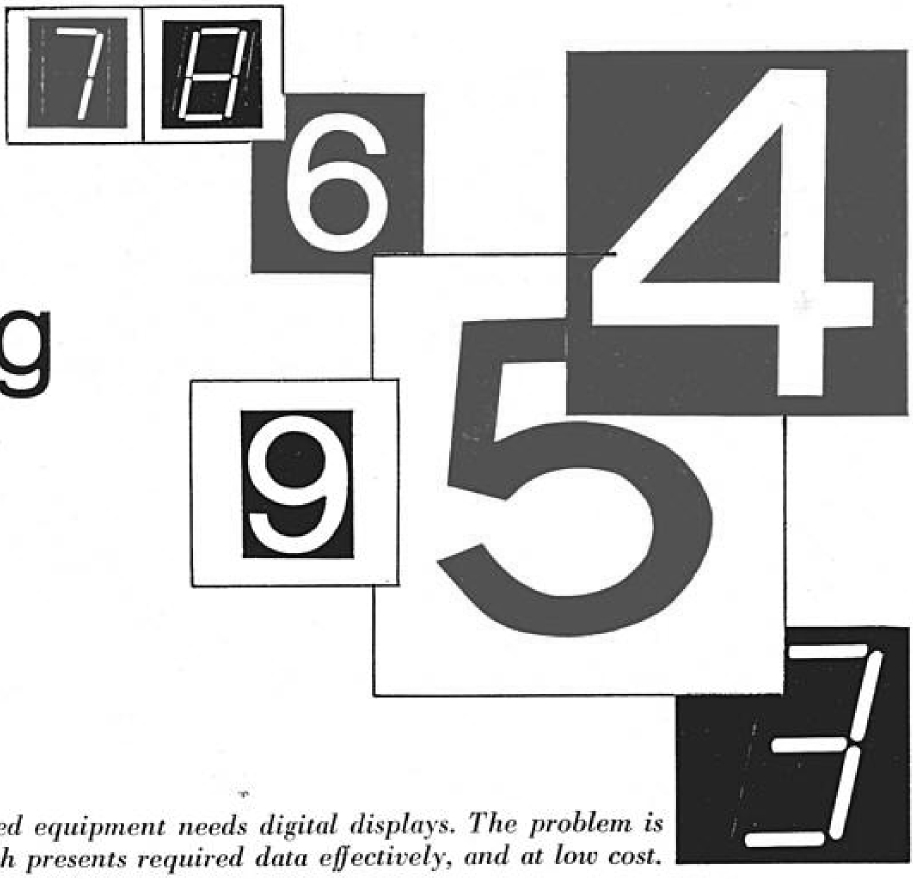
60 CENTS

NEW CONCEPTS IN HI-FI RECEIVER DESIGN
HOW TO ALIGN TV CHROMA CIRCUITS
NEW SOLID-STATE DIODES FOR MICROWAVE
GEOMAGNETIC OBSERVATORIES

## DIGITAL READOUTS



# Choosing a Digital Display

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*Almost all new automated equipment needs digital displays. The problem is to choose a display which presents required data effectively, and at low cost.*

THE development of automation techniques has brought about important changes in the field of data presentation. A few years ago, it was usually cheaper and easier to obtain data from the deflection of a pointer along a calibrated scale, or by other analog methods, and then have an operator translate the data into digital notation for record and computation. But within the past few years, great masses of already processed information have been readily available in digital form, so the trend has been to digital readout and, recently, more and more to electronic types.

Digital readout, the direct display of characters or coded equivalents, offers the following advantages as compared to analog readout (where input is measured in terms of some parameter such as angular displacement, as in a meter), and digital printout (where input is converted to printed characters, as in a teletypewriter).

*Immediate comprehensibility.* An in-line digital display requires no translation. It presents information conventionally whereas meter readings frequently involve verniers, multiple scales, logarithmic calibration, and other complications.

