9.1: Video Risetime Requirements for Computer-Driven Raster-Scan CRT Displays

James G. Hagerman

Digital Equipment Corp., Westford, MA

INTRODUCTION

A problem generally encountered in the design of a raster addressed CRT display is that of determining the requirements for video amplifier risetime. Rules of thumb have been used in the past (e.g. 1/3 pixel time). Other analytical work[5,6] based on MTF or other algorithms neglected the non-linearity of the electron gun. In this paper, the contribution of these non-linearities to the luminance response on the face of the CRT are analyzed. To do this, a computer model is developed to compute the luminance response for various video signals and spot sizes. The model uses a time domain description of the video section as opposed to steady-state. This makes the results more relevant to computer driven displays. It is found that an optimum non-zero risetime for the video amplifier exists.

Note: The term *pixel* is used to specify the time period or the distance traveled by the electron beam during a single clock cycle of the video signal. The direction of travel is along a horizontal scan line in the x dimension.

COMPUTER MODEL

Electron Beam

The beam current magnitude can be represented as an exponential function of the drive voltage

$$I_{magnitude} \approx kV_d^{\gamma} \qquad (1)$$

where k is a constant and V_d is the cathode drive voltage.[1,2,3,7] The exponent γ is usually in the range of 2.5 to 3.5.[1,2,7] For this analysis, a γ of 3.0 is used.

For the moderate beam currents used in computer displays, the beam current is a gaussian function of distance

$$I_{beam}(x) = \frac{I_{magnitude}}{\sigma\sqrt{2\pi}}\, e^{-\left(\frac{x^2}{2\sigma^2}\right)}. \qquad (2)$$

The "width" of this beam is described by the parameter σ. The measured spot size at the 50% amplitude point (S_{50}) is related to σ by

$$S_{50} \approx 2.35\sigma. \qquad (3)$$

Spot size, however, is not constant but varies with beam current. Another author[1] has described this relation by

$$\text{Spot Size} = k_1\alpha^{\left(\frac{\beta}{2}-0.75\right)} \qquad (4)$$

where

$$\alpha = \frac{V_d}{V_{cut\text{-}off}},$$

and

$$\beta = 3e^{0.28\alpha^{2.3}}$$

and k_1 is a constant. Since $V_{cut\text{-}off}$ is constant and β is relatively insensitive to changes in α, Eq. (4) reduces to

$$\text{Spot Size} \approx k_1 V_d^{0.75}. \qquad (5)$$

If σ is set equal to Eq. (5), then Eq. (2) describes the "width" of the beam correctly. Combining Eqs. (1), (2), (3), and (5) we get a complete expression of the beam current profile

$$I_{beam}(x, V_d) = \frac{2.35kk_1V_d^{2.25}}{(S_{50})\sqrt{2\pi}}\, e^{-\left(\frac{2.76x^2}{(S_{50})^2 V_d^{1.5}}\right)}. \qquad (6)$$

Video Amplifier

The video amplifier can be represented by a second order system. It will filter the input signal, $V_i(x)$ (which consists of zero risetime pulses), into a drive voltage having characteristics of finite risetime, overshoot, and settling time.

The second order system is given by

$$H(s) = \frac{V_d(s)}{V_i(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}.$$

To obtain the output response $V_d(x)$, the input $V_i(x)$ is convolved with the impulse response.

$$V_d(\tau) = \int_{-\infty}^{\infty} V_i(\tau)h_\delta(x-\tau)d\tau. \qquad (7)$$

The step response is given by

$$y(x) = 1 + \frac{1}{\sqrt{1-\zeta^2}}e^{-\zeta\omega_n x}\cos\left(\sqrt{1-\zeta^2}\,\omega_n x + \phi\right)$$

where

$$\phi = -\left[\arccos\left(\sqrt{1-\zeta^2}\right) + \pi\right].$$

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The impulse response $h_s(x)$ is obtained by taking the derivative of the step response

$$h_s(x) = \frac{\partial y}{\partial x}.$$

The overshoot is determined by the parameter ς, and the risetime by ω_n. The model uses Eq. (7) to generate the drive voltage waveform.

