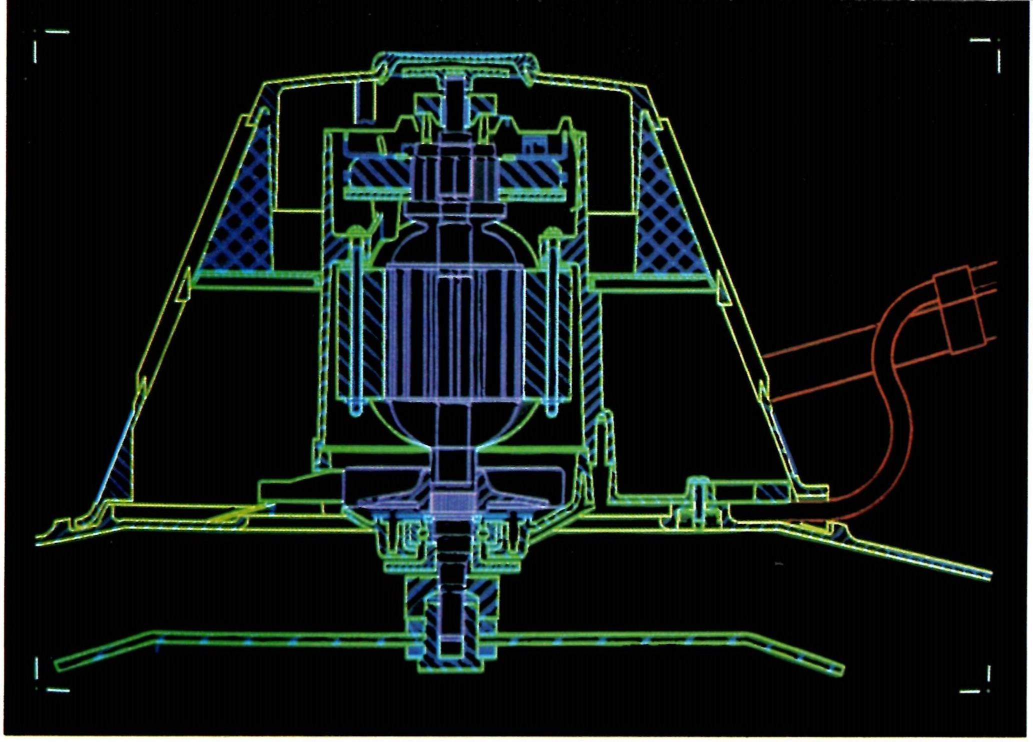


Figure 1. Autoconvergence in the 4115 maintains the sharp, bright graphics displayed on the screen.

Autoconvergence Enhances High-Resolution of 4115B Color Display

by Dan Denham, Marty Singer and Bill Meyer
Tektronix, Inc.
Wilsonville, OR

The purpose of a high-resolution color display is to provide sharp, true colors and accurate data representation for such high-density graphics applications as CAD/CAM and mapping. Color benefits these applications by serving to organize, locate, and highlight graphics information. An engineer designing integrated circuits, for example, can use color coding to identify the circuit's different components, layers, and connecting wires.

One major problem, however, common to all color displays, has caused many computer graphics users who require high resolution to choose monochrome displays. That problem is misconvergence, a condition in which the red, green, and blue beams of a color raster-scan display do not intersect precisely at a specified point on the screen. The effects of misconvergence include poor color, a fuzzy picture, visual fatigue, and even a loss of graphics information.

Though misconvergence occurs on all color displays, even color television sets, its effects are especially critical on a high-resolution color display. Users make a big investment in buying high-resolution color displays and generally make that investment because their applications require the display of high-density pictures in which the operator must be able to discriminate details.

In a high-density graphics application, if the beams are not properly converged, two parallel red and green lines with only a narrow gap between them may appear as one thick yellow line. Misconvergence could cause a sharp thin white line on the display (Figure 2a) to appear as a fuzzy thick pink line with a red fringe (Figure 2b), or, in the worst case, as three separate lines of red, green, and blue (Figure 2c).

A high-resolution color display, of course, loses much of its usefulness when the beams are misconverged to the point of turning thin

Figure 2a. Precisely adjusted beams of a raster-scan display produce a sharp, thin white line.

Figure 2b. Misconvergence might cause the white line to appear as a fuzzy thick pink line.

Figure 2c. Worst case misconvergence separates one line into three separate lines.