*Dependability.* Digital displays reduce chances of mechanical and human error. Electromechanical readouts sometimes malfunction, but electronic digital displays, on the whole, are as accurate as the information fed to them. They require no instrument calibration.

*Speed.* Many digital readouts register data as fast as the human eye can follow (about two counts per second). Furthermore, the characters snap into position, to prevent blurring. This is an obvious advantage over a rapidly fluctuating meter, or a slow printout device. And if faster presentation rates are necessary, there are readouts available which operate in milliseconds and microseconds, although these must be "stopped" by photography or special timing pulses.

*Flexibility.* Many digital readouts can be used as either counters or indicators, depending upon external switching arrangements. In addition to digits (0 to 9), some readouts display letters of the alphabet, full messages, and special characters. Many incorporate dynamic alarms, and some accept, with slight modifications, a variety of inputs—pulses, parallel or serial binary codes, or straight "decimal" selection-switching.

Usually meters handle only one or two closely related units. But with proper switching, the same digital readouts can register widely differing units and symbols, for example, time, temperature, and baseball scores.

*Appearance.* Many of these devices are quite handsome,

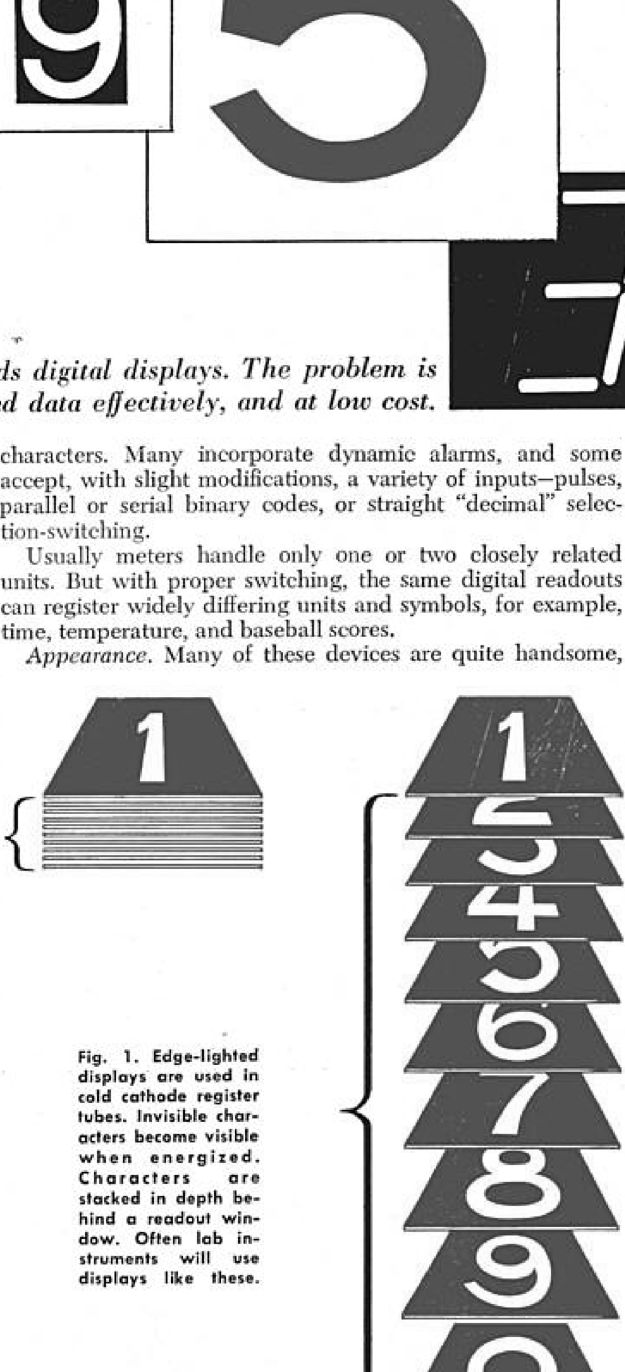


Fig. 1. Edge-lighted displays are used in cold cathode register tubes. Invisible characters become visible when energized. Characters are stacked in depth behind a readout window. Often lab instruments will use displays like these.

