Recent Development in Large Screen Video Display Equipment Technology

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INTRODUCTION

Video display systems and equipment are rapidly becoming the primary source of information, communication and entertainment in today's ever sophisticated society.

The expanding use of this equipment demands increasingly comples capabilities and performance standards.. Video display equipment must now satisfy the needs of one viewer in the darkened living room, or ten-thousand viewers in brightest outdoor stadium.

Matsushita Electric Industrial Company and its communications equipment subsidary -- Matsushita Communications Industrial Company -- recognizes these needs, and have developed and manufactured an array of sophisticated color video display equipment to encompass all possible applications and conditions.

Viewing Conditions And Environment

Current television scanning standards are based on a vertical scan of 525 or 625 lines. Through the loss of resolution by the kell effect, the maximum vertical resolution of commercial television scanning standards is degraded to approximately 300 pixcels. Optimum area resolution capability requires each pixcel to have a unity aspect ratio. If the vertical-horizontal image aspect ratio is 3 to 4, the number of horizontal pixels should be 400.

Looking at Figure 1, in terms of normal 20/20 vision. This means that the human eye is capable of resolving 1 minute arc of solid angle provided that the contrast ratio is at its full excursion. In terms of television viewing, the eye is capable of resolving pixels at a 100 percent contrast ratio if the viewing distance is 6 times picture height.

If we also take into account the fact that the viewer should resolve picture detail of reducing contrast ratio with increasing pixel size, the optimum distance for television viewing should be approximately 4-to-6 times picture height as shown in Figure 2.

In Figures 3-to-5, we've diagrammed typical television viewing conditions in a variety of different situations normally encountered at home and in a small auditorium. The seating density of our auditorium is much like it is in this room-- the standard 24-inch column spacing and 32-inch row pitch which is used in most theaters, auditoriums, and airliner cabins.

Additionally, the diagonal image dimensions of a video display can vary by upwards of a thousand timex when it is used to satisfy viewing populations as diverse as 2 or 20,000. This relationship is illustrated by Figure 6. An equipment manufacturer must satisfy these needs while trying to maintain the aforementioned optimum viewing conditions.

As shown, the current generation of single CRT direct viewing display and three CRT projector units can essentially meet these requirements up to a population size of approximately 200. For larger needs, we have developed two types of large-scale display systems -- the color liquid crystal display and the tricolor incandescent lamp mosaic display trademarked Astrovision.

These two systems not only provide large images but they improve quality by overcoming the fundamental weakness of a CRT based display--the lower brightness that comes with increasing image size. In fact, as Figure 7 shown, new systems are bright enough to be suitable for outdoor daylight applications.

COLOR LIQUID CRYSTAL DISPLAY SYSTEM

This system was specifically developed to fill the gap between large projection CRT displays and the tricolor incandescent lamp mosaic display. The inherent nature of the system makes it suitable for applications requiring a vertical image dimension of between 50 and 300 inches.

The color liquid crystal display system is a back illuminated image transmission system meaning that image brightness is solely dependent on the level of back illumination. The system is suitable for both indoor and outdoor applications.

Figure 8 details the display panel, which consists of: (A) and illuminator; (B) a liquid crystal panel; (C) light dispersant color filters; and (D) LCD driver circuitry.

Liquid Crystal Light Valve

The liquid crystal panel (B) acts as a valve controlling the amount of light travelling from the illuminator to the color filters. As shown in Figure 9, at an applied potential of 12-volts, the gate host panel has a maximum transmission efficienty of 20-percent. The light transmission level drops virtually to zero with zero applied potential, thus giving the system an inherent contrast ratio of approximately 70 to 1.

LCD light output is coupled to the light dispersion capability of the color transmission filters. The band pass characteristics of the filters are designed to match the NTSC chromaticity diagram. The light output capability of the three color sources are shown in Figure 10.

A high image contrast ratio is maintained by treating the front surfact of each color filter to reduce the effect of incidental light.

Illuminator

The back illuminator for this system required the development of a special high-quality flourescent lamp with a panchromatic light output. As Figure 11 shows, the spectrum energy distribution of these lamps consists of three high output lines located at 450, 540 and 620 nanometers.

Overall, the system is also energy efficient. Both the illuminator and the light valve are extremely well designed to give the display an overall power efficiency of one kilowatt power input for every square meter of image size (55-inch diagonal).

And color quality is uncompromised by high efficiency. The system's color reproduction capability, as shown in Figure 12, is essentially equal to an NTSC CRT display.

Wide Viewing Angle

The light dispersion characteristics of the color filter, the final stage of the display system, are responsible for the wide viewing angle capability as characterized in Figure 13.

The diagram shows the deviation angle from the true center axis of the display panel for 50-percent brightness reduction. As shown, the viewing zone extends plus and minus 60-degrees horizontally, 55-percent below the axis, and 20-percent above.

Color Matrix And Scan Progression

Individual primary color sources, red green and blue, are all vertically oriented, and those vertical elements are staggered in columns that are displaced by half an element size as shown in Figure 14. Each complete pixel consists of a green cell from one column and the red and blue cells from the adjacent column. Because of this displacement, the timing of incoming primary color video signals must be pre-adjusted, on both the horizontal and vertical scan directions in order to properly synchronize the images so they will correspond to the original.

Video To Light Transfer Characteristics

The LCD illuminator's transfer of an electrical input into a light output is different from a cathode ray tube transfer. As Figure 15 shows, the gamma of an LCD display is less than unity, as compared to 2.2 or more for a CRT display. In addition, the time constant, especially rise time, is highly dependent on applied voltage, which affects the system's aperture response. Rise and fall time characteristics of LCD system are shown in Figure 16.

Because of these special input-output characteristics, conventional video sources must be modified with special signal processing circuitry -- including both gamma and aperture correction -- in order to properly interface with LCD equipment.

Summary

In summary, the salient features of the color liquid display system include:

- Brightness that is greater than is found on conventional, single CRT direct view equipment.
- A diagonal image of up to 500-inches.
- A contrast ratio exceeding 70-to-1.
- A 120-degree viewing angle.

In addition to all these features, the system's high fidelity color reproduction makes this advanced technology video display equipment perfect for any number of indoor or outdoor applications.

ASTROVISION LARGE SCREEN INCADESCENT LAMP MOSAIC DESIGN

The growing needs for large, primarly outd-or, television and information display systems has prompted Matsushita to develop a system known as "Astrovision." The trademarked system is a mosaic display based on incandescent lamps.

Display Screen

The heart of the system is the display screen, whcih consists of numerous groups of incandescent lamps. Each lamp group has one lamp from each of the primary colors -- red, green and blue. The lamps are arranged along the points of an equilateral triangle. Each triangle represents one pixel. The pixels are densely packed together to provide for the highest po-sible resolution, which is limited only by the area of each pixel and the overall size of the screen.

Because of varying screen size requirements, three different bulb sizes, and thus, pixel sizes are available. Figure 17 illustrates different bulb sizes and pixel configurations. By using three different pixel sizes, as Figure 18 shows, it's possible to tailor make a screen as small as 10-feet or as large as 60-feet in height.

Light Source

The use of incandescant lamps as the light sources for a color television or video display system presents special technical problems. Such systems demand fast reaction time and accurate color and gray scale renditions.

Incandescent lamps vary its color temperature and react slowly to varying electrical inputs. However, the use of alternate light sources, such as small cathode ray tubes or light-emitting diodes, will severely limit the total amount of light emmission, and thereby restrict the range of potential system applications.

Several characteristics are desirable for any video display light source:

(1) An extended operating life with little or no change in light output, hue, or color saturation purity.

(2) The availability of three primary colors whose chromaticity coordinates closely match NTSC color primary points.

(3) A gray scale whose range extends to at least 37dB without a shift in color temperature.

(4) A short time constant for real time display of television images.

(5) A low reflectivity to ambient light to increase contrast reproduction.

We've developed special light bulbs and driving techniques to meet the abovementioned requirements.

(1) Extended Life

Because the rate of tungsten filament evaporation is directly related to its absolute temperature by a power of 5.5, a special filament configuration and support structure was developed to lower filament temperature. The result is a bulb with a design life of 2,000 hours under maximum operating conditions. However, because the lamps are normally only driven to an average picture level (APL), the actual operating life is longer, in the neighborhood of several thousand hours.

(2) Three Primary Colors

The system's bulbs reproduce the three primary colors clearly because of a special exterior coating which filters out all unwanted ranges of the visual spectrum.

