A 16-cm Dual Neck Diameter, Integrated Component, Projection CRT*

(16cmダブルネックサイズ投写型ブラウン管)

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Abstract A 16cm, $\phi 29.1$ mm compatible projection CRT, integrated component system has been developed utilizing an LD-Hi-UPF electron gun with an effective focusing lens of 21mm. This was achieved with a dual diameter neck ($\phi 29.1$ - $\phi 36.5$ mm) integrated component design. The current $\phi 29.1$ mm projection CRT deflection power was maintained while reducing the 5% center beam spot profile size by 20% (2mA optimum focus). The integrated components were optimized to provide the system with improved corner focus. This CRT delivers superior image quality and is compatible with current $\phi 29.1$ mm neck CRTs in rear projection systems.

Keywords : Projection, CRT, HDTV, Integrated, Components, Hammerhead

1. Introduction

Previously developed large ($\phi 36.5$ mm) diameter neck projection CRTs¹⁾ are superior to standard ($\phi 29.1$ mm) diameter neck CRTs in focus performance, however that technology still required a specially designed system (PTV set design) for product utilization. The objective of this paper was to develop a projection CRT system, which could be used with standard ($\phi 29.1$ mm) projection CRT television sets, with optimized integrated component technology maintaining the superior focus performance of large ($\phi 36.5$ mm) neck CRTs.

2. Developments

The developed CRT employs the dual diameter neck design. This design has been proposed earlier²⁾, however, not commercialized in the field of CRTs for the color or projection TV.

The diameters of the neck where the electron gun and the DY (deflection yoke) are installed are $\phi 36.5$ and $\phi 29.1$ mm, respectively, for installing the large diameter

electron gun and standard small diameter DY. Additional changes involved sealing and base modifications to achieve $\phi 29.1$ mm compatible connectivity.

The electron gun design is based on the conventional $\phi 36.5$ gun. Full achievement of the performance goals required electric field modifications in the BFR (beam forming region). In the BFR, if the every dimension, the aperture diameters of G1, G2 and G3 electrodes and their gaps are all reduced in same ratio, the size of cross-over is also reduced in that ratio. Therefore, the size of the screen spot, which is an image of the cross-over, can be improved³⁾. For the new electron gun, those diameters and gaps are all reduced to improve the focus performance, except for the G2-G3 gap. The electron gun was otherwise designed according to $\phi 36.5$ mm neck technology, which has been electrically compatible with standard ($\phi 29.1$ mm) projection CRT television sets.

However, because with the $\phi 36.5$ system, the magnet for "velocity modulation" (VM) is further from the electron beam and becomes less sensitive compared with the $\phi 29.1$ mm standard performance. To increase the sensitivity, the G4 electrode is divided into 3 parts to form gaps to make it easier for the VM magnetic field to penetrate into the electrode against shielding effect caused by eddy current on the electrode surface.

The integrated components' development of this projection CRT system involved the integration and optimization of the deflection and convergence yokes with

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the CRT. The integrated components were designed to have functional compatibility while achieving enhanced picture performance. The deflection yoke (DY) was designed to match the power/sensitivity of the current projection CRT DY technology. A similar inside diameter deflection yoke core was used for the best facilitation of current system compatibility. This design constraint required other dimensional modifications of the DY to accommodate the electron gun. This design achieved the DY sensitivity compatibility with standard $\phi 29.1\text{mm}$ technology circuits.

The combination of the DY for $\phi 29.1\text{mm}$ and the electron gun for $\phi 36.5$ introduces the serious focus degradation at the screen periphery. The decrease of the DY diameter increases the deflection defocusing. Further, when the electron gun diameter is made larger to improve the lens aberration and reduce the spot size, the gun designer should increase the beam diameter in the gun, because for the reduced aberration gun, the optimum diameter becomes larger. This increased beam diameter degrades the deflection defocusing further. So, the DY development has to be aimed at the improvement of the focus performance.

The DY development involved a two step design process for the focus improvement. The first step was a general astigmatism correction by optimizing the DY windings. The second step was a more localized correction using magnets. Fig. 1 shows the beam spot shapes on the Projection CRT screen with the base DY design. The beam spot shape at the four corners are elongated in diagonal direction. This elongation is caused by the strong positive astigmatism. When the astigmatism is positive the beam is constricted strongly in horizontal direction and elongated in the vertical direction. Fig. 2 shows the comparison between 1st derivatives along the trajectories of electron beam deflected to the screen corner by the first design and improved design DY. As is shown in the figure, the more positive the 1st derivative, the more negative the astigmatism. See references for a detailed explanation of the concept⁴⁾.

It was necessary to reduce the positive astigmatism for improving the corner spot size and shape with first step DY design. The first derivative of the improved DY was made more positive to make the astigmatism less positive especially at the gun side where the effect is more pronounced. Fig. 3 shows the beam spot shapes on the Projection CRT screen with the 2nd step DY design. The beam spot size along the longer axis with the improved DY is reduced about 44% over that of the base DY

Fig. 1 Beam Spot Shapes of base DY design (before optimization).