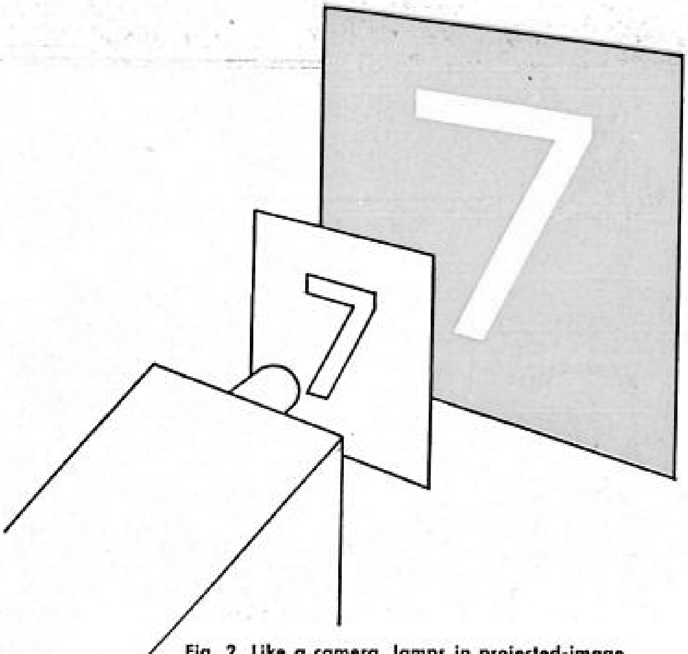



Fig. 2. Like a camera, lamps in projected-image displays are employed to shine digits on screens.

with the strong, clean lines of good modern architecture. They dress up a product—an important factor in today's competitive market.

Table 1 shows most of the basic types of digital displays now available. Of course, it cannot and does not include and compare every make and model but is a guide to help the user eliminate basic types which obviously don't apply to his particular application. It will help him choose those readouts which can display his message most efficiently. It also shows the chief techniques by which digital characters are formed.

### Where to Start

When considering digital readouts first determine what must be read, where and in what form it is available, and who must read it.

If, for example, an engineer is working with binary-logic circuits in some form of digital computation, he needs a readout that accepts a binary input. Here, the problem is relatively easy because many readouts work well with binary inputs.

However, some otherwise suitable readouts may require signal amplification. Others are primarily numeric and some are fully alphanumeric. Some have memories of their own while others don't. Some handle straight 8-4-2-1 binary; while others will work with a variety of binary four-line and six-line codes. (The act of changing from one format to the other may involve nothing more than substituting one particular standard logic card for another in the system.)

The selection is large, but some types may be ruled out immediately. For example, if the output is a decimal stepping relay or other form of automatic selection switching, one does not have to consider binary translating devices; but, if a digital readout is required and an acceptable input is not available, the first concern must be the translation equipment. To read an analog error signal, an analog-to-digital (A-D) converter is necessary. A-D converters have digital readouts built in.

There are times when the cost of auxiliary equipment and its weight, bulk, and power requirements preclude the use of a digital display. In this case, a meter may have to do.

The next most important matter of concern is the audience. Will the information be read by one man within a foot or two of the display or by several people scattered at various distances and at various angles to the display face? Will it be read in a brightly lighted room or in semidarkness? By a programmer accustomed to binary notation? A machinist? A clerk? A crowd?

Of course the answer narrows the field of available displays.

### The Final Choice

When the primary questions are answered, it is possible to make an intelligent evaluation of competing models that have not been eliminated in the preliminary screening.