To maintain the purity of the red, blue and green colors over an extended period of time, the transmission characteristics of the coating must maintain a stable spectral or transmissional response. Special high-temperature, heat-resistant materials have been developed to keep the characteristics constant. Furthermore, Figure 19 shows that both the bulb's inner and outer surface, beyond the color filter, have been treated with a low reflectivity coating to reduce unwanted internal and external reflection. The spectral characteristics of the blue, red and green light sources are shown in Figure 20.

(3) Gray Scale

The bulb's light intensity is controlled by modulating the width of a constant amplitude 60 Hz pulse which is fed into the bulb. Based on the 6-bit word that's used to drive the pulse width modulator, the gray scale's reproduction resolution is one part in 64. Application of a constant amplitude pulse assures a constant color temperature from a light source, regardless of its intensity.

(4) Time Constant

Because ohmic filament resistance increases with rising temperature, an incandescent lamp has a longer rise than fall time, resulting in a reproduced image that's slightly integrated, or with a substantial loss of apeture response.

To compensate for this phenomenon, the variable width pulse applied to the bulb has been modified to have a differentiated leading edge.

(5) High Contrast Image Reproduction

In addition to the non-reflective coating on the inner and outer bulb surfaces, a further precaution has been taken to eliminate unwanted ambient light. As Figure 21 shows, a special shroud has been installed to direct unwanted radiation towards the rear of the display board.

Electronic System

The overall electronic system is shown in the block diagram labelled as Figure 22.

Input video is converted into a digital signal through an A-toD converter whose sampling frequency is determined by the number of pixels in the display screen. Normally, the number of pixels in the horizontal image line is tied to the sampling frequency by an integer relationship. Generally, the number of horizontal display image lines is smaller than the active number of horizontal lines per TV field. Scanning line interpolation is necessary to compensate for this non-integer relationship.

A unity relationship between the vertical scan rate and the bulb driver circuitry is maintained, or the display is reproduced at the television field rate.

In addition to time constant compensation, the driving circuitry for incandescent bulbs requires special gamma correctors, as shown in Figure 22. The driver input to light output characteristics are different for each primary color, because each color bulb must be driven to a different level of color temperature in order to achieve an optimum light output that's consistant with a desired bulb life expectancy. Gamma characteristics are shown in Figure 23.

The duration of the least significant bit of the 6-bit word for the pulse width modulators is 1/64th of the field period, resulting in a modulator output than can vary from 1/64th to continuous DC conditions during a field period.

Summary

The "Astrovision" Display System is unique in its capability to produce usable video images of extra ordinary dimensions under direct sunlight illumination. A contrast ratio of 10 to 1 can be achieved even under sunlight illumination as high as 5,000 foot candles.

Conclusions

The last and perhaps the most important link between the electronics world and human society is the image display devices and systems.

Information, data and entertainment materials, either transmitted and received, or retrieved from storage media must be displayed in a visible form to be useful.

Recent market introductions of large image size equipment described in this paper is the results of our recognition of the above mentioned facts by Matsushita Electric.

Acknowledgements

A. Takada and T. Ohashi of Matsushita Communication Industrial Co., Ltd. and Y. Wakahata of Matsushita Electroic Components, Ltd. have made significant contributions to the development of both large screen Liquid Crystal Display System and the Astrovision.

Visual Acuity

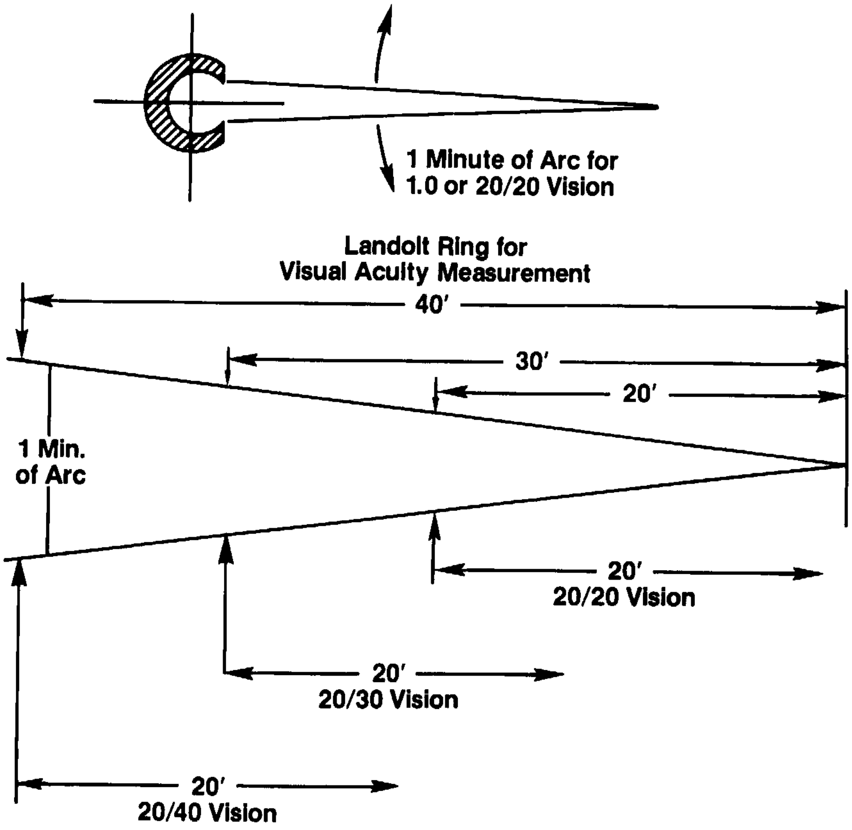
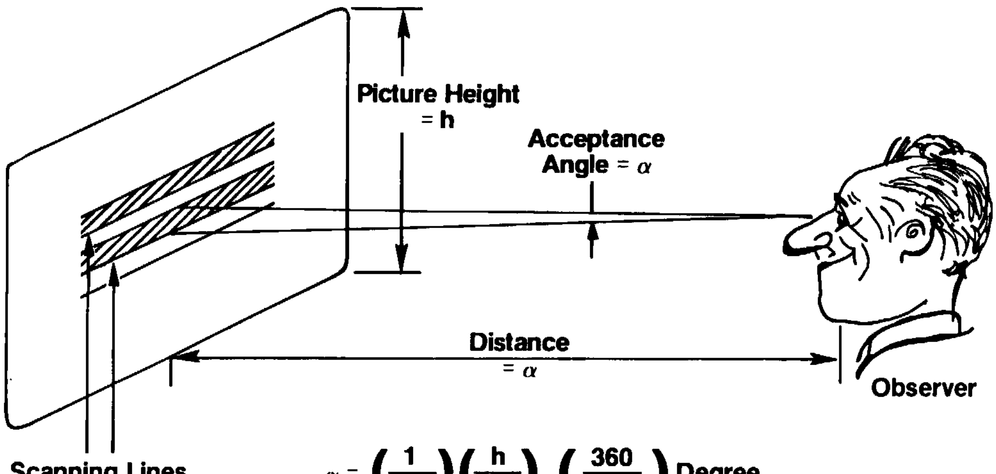


Fig. 1. Visual Acuity.



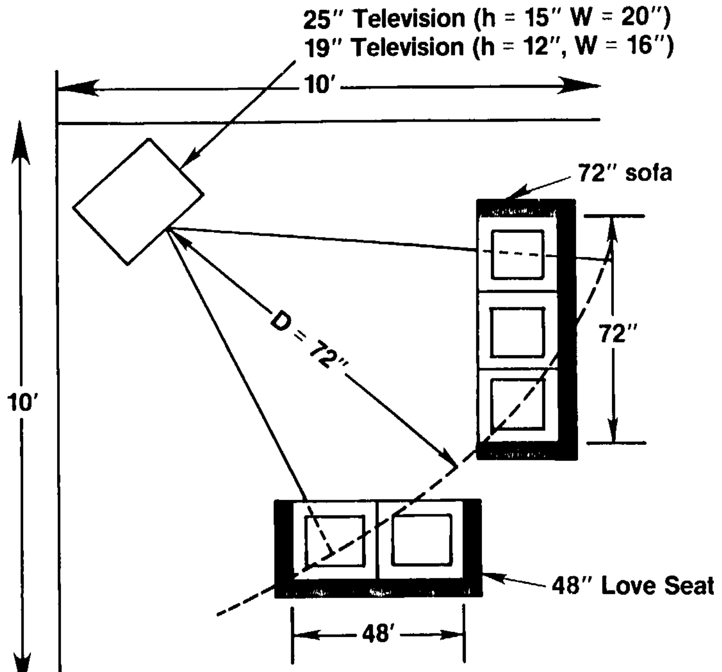
$$\alpha = \left(\frac{1}{525}\right)\left(\frac{h}{\alpha}\right)\left(\frac{360}{2\pi}\right) \text{Degree}$$

Television Viewing Conditions

Distance/Pix Height	α
2	.054° ≈ 3.3′
4	.027° ≈ 1.6′
6	.018° = 1.1′

Fig. 2.

