16.1: A 19-in. Very-High-Resolution Display CRT

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Abstract

A 19-inch 90° CRT capable of displaying 3,000,000 pixels with a minimum brightness of 30 foot lamberts has been developed for use in a raster-scan graphics monitor. A newly designed low-capacitance grid is used to generate a full gray-scale display. Special astigmatism and focus control grids are used to dynamically correct for deflection defocus and electron-beam aberrations due to gun and yoke misalignment and imperfections.

Introduction

Low-cost, flicker-free, bistable storage CRTs capable of 15,000 character resolution have been around for some time.[1] However, because recent trends in ROM pricing indicate at least a ten times decrease every ten years[2] and because high-speed, solid-state technology improves each year, a lower-cost, brighter, and higher resolution raster-scan display system now seems feasible.

At 18 kV, the new CRT described here is capable of greater brightness—40 fL through a 63% filter and, using a P-4 phosphor, shows improved resolution—25,000 characters.[3] The display is nearly flicker free and is capable of full gray-scale operation at a 60-Hz refresh rate.

With 1500 lines displayed, total line and retrace time is given by $1/60 \times 1/1500 = 11.1$ µsec; the line time alone is 9 µsec. Since each line is to have 2000 pixels, pixel time becomes 4.5 nsec.[4] Because it is desirable to have the pixel turn-on time to be, at most, one third of that total pixel time,[5] 1.5 nsec becomes the required rise and fall time of the video pulse. Thus, a high Z-axis bandwidth of $0.35/(1.5 \times 10^{-9})$, or 233 MHz, is required for good horizontal resolution.

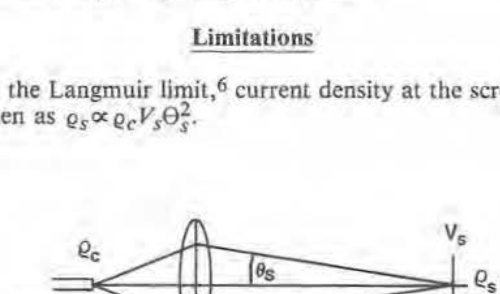
Special Construction

Power consumption was reduced by using a special ceramic-mounted grid assembly (see Fig. 1) connected via a special "bent-pin" transmission-line socket (see Fig. 2). A typical grid capacitance of 8 to 12 pF measured at the CRT base was reduced to 1.7 pF. The higher capacitance of a socket connection is avoided through use of the bent-pin transmission-line connector.

Cathode video drive is not preferred with gray scale because beam-velocity differences within the yoke deflection field will cause spot motion at the edge of the display to be equal to or greater than the pixel spacing of 0.007 in.

Limitations

From the Langmuir limit,[6] current density at the screen may be written as $\varrho_s \propto \varrho_c V_s \Theta_s^2$.



where ϱ_s is the peak on axis-current density in the focused spot at the screen operated at voltage V_s. The term ϱ_c is the emission density of the used electrons at the cathode, and Θ_s is the semi-angle of convergence into the spot.

From the equation above, it can be seen that the best resolution is obtained by designing the CRT to operate with the highest possible values of screen voltage, cathode loading, and unaberrated beam diameter. However, to keep the yoke deflection power at reasonable values and to minimize arcing and X-radiation, the screen voltage V_s is limited to 18 kV.

Cathode loading is limited by life considerations and, although a 0.015-in grid diameter aperture is used, long cathode life is assured because the average cathode loading ϱ_c is 0.6 A/cm^2 when operating the CRT at 40-fL full-screen brightness.

Since current density in the focused spot at the screen is proportional to the square of the semi-angle of convergence Θ_s^2, it is important to allow the largest possible beam diameter to pass unaberrated through the main focus lens and the deflection yoke. Thus, a large bipotential focus lens (see Fig. 3) is formed through the use of a 1-in diameter, low-voltage (2.5 kV) focus cylinder, which is inserted into a precision-drawn 36-mm neck. The positive half of the bipotential lens is formed by a high resistance coating located along the inside of the neck. In the event of an arc, the coating limits the current to less than 10 A. The 1-in diameter cylinder is centered in the neck by a special bottlecap-shaped snubber, which helps prevent high-voltage leakage along the inside of the neck glass.