A simple but effective method is to score the possible selections on a qualitative point scale—based on manufacturer's data and using the following criteria:

- Readability (consider the individual module and of a row of these modules racked together. Place special emphasis on the spacing between characters. See Fig. 3.)
- Life
- Reliability (When external conversion and switching are involved, reliability of the readout device alone means very little, unless of course, it is compared with a like unit in the same system. Do not rate the reliability of a device, such as a lamp, with that of an instrument which translates data from binary to decimal.)
- Size (unit volume *vs* character height)
- Power requirements
- Weight
- Cost

Score each readout type on these parameters, adding any special considerations of your own and tally the individual columns to make your choice.

So much for the precepts. We can now discuss the basic types of digital readout in fairly specific terms without making unfair comparisons.

The simplest digital display is a lamp array which is nothing more than an arrangement of lamps and sockets, either exposed or concealed by a screen of translucent numerals. But in a lamp array, the message is out of line and difficult to read, thus several means of compensation

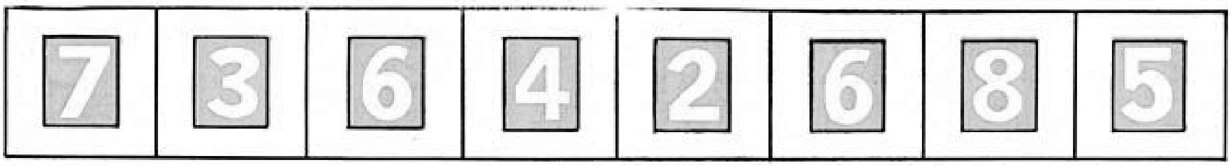
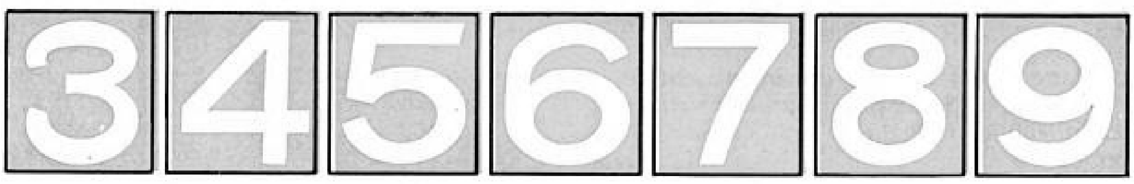



Fig. 3. When you have a choice, don't space characters too far apart . . . or crowd them too close together.