Television Viewing in a Typical Living Room



	19" TV	25" TV
D	6 h	5 h
N	5	5~7

Fig. 3. Television Viewing in a Typical Living Room.

Personal TV Viewing (Kitchen)

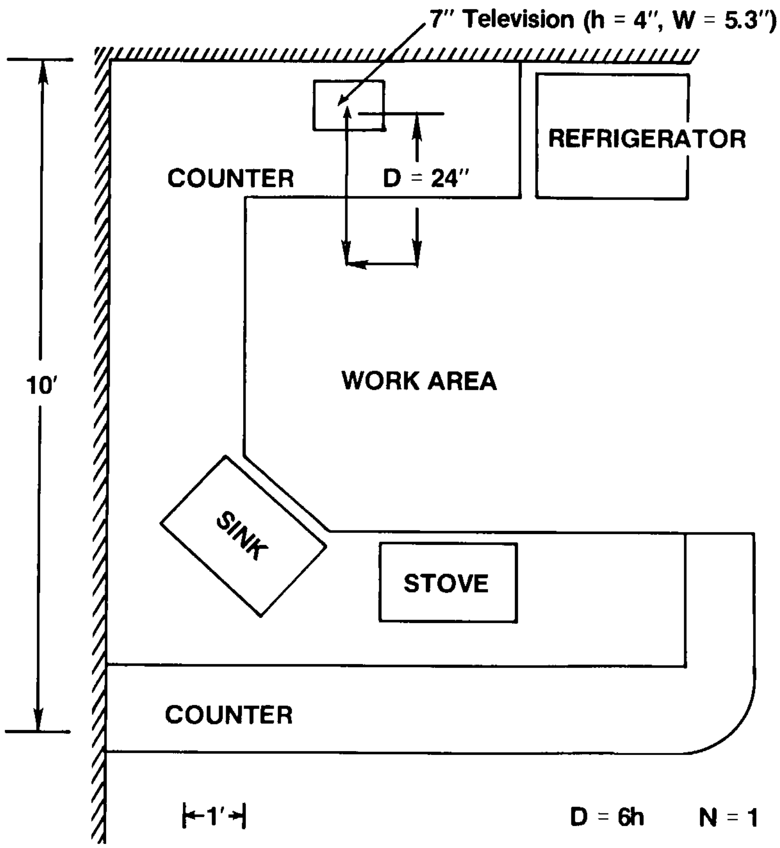


Fig. 4. Personal TV Viewing (Kitchen).

Small Auditorium TV Viewing Arrangement

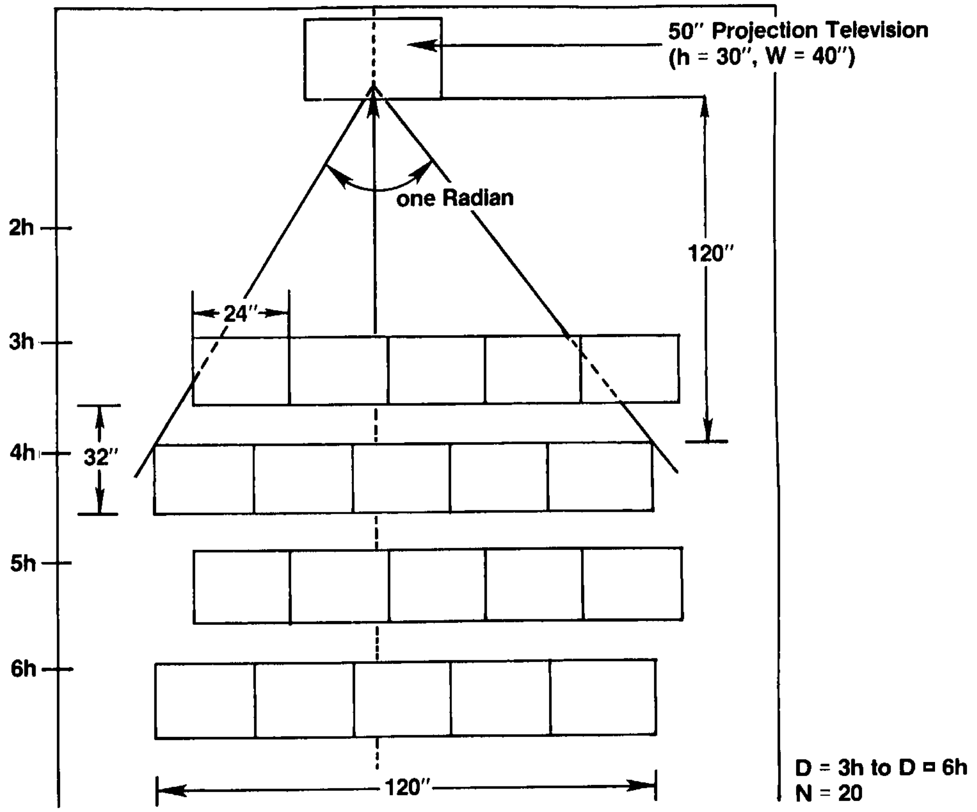


Fig. 5. Small Auditorium TV Viewing Arrangement.

Image Size vs Number of Viewers

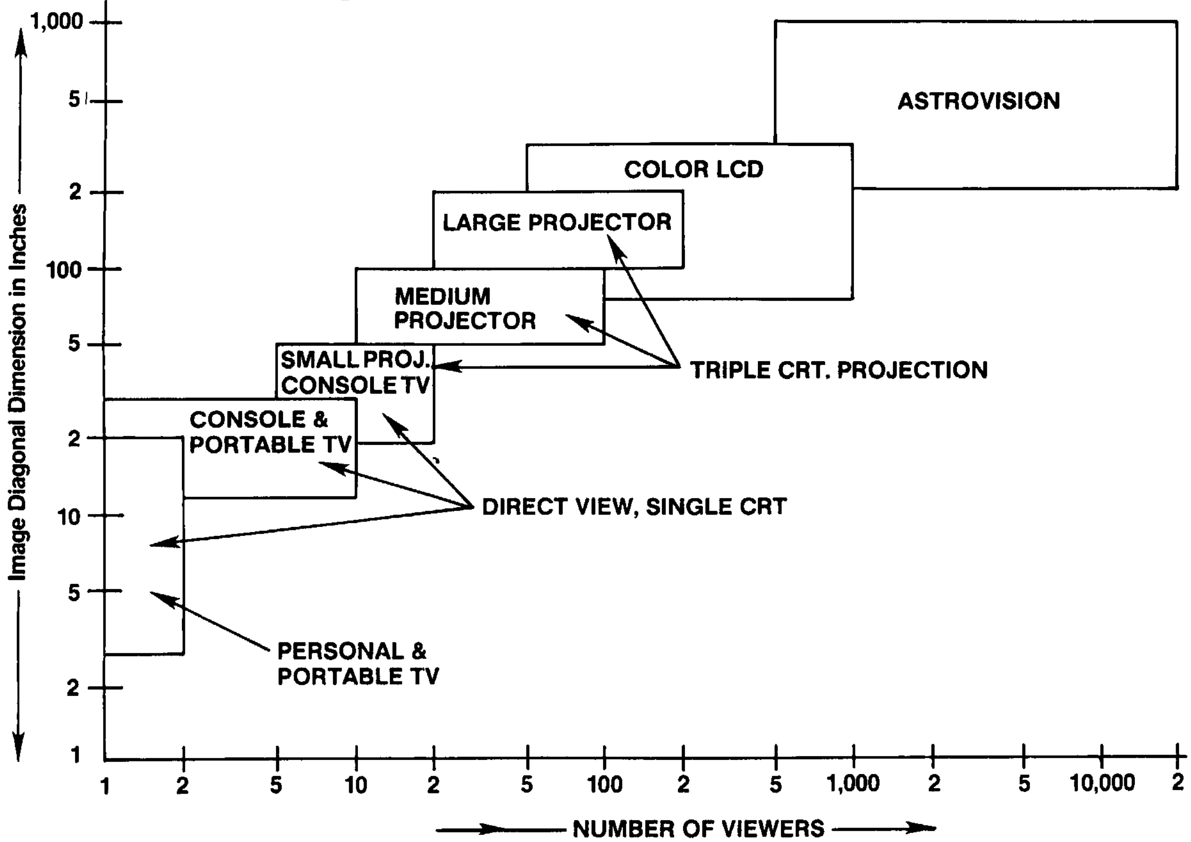


Fig. 6. Image Size vs Number of Viewers.

