3.3: Ultra-Large-Screen Color Display

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1. Introduction

In the development of display devices, a full-color large-screen video display system has always been a goal. In 1982, a plan was conceived to exhibit an ultra-large screen with sufficient brightness to be viewed outdoors in sunlight at the International Exposition Tsukuba, 1985 in Japan. The size of the color display screen is 40 x 25 m and has been named "Jumbotron".

This paper describes the development of the light-emitting device, including its drive circuitry, and the Jumbotron system as a whole.

2. Two Possible Approaches

To determine the minimum brightness required, we studied the images produced on the screen of the brightest picture tube available. Our study indicated that the minimum brightness of the display screen would have to be about 5000 footlambert (fL) after deducting the amount of ambient diffused light. After examining a number of possible approaches for the individual display devices needed to make up the screen, we settled on two final candidates: first, a 44(height)x82(width)x26(depth)mm high-voltage vacuum fluorescent device (VFD) and, second, a 25(diameter)x40(diameter)x40(depth)mm glow-discharge device.

(a) Vacuum fluorescent device

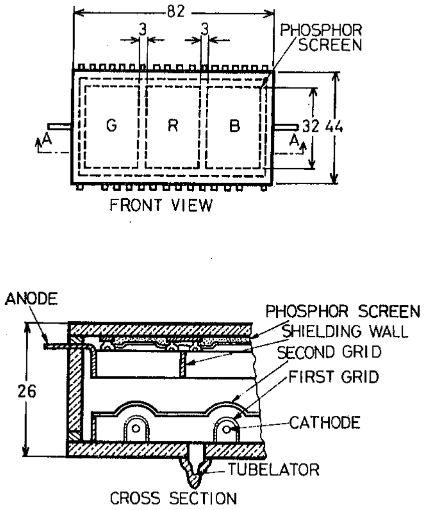

Fig. 1. The VFD.

Figure 1 shows the structure of the VFD. The red, green, and blue phosphor screens are placed in a single vacuum envelope together with the three sets of electrodes which control the electron beams. The vacuum envelope is made of 6 soda-lime glass plates 3mm thick which are joined together with low-melting-point glass frits. The cathode, which is the same as that used in a conventional VFD, consists of a tungsten filament coated with an electron-emitting alkaline earth oxide material.

To simplify the control of the electron beam current, two grid electrodes are provided. Each of these grids is made of a pressed thin stainless-steel sheet which is etched from both sides to create the openings. The first grid turns the electron beam on and off, and the second grid controls the current intensity. The anode consists of three phosphor screens which are coated with thin aluminum film and are in contact with a stainless-steel frame. A stainless-steel shielding wall insures that the screens are not excited by electrons from the adjacent cathodes.

As it was important to design a VFD of sufficient brightness to be viewed in sunlight, a high anode voltage was required. In order to tolerate the high-voltage, the low-voltage region (the cathodes and the grids) and the high-voltage region (the anode and the phosphor screens) are positioned some distance from each other in order to provide some protection against arcing. We tested several different phosphors, including those already used in standard color CRTs and in projection CRTs, as well as newly developed phosphors.

Since the time allowed us was limited, we decided to use the color CRT phosphors--Y_2O_3:Eu for red, ZnS:Cu,Al for green, and ZnS:Ag for blue--as they provide sufficient brightness and are stable. This arrangement achieved a brightness of 14,000fL at an anode voltage of 10kV and at a current of 500 microamperes, which yields a power consumption of 5 watts per VFD.

Typical brightness versus anode current for

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each phosphor screen at 10kV is shown in Fig. 2. When operated at 5 watts, the temperature increase on the device face was only 80°C above the ambient temperature, which means that the glass envelope will not be damaged and that temperature quenching of the phosphors will not be a problem. Based on these results, we decided to employ this device in the Jumbotron.

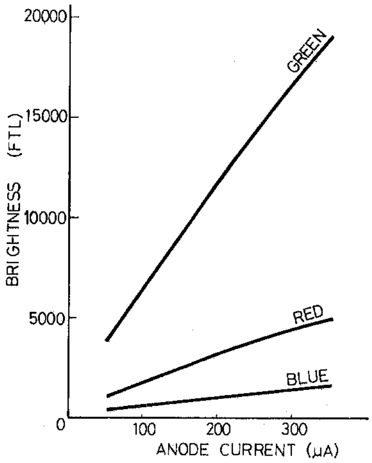

Fig. 2. Brightness vs Anode current of green, red, and blue phosphors.

During the early stage of the development, arcing between the electrodes was a major problem. Two types of arcing occurred: one, surface creepage along the inner wall of the vacuum tube and, two, point discharge from the grids in the low-voltage region. In extreme cases, the arcing caused the thin aluminum film to peel from the screen, which aggravated the arcing. By maintaining strict quality control in the manufacturing process to eliminate dust and debris inside the envelope, and by refining the grid producing process so that the grid surfaces are made smooth, this problem was eliminated.