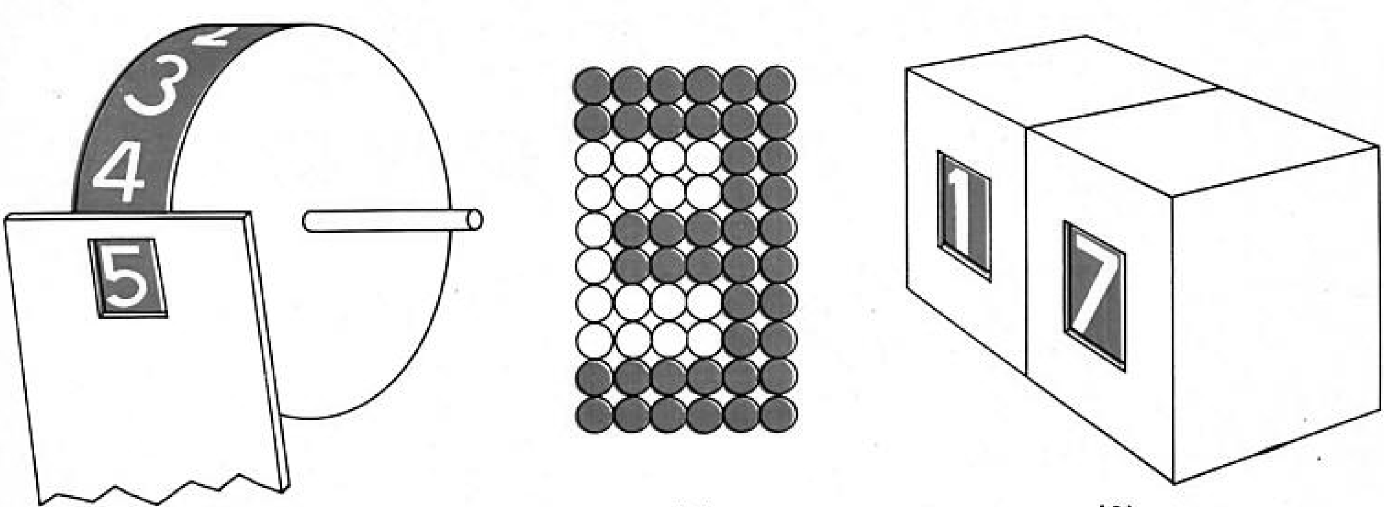



Fig. 4. (A) Some counters use numerals mounted on wheels or belts, but only one number can be seen at a time. (B) A matrix forms characters by lighting appropriate lamps. (C) Windows should be avoided because they increase spacing while limiting the viewing angle.

had to be devised to bring the indicators into line. The individual out-of-line lamps are no longer read directly. The array is concealed and the lamps are used to illuminate the characters of an in-line readout module. This improves readability without adding expensive circuitry.

*Edge-lighted displays* (Fig. 1) contain miniature lamps arrayed so that each one can edge-light one of a series of engraved, transparent acrylic plates arranged in depth behind the read-out window. When a lamp is switched on, the character or message engraved in its plate glows through the other plates, which remain unlighted.

These displays are most suitable for laboratory bench instruments, small one-man consoles, vending machines, and other applications where the display is viewed head-on and close up. The volumetric index (we'll elaborate on this term later in the article) improves with message capacity and character size. But there are disadvantages; interference and parallax reduces the viewing angle.

*Projected-image displays* (Fig. 2) are modules which have lamps arrayed at the rear of a light-tight housing behind a transparent integer outlined on an opaque condensing lens. When a lamp is lit, the character in front of it is projected onto a viewing screen. The major advantages of this display are its versatility and wide viewing angle (up to 150 degrees). The disadvantages include limited brightness, cost, and an increasing volumetric index (ratio of unit volume to character height—wasted space) with increasing character size. Brightness, a function of lamp wattage, is limited by the sensitivity of the module to heat. Character images can be distorted by a slight warping of the plastic lenses or by irregularities in the bulb filament.

Although the following readouts use different approaches and operate on different principles, they are all electronic and offer alternative solutions to the problems of converting electromechanical and electronic signals or pulses directly into readable characters.

*Low-voltage vacuum-tube* digital displays, a new development by *Tung-Sol*, are sold under the tradename of Digi-Vac S/G. The display is segmented, having seven bars of phosphorescent material. Each bar becomes an anode when supplied with signal voltage of 10 to 40 V d.c. The cathodes are two almost invisible wires strung between the segments and the viewer. Cathode temperature is extremely low because only 45 mA at 1.6 V a.c. or d.c. are needed to energize them. Its advantages are low cost, high intensity, long life, high speed, low power consumption, and a single-plane display which ensures a wide viewing angle and precludes the possibility of read-through or interference of the in-depth displays. An inexpensive metal-oxide field-effect transistor (MOSFET) integrated-circuit package is available to supply decoding, storage, and counting functions.

*Register tubes*, or Nixies, have stacked elements in the form of metallic numerals with a common anode. They can be adapted for binary coded decimal input by isolating the odd cathodes from the even ones and using two anodes. Plug-in binary translators are also available. The Nixie's major advantages are long life, high speed, low power consumption. However its principal disadvantage is electronic complexity. The cathode current must be kept within tight limits. There is an additional problem; if the ion current is excessive the "off" cathodes will glow and produce background haze, but if ion current is insufficient, there will be only partial presentation.