Applications of Various Video Display Systems

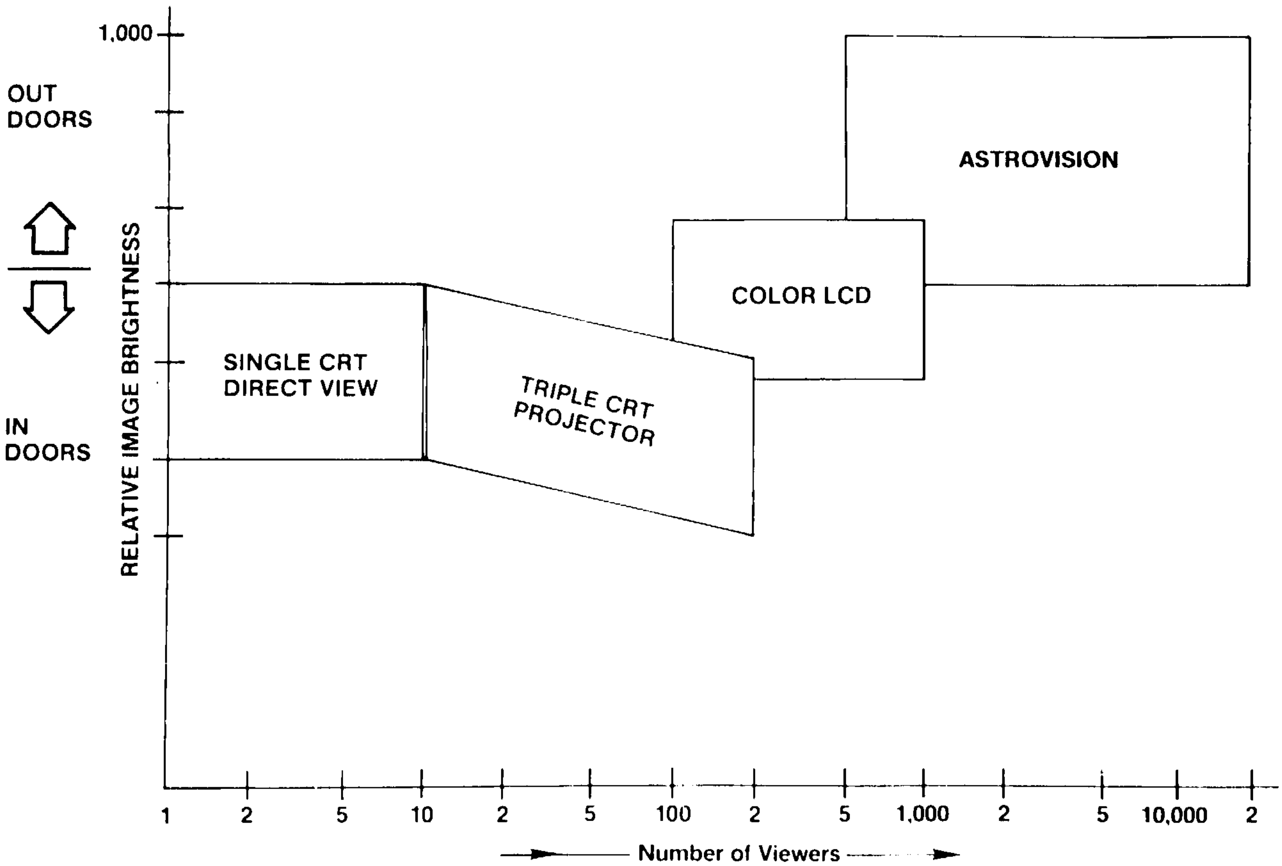


Fig. 7. Applications of Various Video Display Systems.

Color LCD Display System

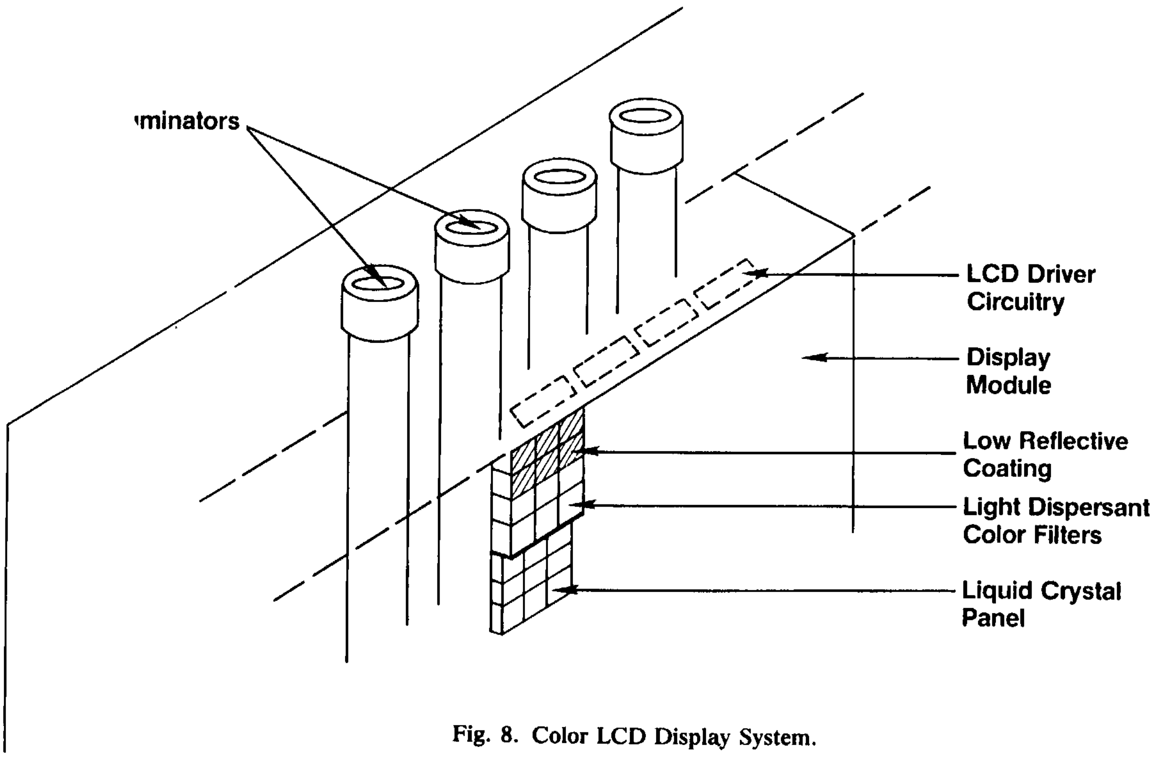


Fig. 8. Color LCD Display System.

LCD Panel Light transmission Characteristics

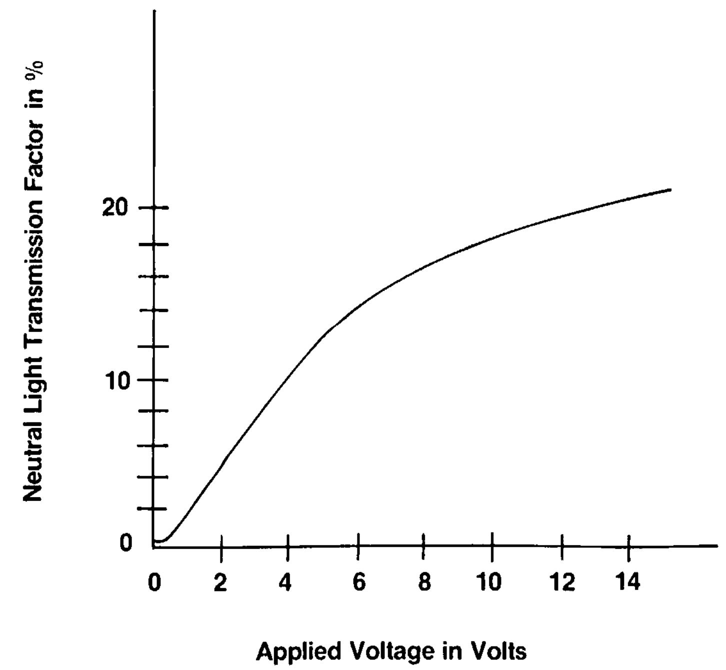


Fig. 9. LCD Panel Light Transmission Characteristics.

