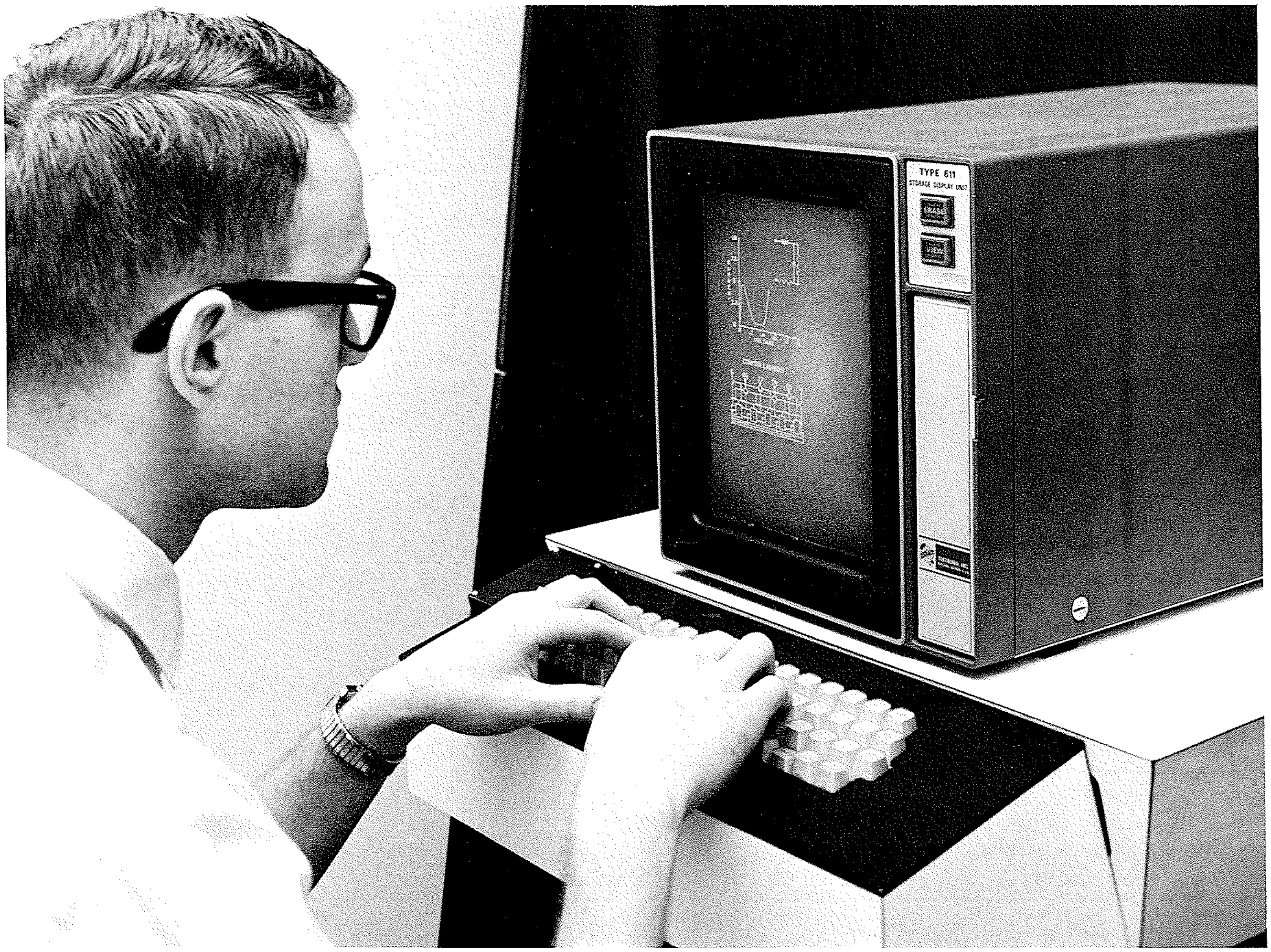


Ray Goolsbey, Tektronix Digital Instruments Engineer, checks out his programs on the Type 611 Storage Display Unit. See photo on page 9.