When negative voltage is applied to a selected character, it glows like the cathode of a simple gas-discharge tube. Usually only the selected numeral is visible in the viewing area because the visual glow discharge is larger than its metallic source.

*Matrices* (Fig. 4B) consist of neon lamps in optical reflectors banked on a solid mosaic pattern behind a viewing screen. The reflectors are for intensity and focus, not for compensation of an out-of-line array. A solid-state miniature integral counter and decoder network translates sequential pulses directly into digital presentations by turning on lamps to form images. Matrix indicators are capable of accepting binary or straight decimal inputs. They have no counter networks thus their major advantages are high speed and long life. Disadvantages are high cost (if used as indicator alone) and a coarse appearance. Matrices using solid-state light sources in place of lamps are also available.

*Electroluminescent panels* require extensive external translation circuitry, power packs, and other equipment. Activated by a.c., the lamps are flat-plate luminous capacitors built up on either glass-base sheets or on metal. One typical readout matrix has a glass-base sheet upon which a thin, transparent conductive film has been deposited in electrically isolated geometric segments. The segments form a pattern from which the numerals or letters of the alphabet are composed. Sandwiched between this base sheet and a metallic black electrode is a layer of an electroluminescent phosphor imbedded in a ceramic dielectric. Since light is emitted only when there is capacitive coupling, each segment can be lighted individually when excited by a high-frequency or high-voltage signal applied across its electrodes. The advantages of this display are generally cool operation with low current drawn and few sudden failures. The thin, solid-state lamps dim slowly with age because they contain

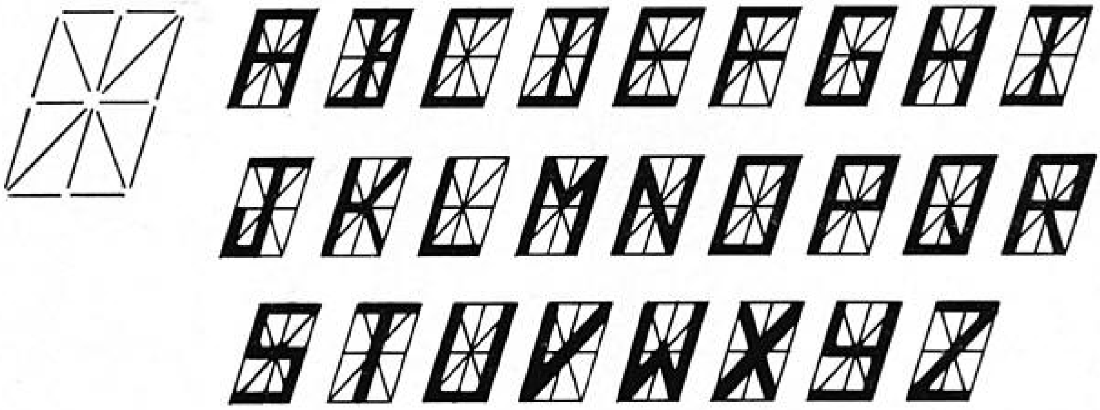


Fig. 5. Sixteen segments form letters and up to 65,000 symbols. Seven segments will form all numerals and 13 letters.

no vacuum, gas, or filaments. The disadvantages are low light level, the need for a high voltage, high-frequency input (240 to 460 V at 400 Hz), and sensitivity to heat, humidity, and surge voltages.