Display System Transfer Characteristics

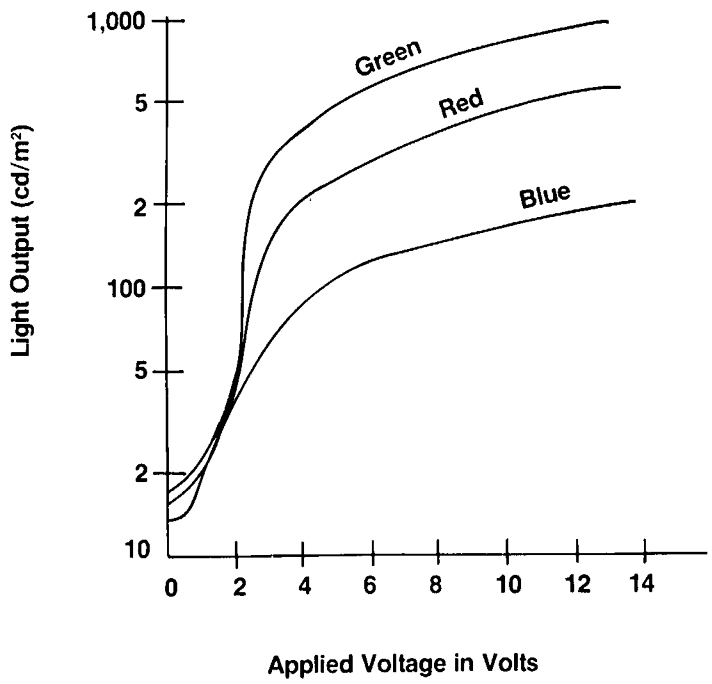


Fig. 10. Display System Transfer Characteristics.

Illuminator Spectrum Energy Distribution

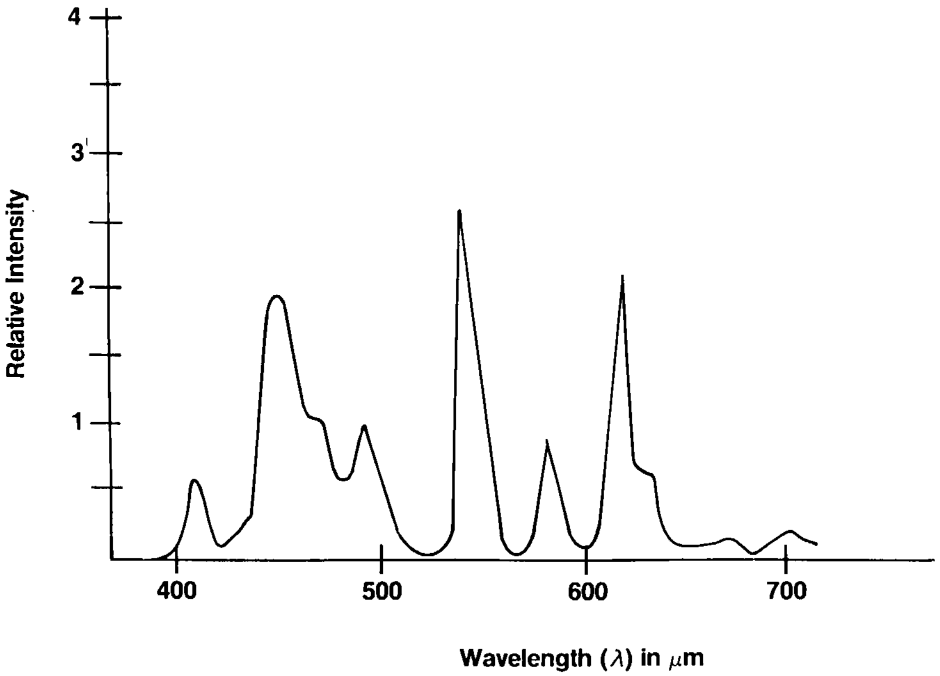


Fig. 11. Illuminator Spectrum Energy Distribution.

Color Reproduction Zone, LCD Display

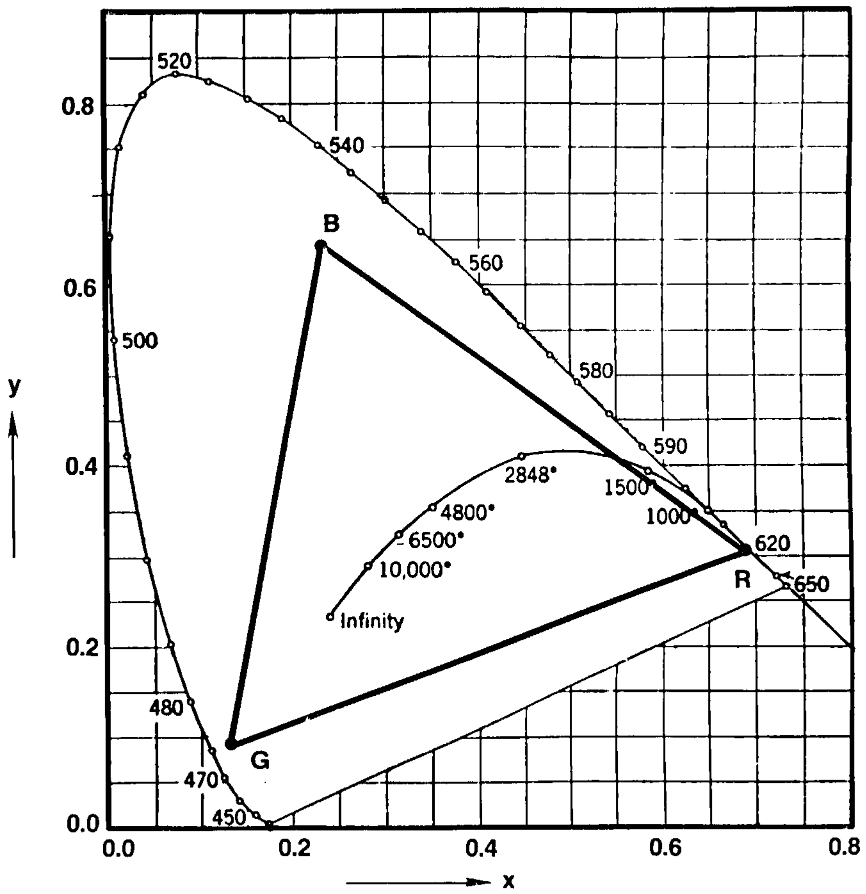


Fig. 12. Color Reproduction Zone, LCD Display.

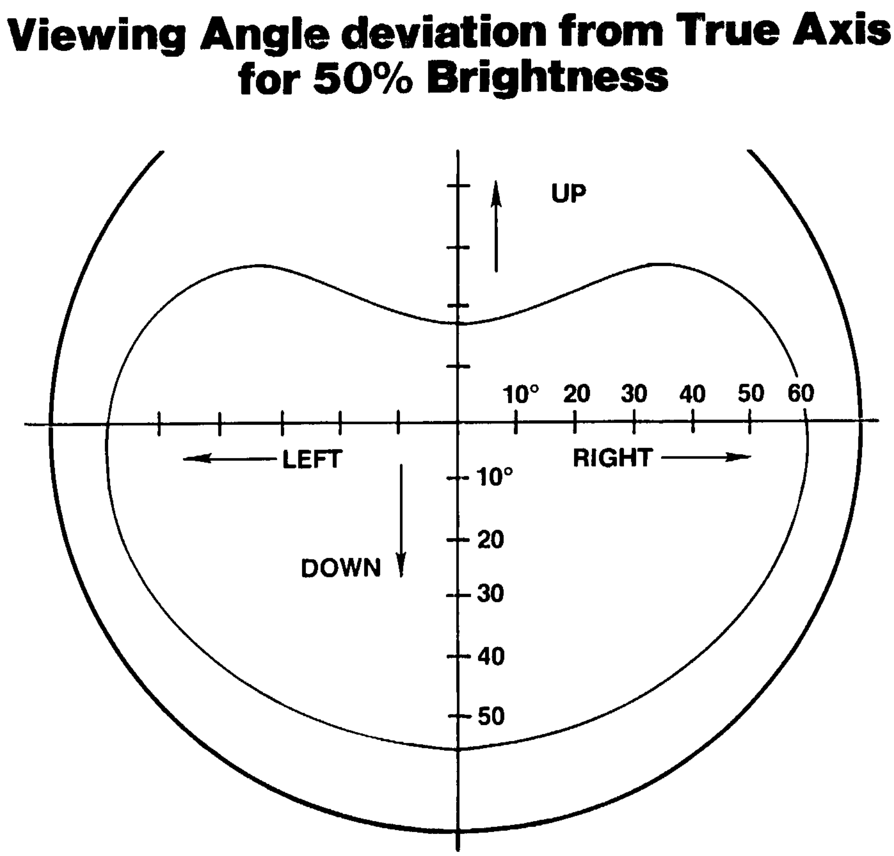


Fig. 13. Viewing Angle Deviation from True Axis for 50% Brightness.