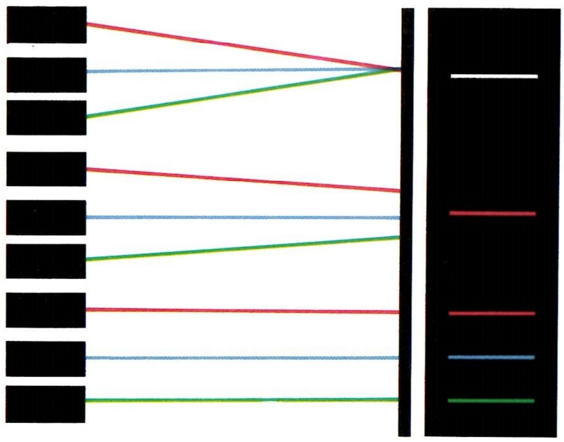


Figure 2. Illustrating misconvergence.

white lines into thick pink lines. The misconvergence could lead to a serious error.

The display's color convergence can usually be adjusted, but it is a time-consuming procedure that often requires a trained technician. In addition, the factors of tube age, temperature, and position, as well as the resolution demands of the application and visual acuity of the user all contribute to the frequency of convergence adjustment. Turning a display to the side at only a slight angle, perhaps to better view the screen, can cause misconvergence, even if the beams were adjusted only minutes before, because of the influence from the earth's magnetic field.

The Tektronix 4115B Computer Display Terminal solves the problem of misconvergence in high-resolution color displays through a system called "autoconvergence." Autoconvergence allows the 4115B to exceed the convergence specifications of all other 19-inch color displays to a point where even very discriminating users cannot visually detect a trace of misconvergence.

When misconvergence does occur, the 4115B, in a few seconds, automatically restores convergence to the original specifications at the press of a user accessible button. Autoconvergence is not merely an enhancement, but a significant and integral part of the high-resolution color display. In fact, as the resolution of a display increases, so does the need for some form of convergence system.

Locating Misconvergence

When giving convergence specifications, manufacturers often divide the screen into two or three sections (Figure 3). The center circular section of the screen, often called the "quality area" generally boasts better convergence specifications than the corners of the screen. It is difficult to maintain tight convergence at the corners because of the wide deflection angle of the beams at these points, a problem especially acute on a 19-inch CRT. A display, then, may claim convergence specifications of 0.5 mm in the "quality area" and 0.7 mm at the corners, or perhaps by shrinking the "quality area," claim specifications of 0.3 mm at the center (region A in Figure 3), 0.6 mm in an area surrounding the center (region B), and 0.8 mm at the corners (region C).

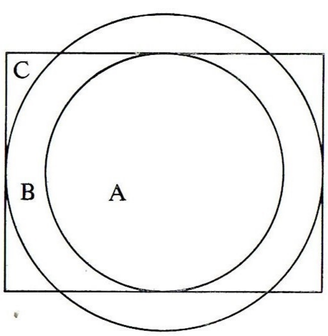


Figure 3. Manufacturers often divide the screen into sections to support tight convergence specifications in the "quality" area. The 4115B does not restrict its convergence specification of .2 mm or less to a circular area in the center of the screen.

The 4115B does not restrict that convergence to a circular "quality area" in the center of the screen. A critical detail in a high-density picture can be displayed as accurately at any corner of the screen as at the center. Convergence over the full viewing area especially benefits the display of alphanumeric text which often begins in the upper left corner of the screen. On the 4115B, very fine text can be displayed with a legibility and color consistency of unvarying high quality across the entire screen. On a display that limits its best convergence to a circular "quality area," the text may appear fuzzy in the corners and sharper in the center of the screen.