Since beam diameter, and subsequently Θ_s, is also limited by yoke-generated astigmatism in the deflected beam, two astigmatism-control electrodes are located in the 3.5-kV anode drift space to correct for astigmatism at the edges and corners of the display. Special dynamic-focus and astigmatism-correction voltages applied to the astigmatism and focus elements ensure that no spot growth or defocus is visible over the entire screen. Figures 4, 5, and 6 show the focus and astigmatism correctors and the respective dynamic-focus correction voltages necessary to correct for focus and astigmatism errors. Correction voltages to the three focus elements are supplied through three programmable ROMs that are specifically made for each individual CRT and yoke combination, which eliminates the need for a high-cost CRT and for tight yoke-misalignment and build tolerances. High resolution at a reasonable cost is ensured since spot size at the edges and corners of the screen (see Fig. 7) can be made equal to, and sometimes better than, that at screen center.

Space Charge and Gray Scale

Since the focus and anode voltages are kept low (2.5 and 3.5 kV) to minimize the possibility of arcing to the grid and cathode circuitry and to reduce the dynamic voltage required for refocusing, space-charge spreading differences in the main focus lens at a fixed focus voltage will cause a spot size change between high and low brightness conditions (see Fig. 8). Because the high-capacitance focus electrode cannot track the extremely fast, low-capacitance grid as the gray level is changed, the gun is required to operate at a fixed focus setting for all levels of gray. Thus,

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the focus voltage is adjusted and fixed to give the minimum spot-size change from zero to 40 fL. If gray-scale operation is not desired, then the focus voltage can be optimized for the brightness setting desired.

Focus Refresh

To ensure a smooth-appearing transition in display focus, focus-voltage values are updated 20 times for each horizontal sweep and 64 times in the vertical direction. The 20 × 64 focus values are burned into 3 separate ROMs after interpolation from a 25-term, 8th degree equation. This equation is generated from 25 uniformly spaced test points on the CRT face. The equation to fit exactly 25 points on the screen is given by:

$$Z = \sum_{m=0}^{4} \sum_{n=0}^{4} amn\, x^{m} y^{n}$$

In actual practice, data from previous tubes are recalled from memory and changed only as required at particular screen locations during yoke and CRT testing.

Figures 9 and 10 show the focusing effect of the astigmatism correction electrodes with and without the correction voltages applied in the lower right-hand corner of the screen. Individual pixels that make up the characters are spaced 0.007 inches vertically.

The Yoke

For maximum efficiency, litz wire is stator wound onto a slotted ferrite core. The winding distribution is arranged to minimize the astigmatism correction required along the sides and corners of the display. The use of litz wire in the horizontal windings minimizes skin-effect loss at high deflection rates (93 kHz). Horizontal inductance is 68 μH and the vertical is 925 μH. See Fig. 11.

Acknowledgments

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[3] C. Infante, D. Denham, and B. McKibben, "A Very High Resolution Monitor," *SID Digest of Technical Papers,* (May 1983) pp. 124-125.

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[6] Hilary Moss, *Narrow Angle Electron Guns and Cathode Ray Tubes,* Academic Press, (1968) pp. 62.