Direct-View Bistable-Storage CRT Resolution

A Definition and Explanation of Resolution for Information Display Instruments

Introduction

In the case of nonstorage measuring oscilloscopes, resolution is usually given in terms of the width of the oscilloscope trace. The conditions under which the trace width was measured must be known before a value can be placed on the results.

(1) Was the width measured at normal or full writing speed?

(2) Was the measurement made photographically or with a shrinking raster?

(3) What percent is edge defocus?

In the case of the direct-view bistable-storage tube (DVBST), measuring trace width is not as difficult as in nonstorage CRT's. The transition from a nonwritten part of the CRT screen to a written portion is fairly abrupt. The gray-scale distance is insignificant and the trace remains stationary while you measure it. The Tektronix Type 601 and 611 Storage Display Units employ the DVBST as a display device and are intended for display of alphanumerics and graphics from computers. In this application the resolution of DVBST's becomes an important parameter. Their resolution is defined in terms considered most useful in the fields which require such displays.

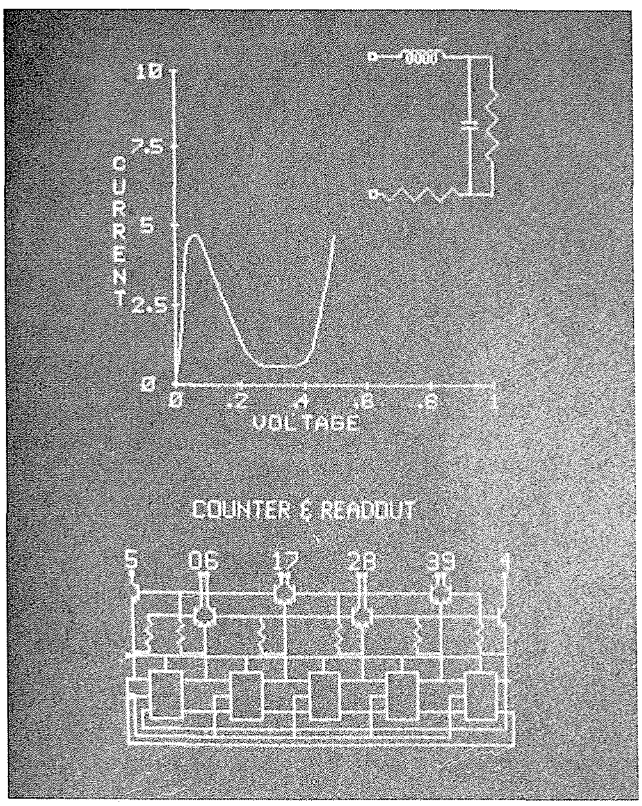
The design objective for the Type 611 required enough resolution to make a set of 4000 alphanumerics unambiguously legible (well-spaced for clarity), based upon a 7 x 9 dot matrix of nominal 10-mil dots. For the Type 601, the resolution objective was to get as much resolution as practical using a conventional electrostatic deflection system in an 8 x 10 cm field. The electrostatic deflection requirement resulted in a spot size approximately twice as large as that of the Type 611, making it capable of displaying about 1250 characters (based upon a well-spaced 7 x 9 dot matrix of nominal 20-mil dots).

Center Resolution

For conventional tubes, the shrinking raster* test is handy for testing center resolution and about 20% correlation

*See Trace Width, P12

Fig 1 The curve and equivalent circuit of a 4.7 mA tunnel diode are shown on the upper display. The lower display shows the logic diagram of a Tektronix Decimal Counter with 10-line readout.



can be obtained between skilled operators. Photographic measurement is slow, tedious, and quite repeatable with skilled operators, with results usually more conservative than the shrinking raster method. This resolution test is usually expressed as either a trace width, or as lines per unit distance. One caution here—perform the test in both directions to be sure the CRT spot is round. Do not reset the astigmatism, focus, or intensity settings between tests. The lines per unit distance may be defined as **specific** resolution. The number of lines obtained by multiplying the specific resolution by the length of the display is then **total** resolution, if the display is uniform.