(b) Glow-discharge device

The glow-discharge device, in which electrons from a glow-discharged helium-filled chamber bombard a phosphor screen, has been designed based on Paschen's Law. This device consists of a glass envelope with a round glass faceplate and a glass cylinder containing 5 torr He gas, a phosphor screen, a cathode, and two electrodes in the form of meshed screens. The structure is shown in Fig. 3.

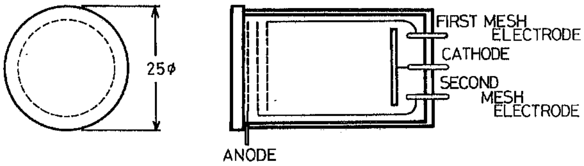

Fig. 3. The glow-discharge device

The phosphor, having the same components as conventional color CRT phosphors, is silk-screened onto the faceplate and coated with a thin aluminum film by vacuum evaporation. Three units, one each for red, green, and blue, are necessary to make one pixel of the Jumbotron screen. When 5-7kV are applied to the anode and -300V are applied to the cathode, a glow-discharge is induced between the cathode and the grounded first electrode. When 0V is applied to the second electrode, which functions as a control grid, the electrons from the ionized helium will travel through the mesh screens of the two electrodes and bombard the phosphor screen. When -30V are applied to the second electrode, the electrons are blocked.

Although we achieved a brightness of 9000fL for this device, which is more than sufficient for our purposes, we postponed further development of this device because of a major design problem. To produce the brightest possible device based on Paschen's Law, the distance between the anode and the second electrode was set at only 1mm. Unfortunately, at this distance, arcing tended to occur. In addition to the relatively short distance between the anode and the electrode, we suspect that the shape of the two electrodes contributed to this problem. Further research into these two conditions required more time than we were allotted, so we set aside this design for the present and concentrated our efforts on developing the high-voltage VFD.

3. Arrangements of the High-voltage VFDs in the Jumbotron Screen

Figure 4 shows the Jumbotron. The screen is 40m wide and 25m high, giving an aspect ratio of 5:3 as opposed to the 4:3 aspect ratio of a conventional TV screen. This allows the Jumbotron to be used for HDVS (High Definition Video System) images as well as for conventional TV images. The picture resolution is 400 pixels in 378 lines, which is more than sufficient for reproduction of conventional color TV images.

Since one high-voltage VFD makes up one pixel, 151,200 VFDs are required for the Jumbotron screen. The VFDs are grouped into units and the units into modules. Each unit containes 24 VFDs arranged 4 across and 6 high in a 0.4x0.4m synthetic resin, water tight weather proofed cabinet. Also in this cabinet reside the drive circuits for the devices. 175 units, arranged 25 across and 7 high, are assembled into a 10 (width)x2.8(height)m module, which is then fitted into the steel framework of the Jumbotron. The 36 modules fit into the framework 4 across and 9 high.

In order to eliminate the irregularity of the non-light-emitting areas between the units and modules, the devices were spaced so that the distance between the devices within a unit was the same as the distance between adjacent units and the distance between adjacent modules. As a result of this spacing, which created more non-light-emitting areas than anticipated, the total brightness of the screen was reduced to one-third the brightness of a VFD. Consequently, the maximum brightness of the Jumbotron screen was reduced from 14,000fL to 4600fL.

Since brightness alone does not guarantee a good image, a neutral density plastic filter was applied to each VFD to improve the image contrast. Although the brightness was further reduced by 36%, the image on the screen is clear and easy to view.

4. Drive Circuitry of the Vacuum Fluorescent Device

Figure 5 shows a schematic diagram of the VFD and its drive circuitry. The cathode voltage is fixed at the ground level, the second grid at 30V, and the anode at 10kV. The beam current from the cathode is controlled by the voltage level of the first grid. When the applied voltage is 30V, the current is in the on state, and when 0V is applied, the current is in the off state.

During operation, the electron emission in the VFDs tends to degrade, but this degradation rate is not uniform for every device. To compensate both for the reduction in electron emission and for the non-uniformity of screen brightness, resistors are inserted in series between the first grid and the driving transistor. As is shown in Fig. 6, because the current at the first grid is proportional to the anode current, the voltage increase of the first grid, caused by the reduction of the electron emission, causes the beam current to increase. This results in the compensation of the anode current.

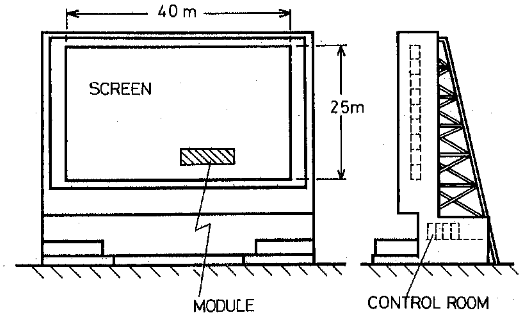

Fig. 4. Overall view of the Jumbotron.