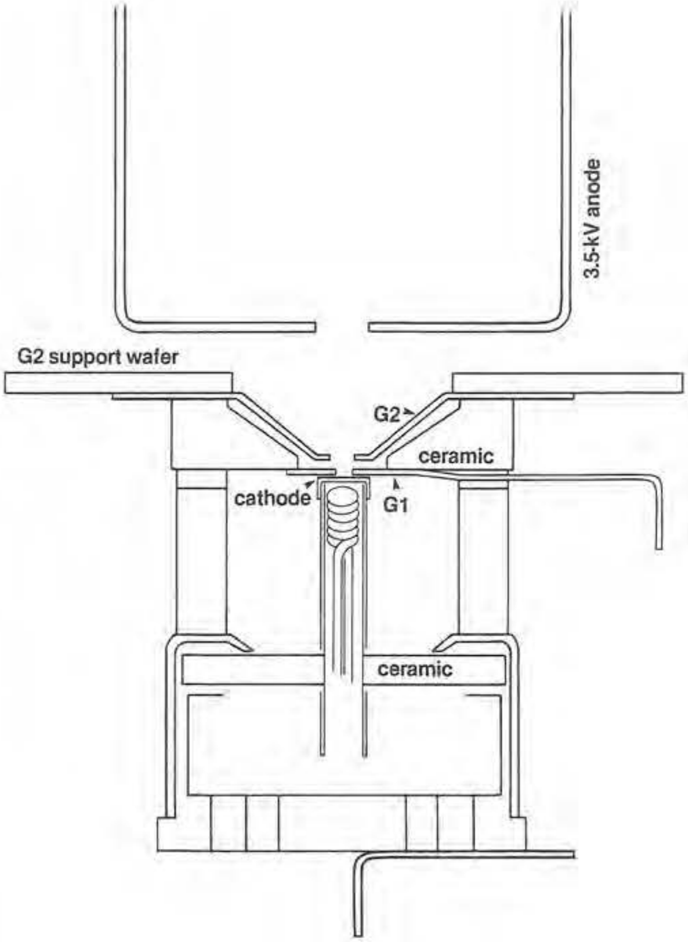


Fig. 1. Low-capacitance grid-cathode assembly.

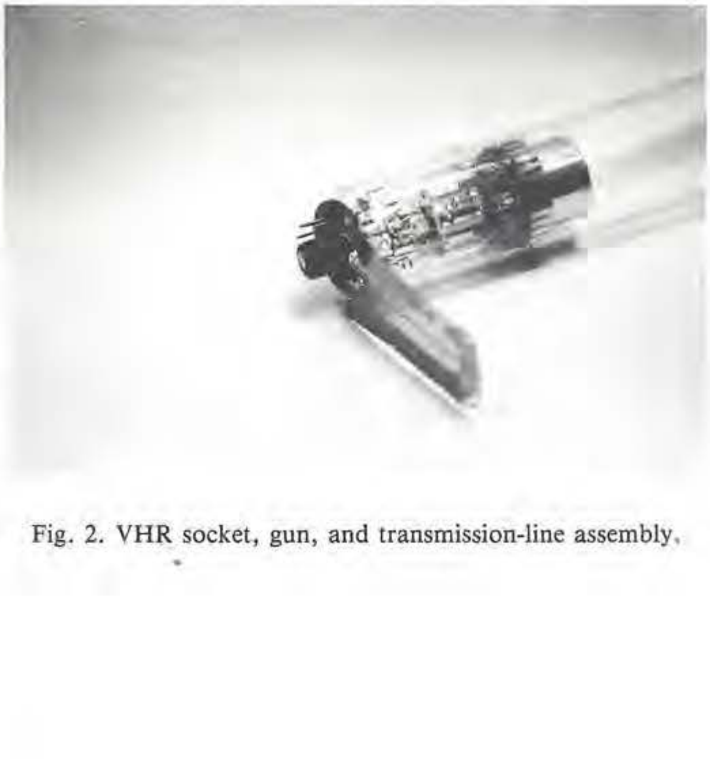


Fig. 2. VHR socket, gun, and transmission-line assembly.

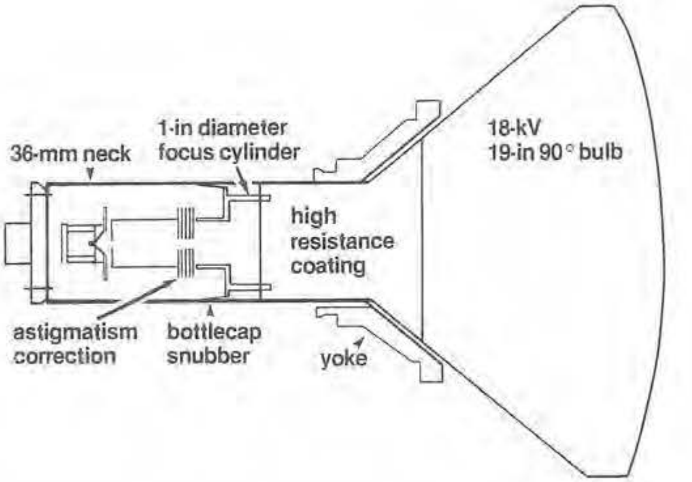


Fig. 3. 19-inch VHR CRT.