Luminance

Luminance is proportional to beam current. Thus, the luminance response of this electro-optical model is obtained by convolving the drive voltage with the beam current expression

$$L(\tau) = \int_{-\infty}^{\infty} V_d(\tau) I_{beam}(x - \tau, V_d(\tau)) d\tau.$$

RESULTS

To keep this analysis generalized, the spot size and drive voltage risetime are represented as fractions of a pixel. For example, a spot size (S_{50}) per pixel ratio of 1.0 would mean that the 50% spot size is equal to one pixel width. Similarly, a risetime (10% to 90%) per pixel ratio of 0.5 would mean that the risetime of the drive voltage is exactly 1/2 of one pixel time.

Constant Overshoot

For each combination of risetime and spot size values, there is a corresponding ς which will result in a given overshoot of the luminance step response. The parameter ς was chosen to maintain a constant luminance overshoot of 1%. The solutions for ς were found by iterative guesses to the computer model. These are plotted in Figure 1.

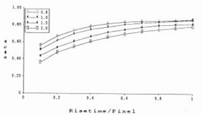

Figure 1. 1% luminance overshoot.

Simulations

The computer model can do simulations for inputs of step, single pixel, and alternating on/off pixels. Figures 2, 3, and 4 are examples of these.

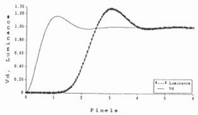

Figure 2. V_d and luminance response for step input.

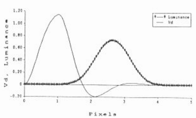

Figure 3. V_d and luminance response for single pixel input.

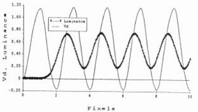

Figure 4. V_d and luminance response for on/off pixels input.

The single pixel simulation is used to obtain data for spot luminance and spot elongation. Spot elongation is defined as the ratio of the moving spot width to the stationary spot width.

$$\text{Spot Elongation} = \frac{\text{Moving Spot Width}}{\text{Stationary Spot Width}}$$

The on/off pixel simulation is used for modulation data. Luminance modulation is defined by

$$L_{mod} = \left(\frac{L_{max} - L_{min}}{L_{max} + L_{min}}\right) \times 100\%$$

The results of these simulations are plotted in Figures 5, 6, and 7. They illustrate the effects on peak spot luminance, spot elongation, and on/off pixel modulation for various risetimes and spot sizes.

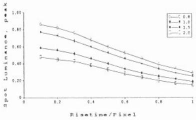

Figure 5. Spot luminance, peak.

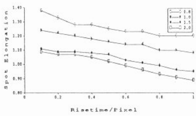

Figure 6. Spot elongation.

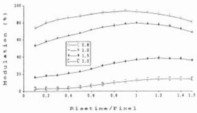

Figure 7. On/off pixel modulation.

By inspecting these plots, several significant conclusions can be drawn.

- The spot luminance is very dependent on risetime.
- The smaller the spot size, the greater the spot luminance. This should not be confused with the integrated luminance.
- The spot elongation is relatively constant for various risetimes.
- The smaller the spot size, the greater the elongation.
- Infinitesimal risetime does not produce the greatest modulation.
- There is an optimal risetime for each spot size to obtain maximum modulation.
- The smaller the spot size, the greater the modulation.

CONCLUSIONS

A computer model for simulating the luminance response at the face of a CRT was described. The analysis showed that infinite video bandwidth did not result in maximum luminance modulation, but rather that an optimum risetime exists. This risetime was found to be somewhat "soft".

The analysis presented here is not intended to replace the methodologies which incorporate the effects of the human eye, such as MTFA and SQRI, but to complement them.

ACKNOWLEDGEMENT

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