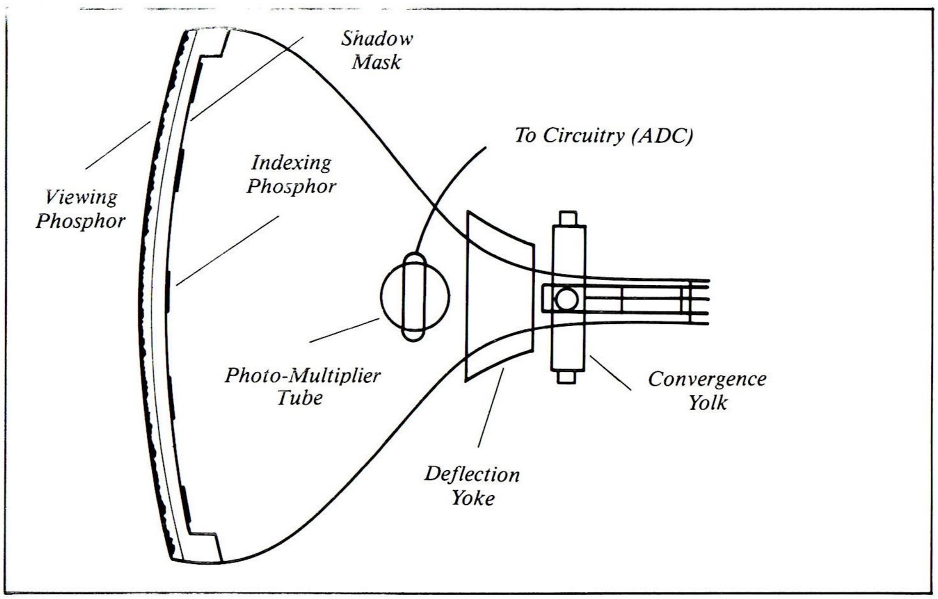


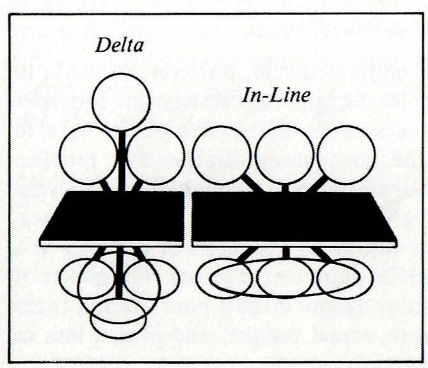
Figure 5. The physical aspect of autoconvergence.

CRT Selection and Convergence

To provide as small a screen spot size as present raster-scan technology allows, the color beams of the 4115B originate from a delta gun (with two beams at the base of the gun and one on top, in the form of the Greek letter delta).

In conjunction with the delta gun, the 4115B uses a shadow mask, a metal plate positioned just behind the screen. The shadow mask has many small holes through which the electron beams are funneled so that they illuminate the correct phosphor dots on the screen. The "red" beam should hit the red phosphor dots, the "green" beam should hit the green dots, and so on. For delta gun configurations, the phosphor dots are arranged on the screen in triads, each triad consisting of a red dot, a green dot, and a blue dot.

A delta gun is more difficult to converge than the more commonly used in-line gun (in which all three beams are arranged in a horizontal line), but in-line gun CRTs sacrifice spot size for ease of convergence. Tektronix's autoconvergence system, however, achieves convergence on a delta-gun CRT better than that obtained by any in-line CRT-yoke combination available, allowing 4115B designers to opt for the smaller spot size.



How Autoconvergence Works

Traditionally, convergence was adjusted manually by a trained technician. By rotating a number of potentiometers and viewing the results on the screen, the technician adjusted the convergence over selected areas of the display, a procedure that could take an hour or more.

Though many displays still use the adjustment technique of manual (or analog) convergence, a few recently developed displays offer digital convergence. To adjust convergence digitally, the operator interrupts the application to put the display into a convergence mode. In the convergence mode, the display restores approximate convergence and draws a grid on the screen. By pressing keys on a keypad connected to the display and viewing the screen, the operator fine-tunes the approximate convergence until it reaches an acceptable level for the application. This typically takes several minutes for the operator to complete.

With the 4115B's autoconvergence system, convergence can be automatically adjusted to the original specification at any time during an application. If convergence drifts, the operator need only press a button on the display and wait a few seconds to correct the condition.

Figure 4 shows block diagrams for the analog, digital, and autoconvergence adjustment systems. In analog convergence adjustment (Figure 4a), setting the potentiometers generates a complex waveform which, when amplified, drives the convergence coils. The coils' electromagnetic field independently deflects each electron beam to maintain convergence.

In digital convergence (Figure 4b), the display is first converged at the factory. The resulting waveform is then stored in EEROM. During the convergence procedure, the values in EEROM are fed through a digital-to-analog converter (DAC) to generate the original complex waveform. The convergence is only approximate because it represents the condition of the new display in the factory. The operator must further adjust the convergence to account for the current condition of the display, which has been affected by such factors as temperature, age, and position.

Measuring Misconvergence

by Jerry Murch
Tektronix, Inc.
Wilsonville, OR

As with most specifications, the problem when considering convergence values is determining how to make a qualitative judgment from purely quantitative information. How much better is a convergence of 0.3 mm than 0.5 mm or 0.8 mm? While designing the 4115B, Tektronix engineers tried to answer this question by devising an experiment to find the value at which a user could no longer detect misconvergence.