*Incandescent bar segments* (Fig. 5) are modular displays consisting of either seven or 16 segments on a viewing block, each lighted by a separate incandescent lamp. Various combinations of the seven display all numerals from 0 through 9 and part of the alphabet. The 16-segment type displays all numerals and the complete alphabet. In fact, up to 65,000 combinations are available. This is far beyond the usual demand for various symbols. Each segment, with its own lamp source, is a separate unit. The seven units (or 16) together with an extra one which provides a decimal point, are bonded to the molded viewing block to form a single display. Light is piped from each bulb to the surface of the viewing block through some sort of light pipe or chamber. Some advanced models provide for high contrast between lighted and unlighted segments by means of a 0.025-in thick filter molecularly bonded to the surface of the viewing block. The filter reduces surface glare, but more importantly, it virtually eliminates external lighting of the unlighted segments caused by light striking the surface, traveling down the light pipe, and reflecting back.

The incandescent bar-segment displays are extremely reliable because only the lamps are subject to wear and, in a properly designed unit, the lamps may last more than a 100,000 hours. Maintenance varies with the supplier: some provide for direct lamp replacement, some for lamp bank (sealed unit), and others recommend replacing the whole display. The advantages are light weight, maximum readability (because intensity can be varied as the environment requires), and long life. Disadvantage is high initial cost.

*High-voltage vacuum tubes* are a recent development that

Table 1. Characteristics of popular digital displays.

| | Edge-Lighted | Projected Image | Low-Voltage Vacuum Tube | Register Tubes | Incandescent Bar Segments |
|---|---|---|---|---|---|
| Type of Information Displayed | Numeric or messages | Alphanumeric | Numeric and some alpha | Numeric | 7 bar numeric and some alpha.; 16-bar complete alpha./numeric |
| Capacity per Unit | 1-3 messages, numerals 0-9, and decimal | Up to 24 displays | 23 | 10 characters | 7 bar (23 characters) 16 bar (unlimited) |
| Character Formation | Solid, can be color lighted | Solid, usually luminous on dark or colored field | Segmented fluorescent glow | Solid neon glow | Back-lighted segment |
| Signal Input | 6-28 V a.c./d.c. depending on bulb | 6-28 V a.c./d.c. depending on bulb | 10-40 V d.c. | 170-300 V d.c. | 4.0-5.0 V a.c./d.c. |
| Included Angle (°) | 30-40 | 120-150 | 150 | 90-120 | 150 |
| Additional Power Requirement | None | None | 1.6 V a.c./d.c. at 45 mA | None | None |
| Symbol Height (in) | ½-1 | ⅝-3¾ | 0.57 | 0.303-2.25 | ⅛-½ |
| Volumetric Efficiency Index | 3.3-9.6 | 11.7-5 | 2.0 | 1.1-2.0 | 1.5-2.0 |
| Response or Count Rate | Depends on switching | Depends on switching | 15-20 m-sec | As low as 10 μsec | 15 msec max. |
| Maintenance | Lamp replacement | Lamp replacement | None | None | Lamp, lamp bank, or module replacement, depending on supplier |
| Life (hrs) | Lamp life 1000 | Lamp life 500-3000 | 10,000 (est.) | To 100,000 | 40,000 (avg) |
| Cost Range ($) | 11 (one message)-45 | 13-35 | 2 (approx.) | 3.95 | 18 up |

combine the rear-projection type display with a cathode-ray tube. A 10-gun CRT projects any one of the 10 numerals through a grid onto a fluorescent screen. Unlike a true CRT display, the gun doesn't scan; each gun is focused through a grid which forms a particular numeral. The advantages are relatively low cost, brightness, single-plane for good readability, and light weight. The major disadvantage is the need for a high-voltage (2.5 kV d.c.) power supply, although the over-all power consumption is low.

*Solid-state bar segments* are very similar to the incandescent bar segments except the light source is a gallium-arsenide phosphide instead of an incandescent lamp. This means that life is practically infinite (failures are indicated by a gradual dimming of the light source) but, in terms of today's development, price is high and brightness is limited compared to the incandescent type.

*Cathode-ray tubes* are usually custom-engineered for highly specialized applications. And most are military. Several products can be considered stock items, such as shaped-beam cathode-ray tubes, and character generators that can write decimal information on conventional tubes. Complete systems provide alphanumeric information positioned on detailed maps, catalogue formats and page prints.