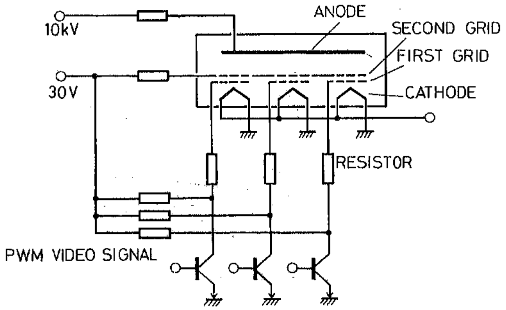

Fig. 5. Drive circuit of the VFD.

A pulsed video signal is applied to the voltage switching transistor. As the brightness of the device is proportional to the time the phosphor screen is exposed to the electron beam, pulse-width-modulation (PWM) is employed. The gradation is of 256 levels, which is carried out by 8-bit data. The refresh rate is 60Hz and maximum brightness is obtained at a signal pulse width of 1/60s.

5. The Jumbotron Circuitry

Figure 7(a) shows a block diagram of the Jumbotron system and its circuitry. As is shown in the figure, the display screen is composed of 9 rows of 4 modules, as described in Section 3. Figure 7(b) shows the detailed diagram of signal-line connections.

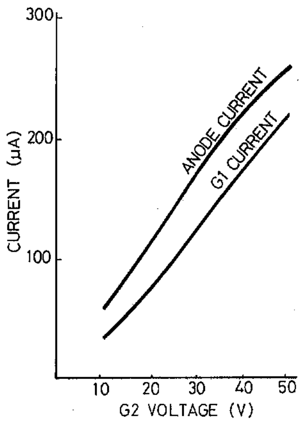

Fig. 6 Anode and first-grid (G1) current vs 2nd-grid (G2) voltage.

Various video-signal sources are used in this system. These sources are selected by a video-switcher. After a video signal is selected, an analog-signal decoder is used to decode and divide the signal into blue, green, and red components. These three components are digitized by a analog-to-digital converter and stored in a digital frame memory. The stored data are then divided into 9 time domains, each of which correspond to a row. Each domain is then multiplexed with control signals which switch the grid voltage of the VFDs.

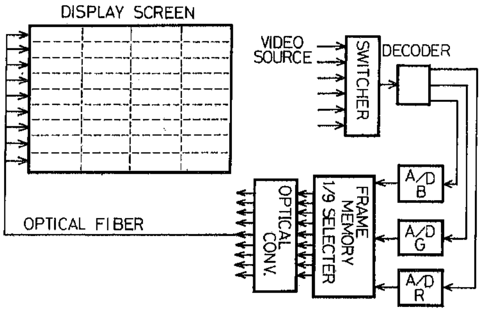

Fig. 7.(a) Block diagram of the Jumbotron system.

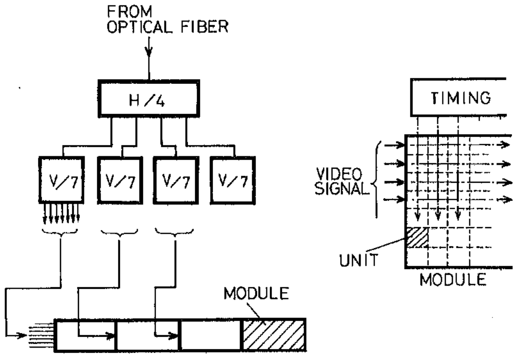

Fig. 7.(b) Detail of signal-line connection.

The multiplexed 14MHz electrical signal is then converted into an optical signal and transferred through an optical fiber to the row, where it is reconverted to an electrical signal and decomposed to the four horizontal time domains. The signal is then further divided into the seven vertical time domains which correspond to the 7 rows in a module. Twenty-five units are connected to this signal line. Finally, the video-signal is converted to a pulse-width-modulated signal to serve as a drive signal for each VFD. The control signals are also separated from the video signal and applied to each VFD.

6. Summary

An ultra-large-screen color display employing high-voltage VFDs capable of emitting blue, red, and green light has been developed. A VFD and a glow-discharge device were developed and tested, and the VFD chosen for the present application.

The main problem in developing the high-voltage VFD was the electronic arcing which induced a peeling of thin aluminum film on the phosphor screen. A secondary problem was how to maximize the ratio of light-emitting area to non-light-emitting area. Because a 3mm-thick glass plate must be used to insure that the vacuum envelope does not break, and because there must be some space between the VFDs when they are arranged as a screen, some non-light-emitting area is inevitable. If we are going to develop a smaller system using the same type of device, much smaller pixels will be required and the ratio of light-

Finally, as this type of an ultra-large screen display requires an extremely high power source, even more efficient phosphors are necessary in order to obtain as bright a screen as possible with low power input.

Acknowledgements

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