Fig. 2 Comparison between the 1st derivatives of the deflection fields between the two DY designs.

design. The beam aspect ratio (the ratio of horizontal to vertical beam diameter) in this DY design was only improved from 3.0 to 2.9 and was still excessively elongated in diagonal direction. This is because, even if the astigmatism is improved, non-perpendicularity of the beam landing angle and an imbalance in the magnification factor between vertical and horizontal direction causes the degradation of the beam aspect ratio.

Fig. 3 Beam Spot Shapes of the improved (2nd step) DY design.

Fig. 5 Beam Spot Shapes of the final DY design.

Fig. 4 Beam forming magnet locations on the Deflection Yoke.

If the 1st derivative of the deflection field of the vertical or the horizontal DY became more positive, the corner spot shape would be improved further, however, the left and right edge spot shape would be elongated horizontally. It was, therefore, not possible to improve both top, bottom, left and right edge spot shapes at the same time by optimizing the DY winding distribution. It is necessary to control the beam shape independently for each general screen position. Six magnets were added to the improved DY to control the peripheral spot shapes. The Fig. 4 shows the position of the magnets attached to the DY. The magnets in the top and bottom position of the DY exit have the effect of correcting the beam shape by

reducing the beam diameter in the vertical direction. The four magnets at the left and right side of the DY have the effect of correcting the beam shape by reducing the beam diameter in diagonal direction. The resultant beam shapes produced by the final DY with the magnets are shown in Fig. 5. The beam aspect ratio at the screen corner is improved to 1.6 without sacrificing the peripheral beam spot shapes.

With the addition of the magnets, the raster distortion is varied. However, in this case, the pin-cushion distortion is rather decreased about 1 mm on the CRT screen.

Further corner focus enhancements were achieved through magnetic field control. To reduce normal manufacturing variations which plague DY performance, the control of the field through the manufacturing process was required. Measurement of the fields during the manufacturing process was done. This measurement provided the ability to control the consistent application of the optimum magnetic field for each integrated component as it was incorporated into the product.

The convergence yoke (CY) also required similar power/sensitivity with respect to the $\phi 29.1\text{mm}$ CRT. The convergence yoke was dimensionally optimized to achieve the best electrical compatibility with standard ($\phi 29.1\text{mm}$) projection CRT television sets while accommodating the larger electron gun.

Fig. 6 and Fig. 7 show the configuration of the new system. The CRT is shown along with the placement of the DY coils on the $\phi 29.1\text{mm}$ neck portion.

Fig. 6 Integrated component system.

Fig. 7 Inside of DY (Section A of Fig. 6) .

3. Results

3.1 Product compatibility

CRT compatibility of the new CRT with current systems was achieved. Table 1 compares the specifications of the current and the new integrated projection CRT systems. The same screen, panel, funnel and base dimension were used for cross compatibility.

For the new CRT, it is not possible to use the conventional assembled DY, because that can not be inserted through the larger size neck portion. Therefore, the DY has to be assembled on the smaller ($\phi 29.1\text{mm}$) size neck portion. For keeping the assembling accuracy, separator of the DY is divided along the horizontal axis to make it possible to integrate the separator and the horizontal winding.

Integrated component compatibility of the new integrated components with current systems was achieved. Table 2 compares the specifications of the current and the new integrated projection CRT systems. The same power /sensitivity was achieved.

Table 1 CRT specification comparison.

Product	Current System	New System
Commercial name	P16LFM00 RFA(TU) HHA(TU) BMB(TU) "Stingray"	P16LXT00 RFA01 HHA01 BMB01 "Hammerhead"
CRT Panel	16cm (7inches) 350mm inner radius	
CRT Neck	$\phi 29.1$ single neck diameter	$\phi 29.1 - \phi 36.5$ Dual neck diameter
CRT Funnel	90 degree deflection funnel contour	
Deflection System	Market based DY and CY systems	Integrated optimized DY and CY
Useful screen	124.1mm x 98.3mm	
Overall Length	270mm	273mm
Socket-Base	$\phi 15.24$ mm pin circle	
Electron Gun	Large aperture Hi-UPF with 16mm lens diameter	Large aperture Hi-UPF with 21mm lens diameter
Focus System	Electrostatic	
VM sensitivity	0.3mm/A (1MHz)	0.3mm/A (1MHz)
DF	Horizontal	520V
	Vertical	160V
Phosphor	Red- $\text{Y}_2\text{O}_3:\text{Eu}$ Green- $\text{Y}_2\text{SiO}_5:\text{Tb}$ Blue- $\text{ZnS}:\text{Ag, Al}$	

Table 2 Integrated component compatibility comparison.