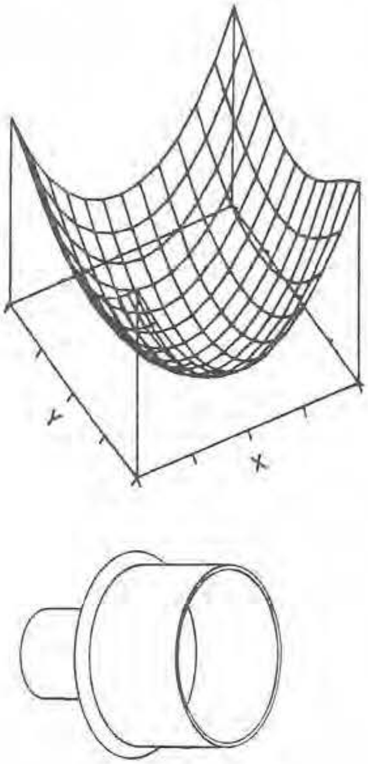


Fig. 4. Focus cylinder and dynamic correction curve.

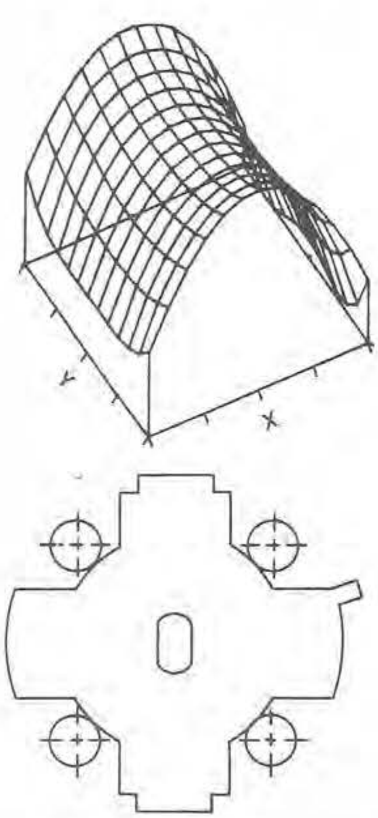


Fig. 5. Astig 1 wafer and dynamic correction curve.

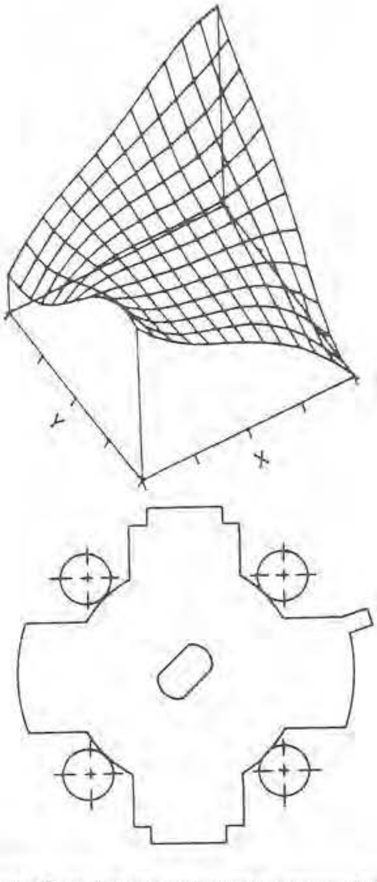
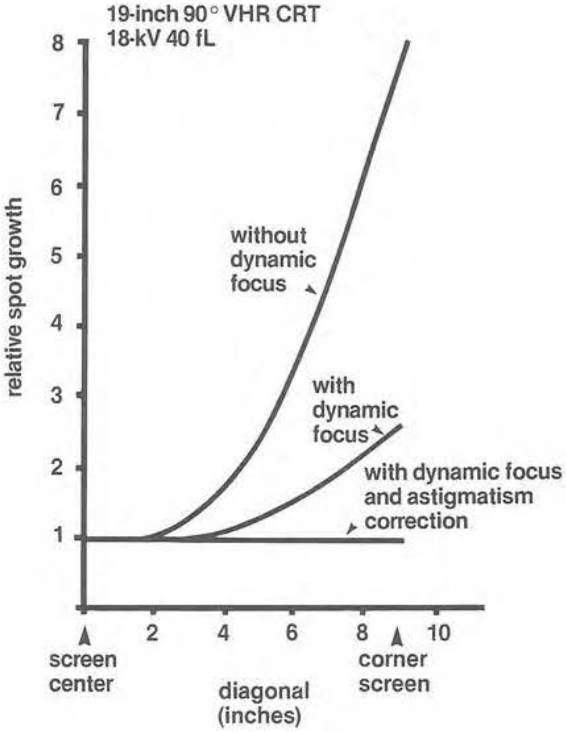