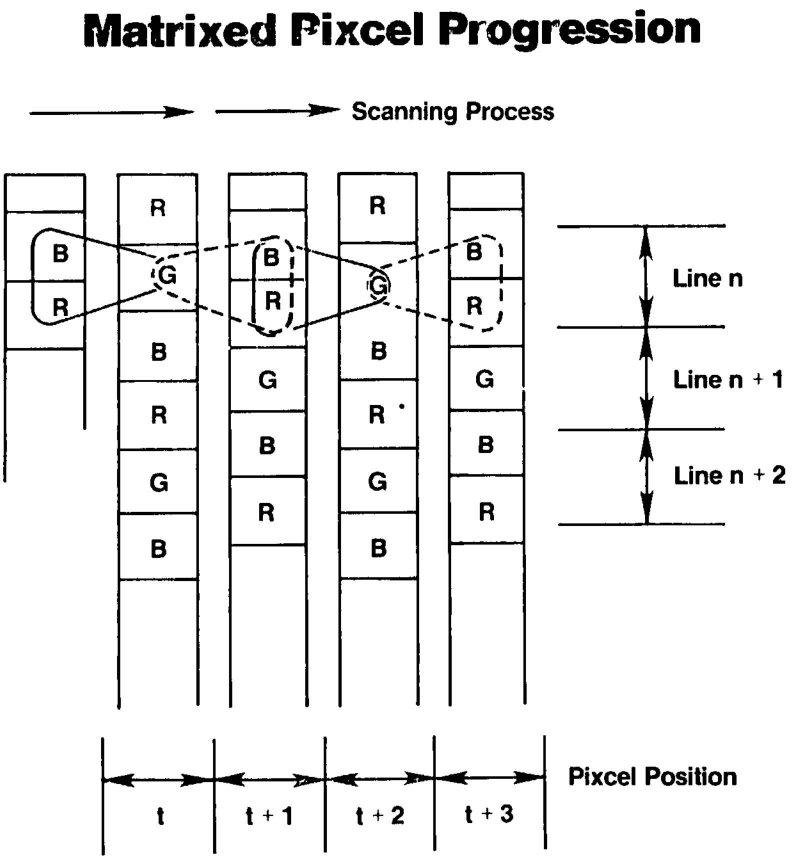


Fig. 14. Matrixed Pixel Progression.

Gamma Characteristics

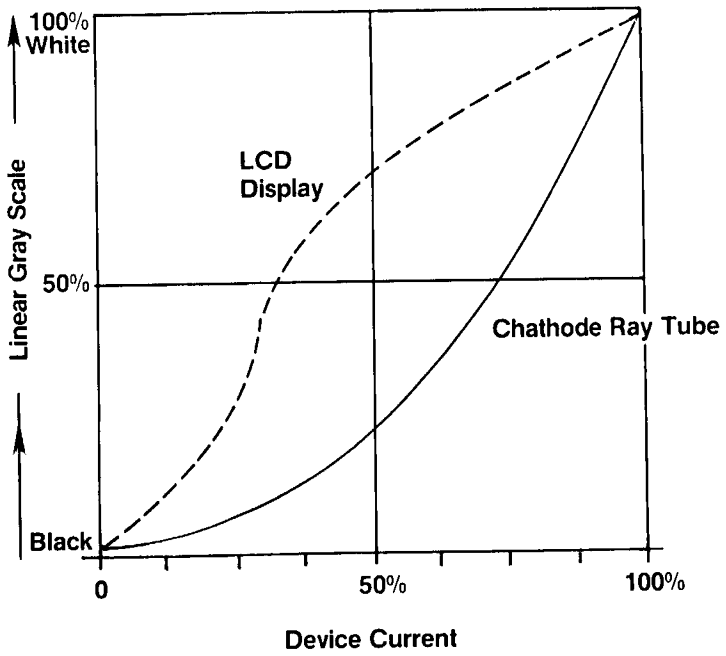


Fig. 15. Gamma Characteristics.

LCD Time Constant

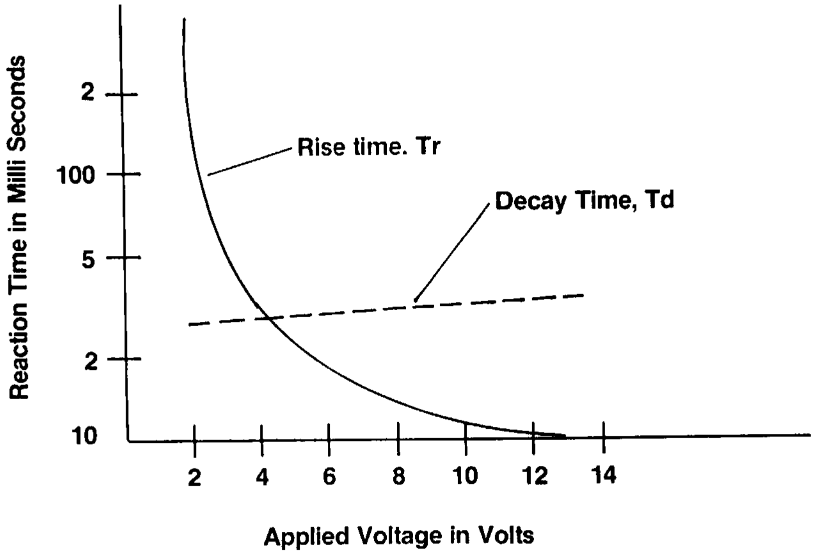


Fig. 16. LCD Time Constant.

Bulb Size and Configurations

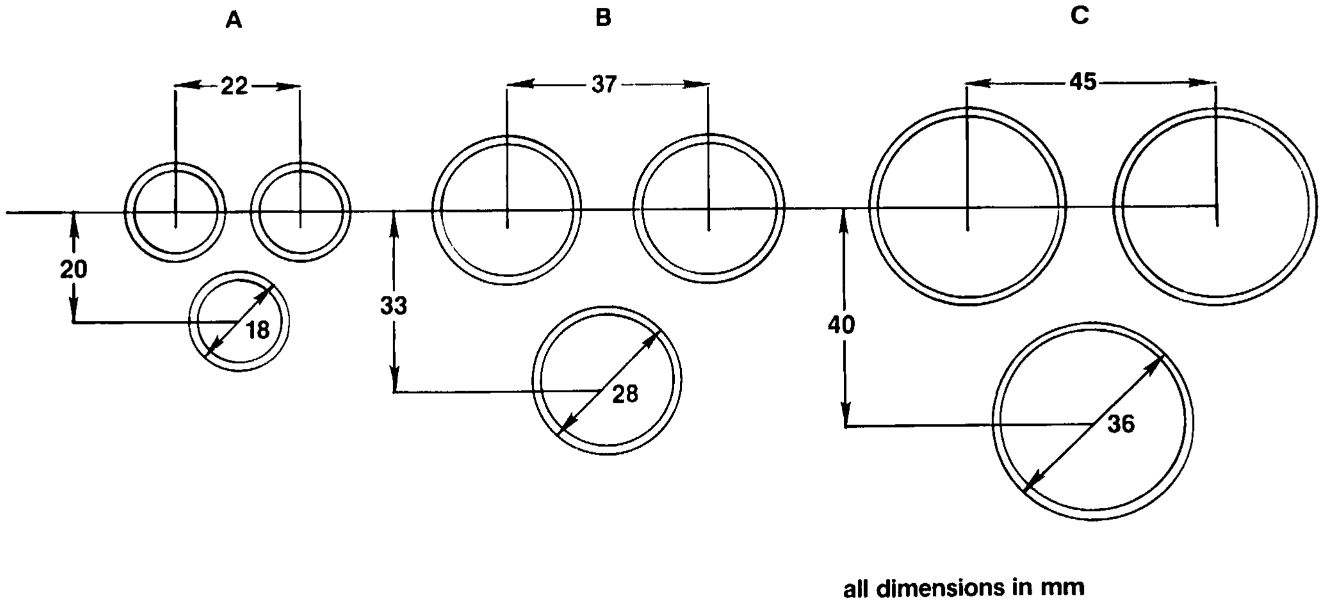


Fig. 17. Bulb Size and Configurations.

Astrovision Configurations

Bulb Diameter	18 mm	28 mm	36mm
Image Dimensions Height (feet) Width (feet) Area (feet)	 10~30 13~40 130~1200	 17~51 23~70 390~3600	 20~60 27~80 540~4800
Pixel Density number/(feet)^2	41	25	17
Viewing Distance (feet)	> 130	> 230	> 300

Fig. 18. Astrovision Configurations.