Product	Current System	New System
Name	"Stingray"	"Hammerhead"
Operating Conditions	Eb = 30kV Raster Size: 110mm x 62mm	
DY Sensitivity	PH	9.1 mHA ²
	PV	9.7 WA ²
CY Sensitivity	PH	0.1 mHA ² /5mm
	PV	0.1 mHA ² /5mm

3.2 Performance Improvements

CRT improvements were gauged by the center focus performance. Focus performance varies with beam current. Projection CRTs have been generally operated in the 0 to 4mA range with the high resolution images typically operating below 2mA. Fig. 8 shows a comparison of center focal performance between the two systems excluding the integrated components with a 2mA optimum focal adjustment. At a beam current of 2mA, there was a 15% advantage of the dual neck technology over current technology projection CRTs. As the CRTs were operated at lower beam currents the advantage was increased to 20%.

Fig. 8 5% Center Beam Spot Diameter with respect to Cathode Current (2mA optimum focus) .

Fig. 9 5% Center Beam Spot Diameter with respect to Cathode Current (2mA optimum focus) .

Integrated components' accomplishments were gauged by corner focus performance. Fig. 9 shows a comparison of corner focal performance between the two systems including the integrated components with a 2mA optimum focal adjustment. The beam spot diameter in Fig. 9 means the vertical widths of the horizontal scanning line at the screen corner. Within the 2mA beam current range, there is a 5% advantage of the dual neck technology over current technology. As the CRTs are operated at lower currents the advantage is increased to 6%. Higher beam currents were not available for this measurement due to equipment limitations.

Screen center performance as a practical application can be shown in "high-end" HD projection sets. HD

Fig. 10 Modulation Transfer Function (MTF) characteristics for extreme screen corner with anode voltage 30kV, a beam current of 2mA and a raster size of 110 (H) mm x 62 (V) mm.

projection should be operating at or above the display resolution of 720 x 1,280 TV lines. Fig. 10 shows the relationship between the Modulation Transfer Function (MTF) derived from center beam spot size and signal resolution for both systems. The brightness profile of each spot is assumed to be a Gaussian (Eq. 1). The resultant superposition of spots was represented by the integration of this expression. This results in the expression (Eq. 2) for screen spot brightness profile where p is spatial separation described by (Eq. 3). MTF was found by the basic definition for this system (Eq. 4) where the max-min is defined by (Eq. 5).

$$F(r) = \exp(-\alpha r^2) \quad (\text{Eq.1})$$

$$G(r) = \sum_{(k=-\infty \text{ to } \infty)} \exp(-\alpha(r+kp)^2) \quad (\text{Eq.2})$$

$$p = \text{Screen width} / (\text{TV Dots per screen width} / 2) \quad (\text{Eq.3})$$

$$\text{MTF} = (G(r)_{\text{max}} - G(r)_{\text{min}}) / (G(r)_{\text{max}} + G(r)_{\text{min}}) \quad (\text{Eq.4})$$

$$G(r)_{\text{max}} = G(0) \text{ and } G(r)_{\text{min}} = G(p/2) \quad (\text{Eq.5})$$

Just within the HD range, specifically at 1,280 dots of resolution (H), the new system displays a 20% improvement over current products when gauged by center screen MTF. Full HD, or 1,920 dots, displays the greatest advantage with a 70% improvement over current system.

This improvement has provided for a great practical advantage for the HD PTV set. At 1,920 dots of resolution, a lens MTF (12.2 magnification) is 0.66 and a screen MTF (61 inches, 0.52mm screen pitch, including aperture effect and diffuser effect) is 0.69. The total MTF of the current PTV system calculates to 0.11 and that of the new system calculated to 0.20. The new system is clearly sufficient to resolve 1,920 dots on the PTV screen⁵⁾.

Screen corner performance is important for the practical application to HD projection systems, as the corner screen performance in current systems has been at

Fig. 11 Modulation Transfer Function (MTF) characteristics for extreme screen corner with anode voltage 30kV, a beam current of 2mA and a raster size of 110 (H) mm $\times$ 62 (V) mm.

the limit of HD discernment. The integrated system provided for a large practical increase in corner performance over current technology. Fig. 11 shows the relationship between the Modulation Transfer Function derived from corner beam spot size shown in the Fig. 9 and signal resolution for both systems. At 1,280 dots of resolution (H), the integrated component system displays a 30% improvement over current products when gauged by corner screen MTF.

4. Conclusion

A new product has been developed which utilizes a dual-diameter neck CRT in an integrated component system. This system's technology is new to the projection television market. This system's technological innovation provides superior image quality across the entire screen when compared to previous projection CRT technology.

The increased requirement for image quality for HDTV has inspired CRT manufacturers to meet the challenges of the new standards in image performance with the constraints of product cost. The development of this dual diameter neck CRT with an integrated component system has propelled the continuing progress of CRTs competitiveness in high quality projection displays.

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