In the experiment, the 4115's screen was split in half and two identical images were displayed. At first, both images were converged as well as possible within the technical limits of the display. One of the images was then misconverged to one of a series of specified values. The subjects were asked to choose the better image. When the misconvergence reached 0.4 to 0.5 mm, all the subjects preferred the converged image. Often they could not indicate why one image appeared better. The engineers repeated the experiment, this time telling the subjects that one of the images was being misconverged. The subjects were asked to choose the best converged image. When the misconvergence reached 0.2 mm, almost all the subjects could detect the difference in convergence between the two images.

The results of the study show that most people will notice a decrease in the display quality of an image if misconvergence exceeds 0.4 to 0.5 mm. People who are aware of the problem can detect any misconvergence of more than 0.2 mm. Reasoning that the users of a high-resolution color display are or will soon be aware of misconvergence, Tektronix designed the 4115B to meet a convergence specification of less than or equal to 0.2 mm across the entire viewing area of the screen. The display's autoconvergence system not only makes this possible, but also automatically maintains what is, in effect, optimum convergence. When the 4115B's convergence is set to its specification of less than or equal to 0.2 mm, most users will not be able to detect misconvergence. When misconvergence does become detectable, the user need only press a button to restore convergence to the original specification.

The 4115B's autoconvergence system (Figure 4c) removes the user from the convergence adjustment task, not only saving adjustment time, but enabling more precise convergence. Basically, autoconvergence uses optical feedback to sense the location of each electron beam. As in digital convergence, a complex waveform is stored in EEROM in the form of digital values. By modifying these values, which are then fed through a DAC and amplified, the display's microprocessor can adjust the beams so that they converge within the specified range of less than or equal to 0.2 mm at any viewable point on the screen.

Figure 5 shows a side view of the autoconvergence CRT. As the electron beams scan the screen, phosphor patterns (indexing phosphor) on the back side of the shadow mask emit light back into the tube. Through a window in the CRT, the photodetector senses this light and outputs the information to the processor. The phosphor patterns do not block the holes of the shadow mask and have no effect on beam energy reaching the phosphor dots (viewing phosphor) on the screen. An aluminum layer between the shadow mask and the screen, while reflecting light from the phosphor dots out toward the viewer, also serves to prevent any errant screen light from reaching the photodetector.

The phosphor patterns on the shadow mask are deposited in locations corresponding to major convergence points on the screen. The processor adjusts the beam positions at every major point, enabling the 4115B to maintain its convergence specification across the entire viewing area. Each phosphor pattern is shaped so that the photodetector will output two pulses (Figure 6). The photodetector outputs a pulse when the beam scans first the vertical line in the pattern and again when the beam scans the diagonal line. From the time difference between the two pulses, the processor can determine the relative positions of the electron beams.

During the autoconvergence procedure, the processor directs the display to turn on one electron beam at a time. In this way, it receives a pair of pulses for each beam at each pattern location. By comparing the pairs of pulses, then individually moving each beam, the processor can adjust convergence. When the pulse pairs for all three beams match, within the range of the convergence specification, the autoconvergence procedure is complete.

Figure 7 illustrates the autoconvergence procedure. In this example, the green and red beams are turned on to produce a yellow line. The beams, however, are misconverged so that separate red and green lines appear (Figure 7a). As the first step, the processor turns off the red beam to get a photodetector output for the green beam (Figure 7b).

In Figure 7c the processor turns off the green beam, activates the red beam, and compares the new pair of pulses with the green beam's detector output. From the difference in the red and green pulses, the processor computes the required corrections and moves the beams until the pulse pairs match and the beams are converged (Figure 7d).

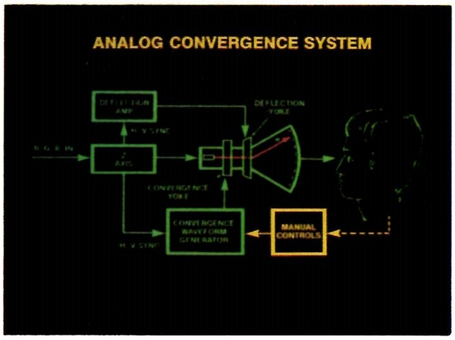


Figure 4. Three different ways to correct misconvergence.

Figure 4a. Analog convergence adjustment.