Primary Color Light Source

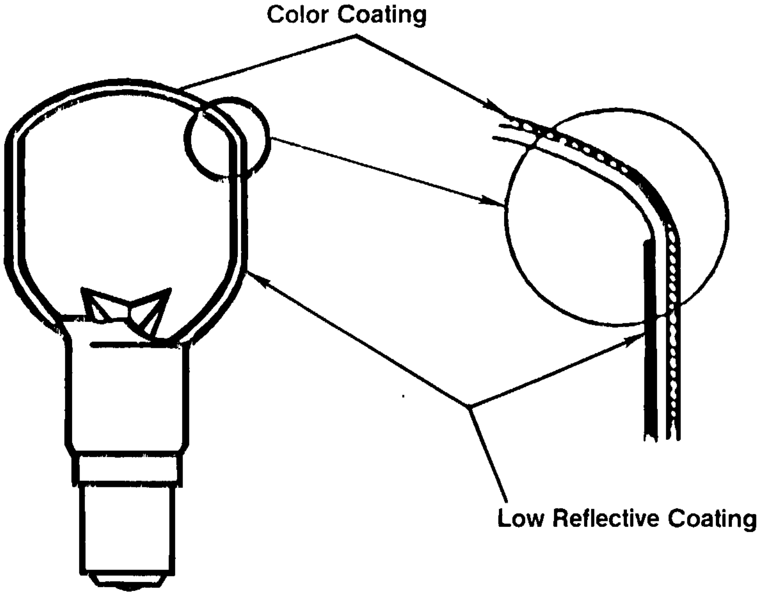


Fig. 19. Primary Color Light Source.

Energy Spectrum, Blue/Green/Red Light Sources

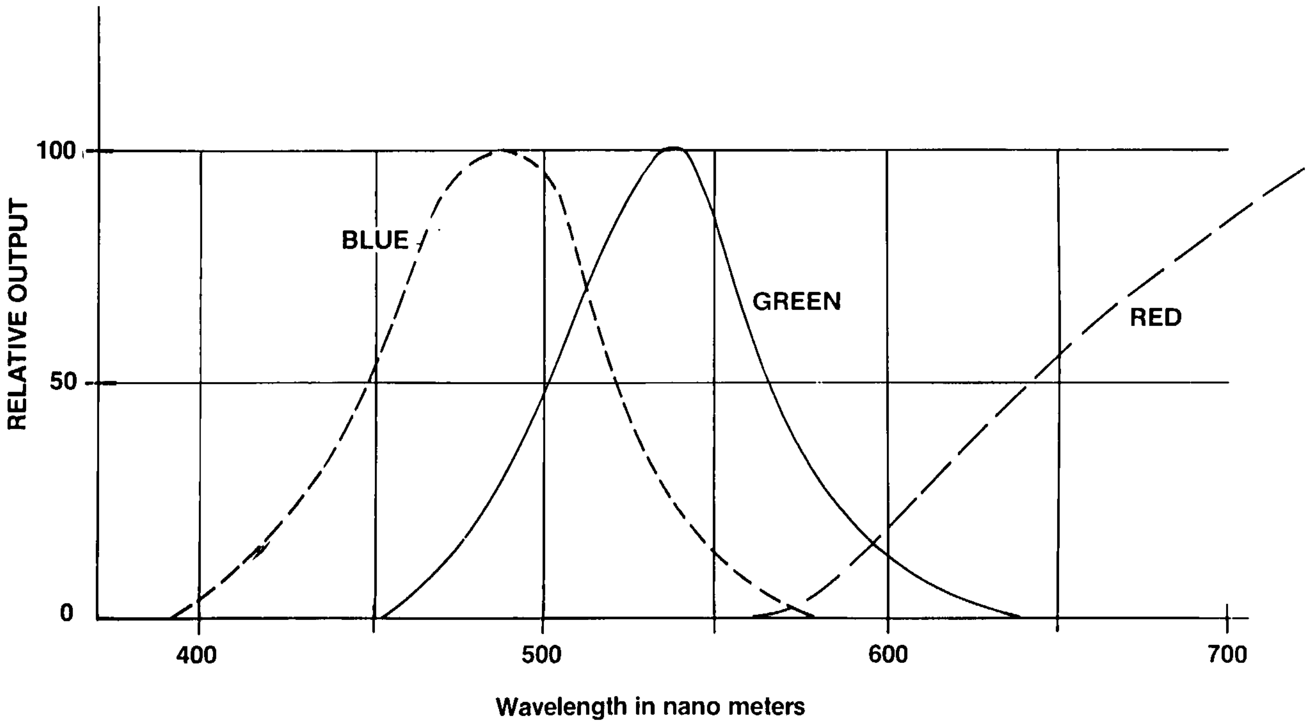


Fig. 20. Energy Spectrum, Blue/Green/Red Light Sources.

Light Source and Light Shield Assembly

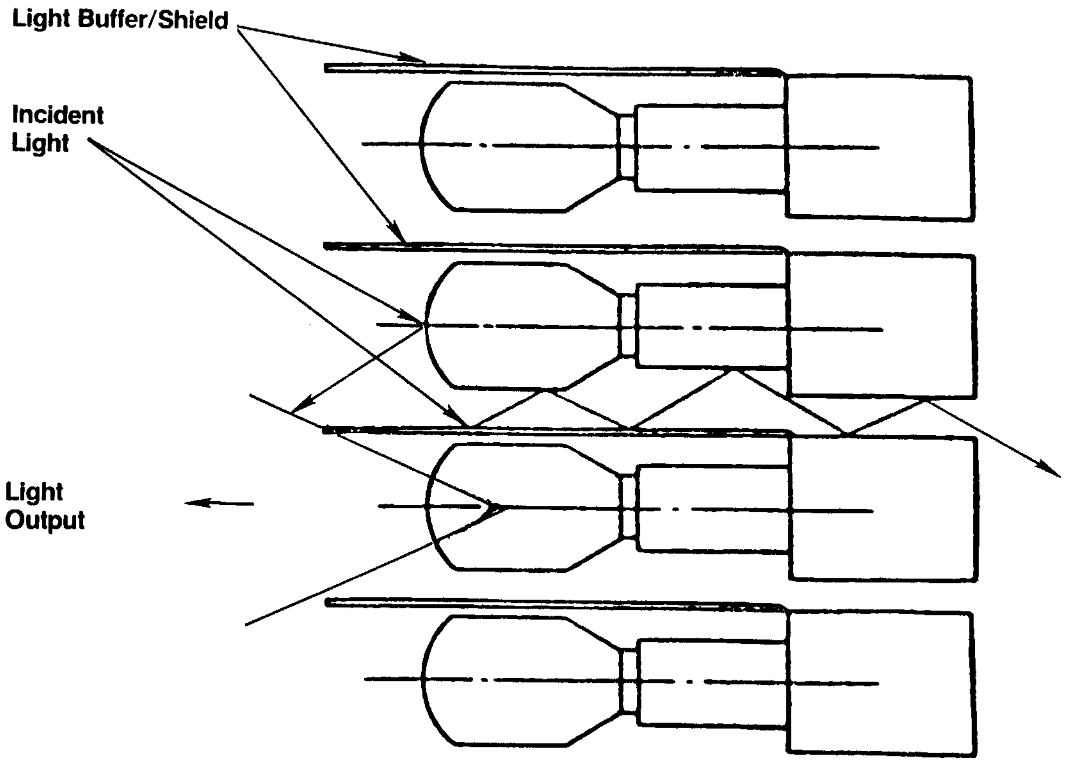


Fig. 21. Light Source and Light Shield Assembly.