Fig. 6. Astig 2 wafer and dynamic correction curve.



. 7. Spot growth with astigmatism and focus correction.

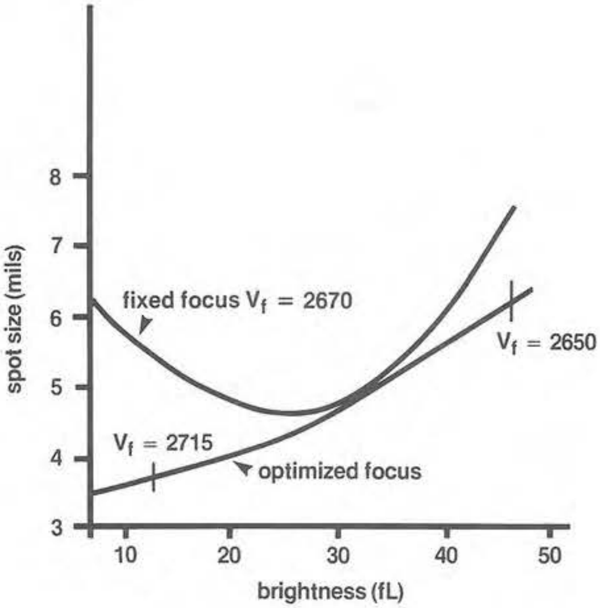


Fig. 8. Spot size change with brightness.

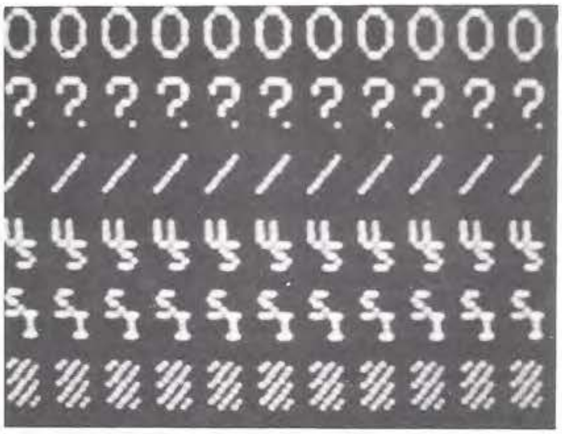


Fig. 9. Lower right-hand screen corner with astigmatism correction.

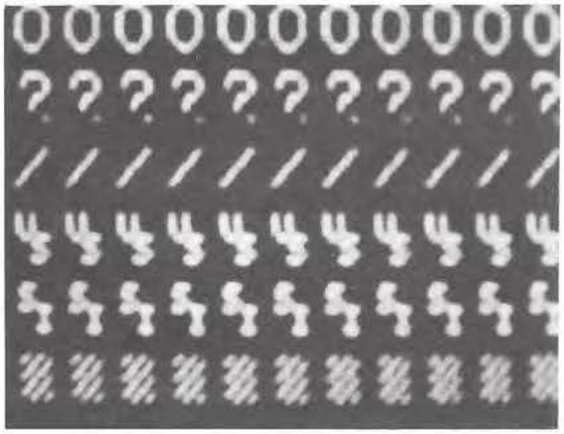


Fig. 10. Same as Fig. 9 without astigmatism correction.

Fig. 11. VHR yoke.