Digital character formation on this level is generally accomplished either by extending an electron beam through individual "character cutters" pierced in a stencil-like mesh or by generating X and Y deflection voltages that cause the cathode-ray to trace out a fixed character matrix. On command, selected segments are intensified to produce the required character.

## Volumetric Efficiency Index

The volumetric efficiency index is used in this article as a means of relating size efficiency. It is the ratio of unit volume to character height (Fig 6) and is applied only to modular units since it would be unfair (and unrealistic) to compare readouts of different types (particularly those that have decoding and memory capabilities with those that do not.). If a unit requires external equipment to provide equivalent performance, the gross volume of the external equipment should be included. The unit with the lower number is, of course, the more efficient. ▲

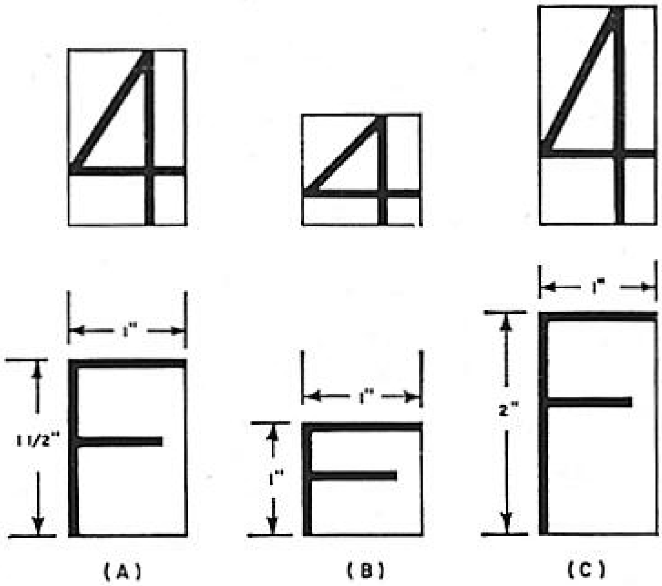



Fig. 6. Vary character size according to the spacing available. (A) is normal; (B) is for wide spacing; and (C) is for close spacing.

| Matrices | Electroluminescent Panels | High-Voltage Vacuum Tube | Solid-State Bar Segments | Cathode-Ray Tubes |
|---|---|---|---|---|
| Alphanumeric & symbols | Numeric & some alpha.; alphanumeric | Numeric; symbols; messages | 7-bar numeric & some alpha.; 16-bar complete alphanumeric | Alphanumeric, with special symbols, superimposed pictorial data, etc. |
| Unlimited | 0-9, +—, 16 letters<br>0-9, +—, 26 letters | 10 | 7 bar (21 characters)<br>16 bar (unlimited) | Full alphabet, all numerals, many special symbols |
| Dot formation | Segmented glow | Fluorescent glow | Back-lighted segment | Solid or imperceptibly segmented trace |
| Depends on light source | Complex selective switching | 6.0 V d.c. | 2-50 mA | Computer codes |
| To 90 | Wide | 90 | 150 | Varies |
| Varies from 1 V d.c. for solid state to 110 V a.c. for lamps | 240/460 V a.c. at 60-1000 Hz | 2.5 kV d.c., 1.1 V at 0.2 A | None | Varies |
| Wide range | ⅜-2¾ | ⅝ | 0.32 | Variable at will |
| Wide range | 2.3-4.8 | 3.5 | 0.5 | Not applicable |
| Depends on switching & light source | msec | 20 msec | 1.0 μsec | μsec |
| Depends on light source | None | None | None | Periodic |
| Can be infinite, depending on light source | 3000 | 10,000 | Indefinite | Varies |
| 25 up | 15-50 | 14 | 50 up | 1400-1500 for character generator; 5000-100,000 for display console |