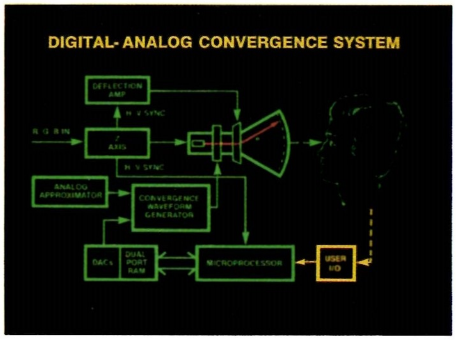


Figure 4b. Digital convergence requires operator intervention to adjust for the current condition of the display.

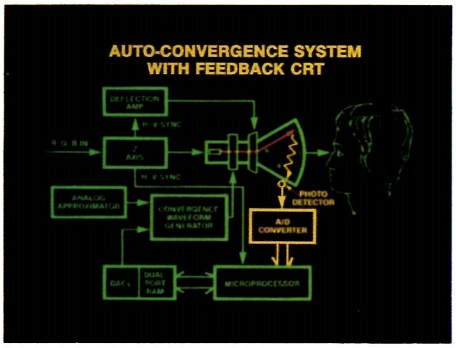


Figure 4c. The 4115B's autoconvergence system removes the user from the convergence adjustment task.

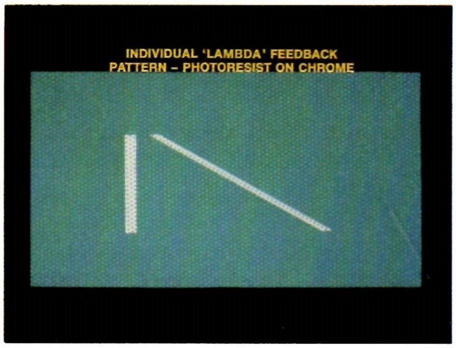


Figure 6. Each phosphor pattern is shaped so the photodetector outputs two pulses.

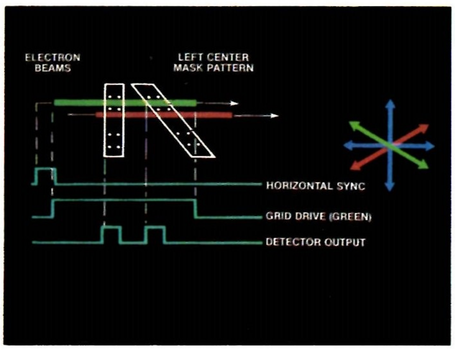


Figure 7. Correcting misconvergence in the 4115B.

Figure 7a. A misconverged yellow line appears as separate red and green lines.

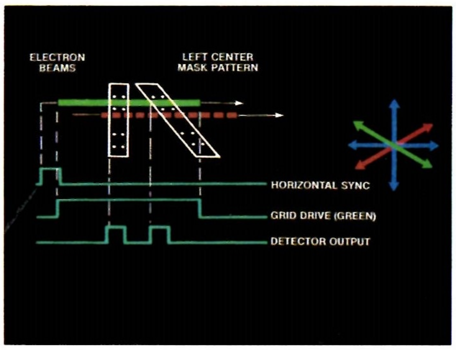


Figure 7b. The processor turns off the red beam to get a photodetector output for the green beam.

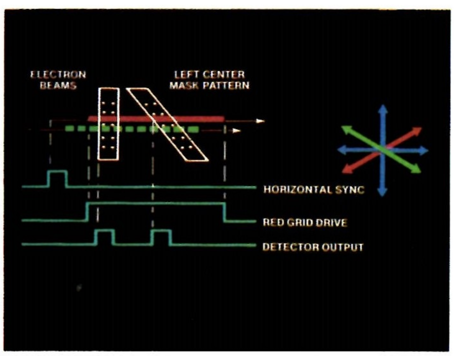


Figure 7c. Removing the green beam and activating the red beam, the processor compares the new pair of pulses with the green beam's detector output.

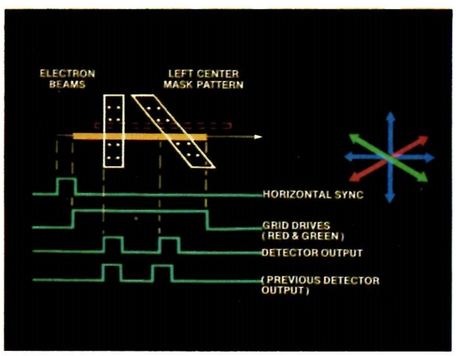


Figure 7d. From the differences in the red and green pulses, the processor computes the required corrections.