Signal Processing and Lamp Driver Circuits

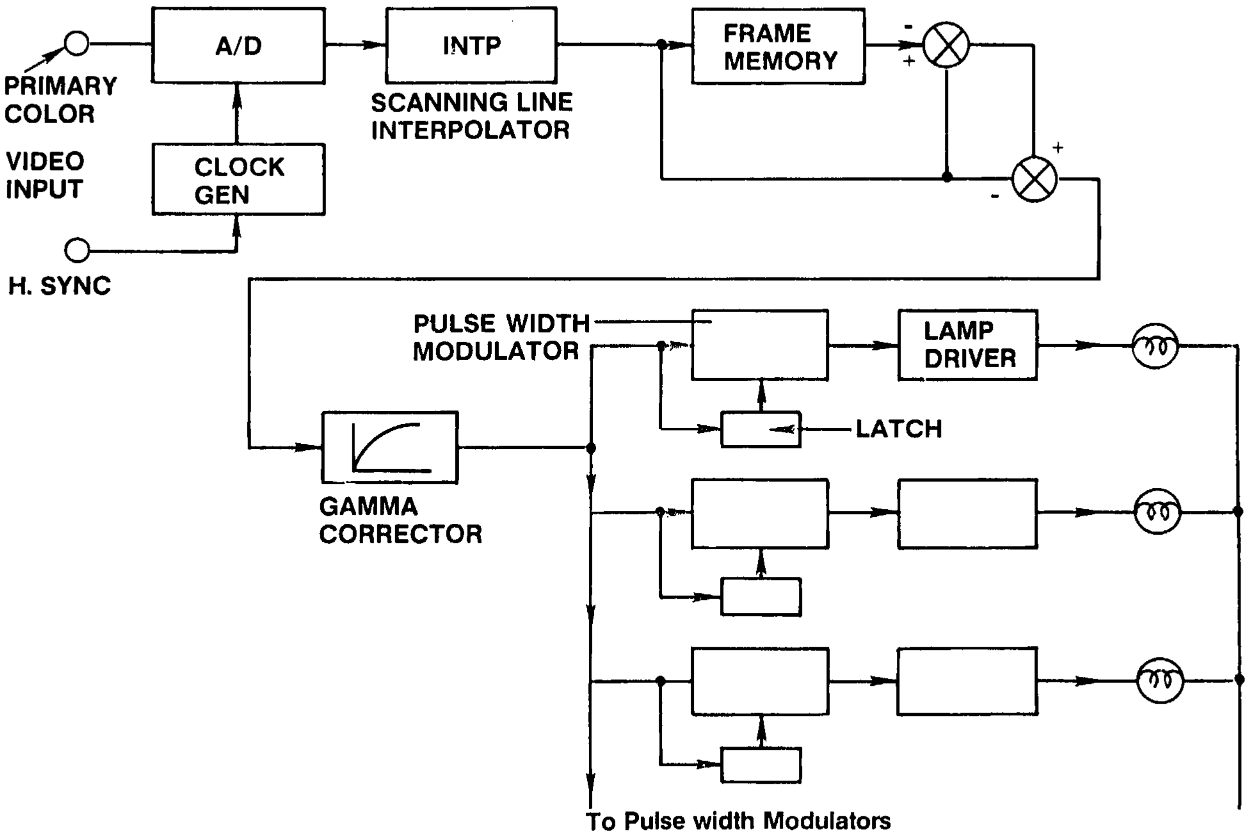


Fig. 22. Signal Processing and Lamp Driver Circuits.

Input / Output Transfer Characteristics (Gamma)

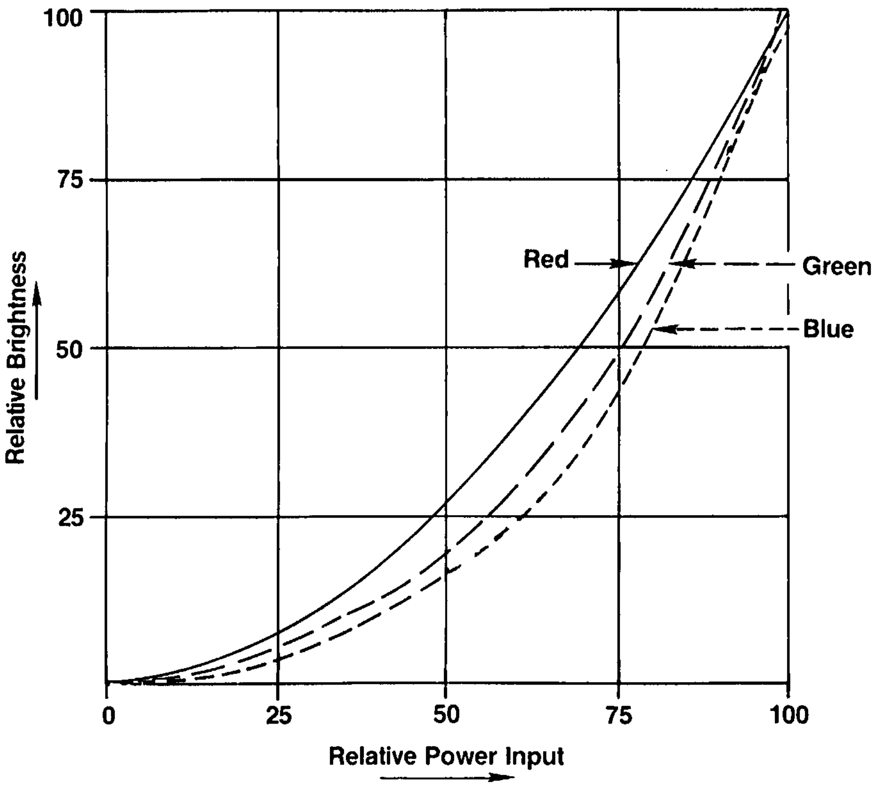


Fig. 23. Input/Output Transfer Characteristics (Gamma).

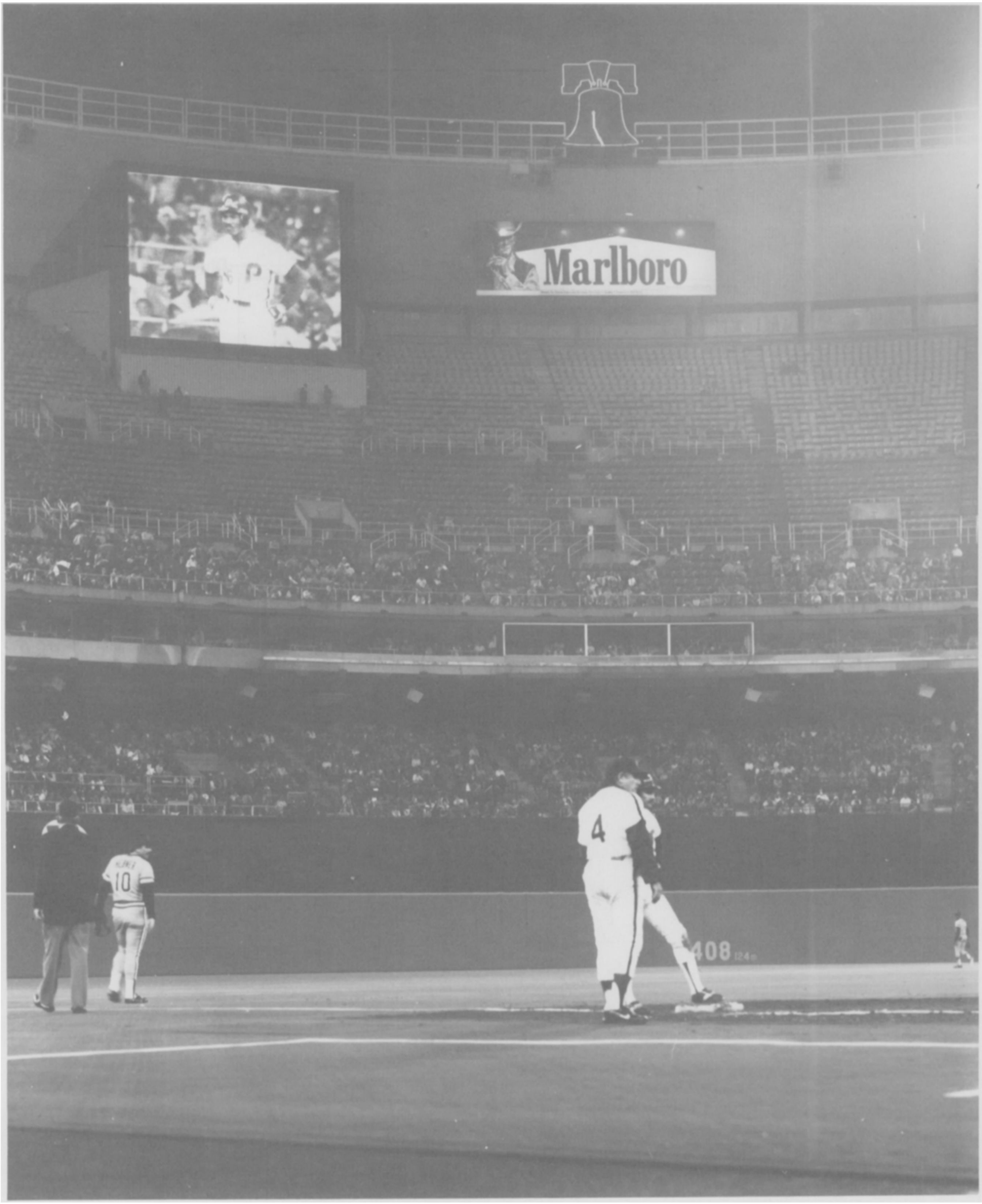


Fig. 24. An Example of a Large Screen Video Display.

Fig. 25. Another Example of a Large Screen Video Display.