Effective Resolution

A **total resolution** of 525 lines (as used above) is more total resolution than 525 lines of **TV resolution**. In the case of television, approximately 40 of the 525 total lines are lost due to retrace blanking. As a result, only 485 lines are available for viewing. Even further, TV has less **effective resolution**, because its horizontal format may not be in registration. If a scene is composed of 243 horizontal white lines and 242 black spaces, the TV raster may not line up with a scene (it is understood that the 485 available TV lines are nominally just in contact so there is no space between TV lines). If the TV camera is aimed just right, where the lines of the raster scan just superimpose the scene, the scene will then reproduce correctly. However, if the camera target is moved ½-line width, all the lines reproduce gray, since the scanning line will be split horizontally—half white, half black—the camera will respond gray. To be certain of avoiding this problem (100% resolution or 0%, depending on how the scene is arranged), the system could be designed with twice the number of lines. Ordinarily this would be wasteful, since such severe scenes are not usually encountered.

In TV work, this problem is referred to as the Kell effect, and is accounted for by stating that the effective resolution of a non-registered raster is about 70% of the line count. A 525 TV line system then is actually about a 340 effective line system (vertical resolution), or about ⅔ of what it sounds like.

This is not true along a horizontal line; that is, there is no Kell effect along a line, because the video signal can appear anywhere along a horizontal line. For example, a properly gated 4-MHz sine-wave train could produce alternate black-to-white bars vertically along the screen. With about 54 μs visible along each horizontal line, there would appear to be 432 total alternate black and white bars across the screen. The bars can be moved to any desired position by simply shifting the starting phase of the gated 4-MHz signal. In other words, if a scene consisted of 216 white vertical stripes alternating with 216 black stripes, the camera would reproduce the stripes, even when the scene moves slightly, because there is no restriction on video time position **along** a line—only in registration of the lines themselves.

Computer Driven Displays

In most computer-generated displays, there is no Kell effect either, because the computer usually generates a registered format. For example, the computer might have 512 possible vertical addresses for the spot. It will never have to worry about something being in the 468½ memory! In figure 2a, the letter "A" is shown with each spot written at a specific address as determined from a grid which is basically 9 x 7 dots in size. If the dots are at the resolution limit of the CRT, it is tempting to measure the spot size, measure the screen, and predict the number of addressable points on the display. But note that if the CRT screen is substantially grainless (spot size bigger than the phosphor agglomerates), an improved "A" may be written by addressing the beam in half spot steps, as per figure 2b. Thus, the number of addressable points is a property of the system, not the display device (an exception is when the display device is quantized, such as an array of gas-discharge cells, which can light up only at discrete positions). Thus a computer system of 1024 x 1024 addresses has about 10^6 addressable points, but if the display device has a 512 line x 512 line total resolution, then there are less than 3×10^4 **simultaneously** resolvable points for the system. In 4-MHz, 525-line TV (forgetting Kell effect for the moment) there are approximately 485 x 432 simultaneously resolvable points. However, there are an infinite number of addressable points—485 fixed vertical addresses with an infinite number of horizontal addresses! For a computer driven display, the addressable number of points are approximately equal to, or to some sensible low multiple of the number of simultaneously resolvable points.

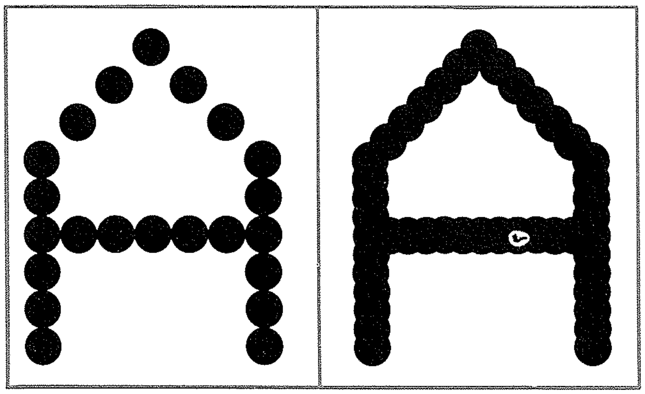


Fig 2a Letter A—9 x 7 matrix   Fig 2b Letter A—½ spot width steps

Dot Resolution

Simultaneously resolvable points could be determined by building a generator which would fill the screen with dots based upon some coarse grid, see figure 3a. Turning up a control knob, to increase the number of dots would produce figure 3b. The problem is to know when enough dots are present. Because the dots are not uniform, some dots will touch before others. A realistic specification will take this into consideration.

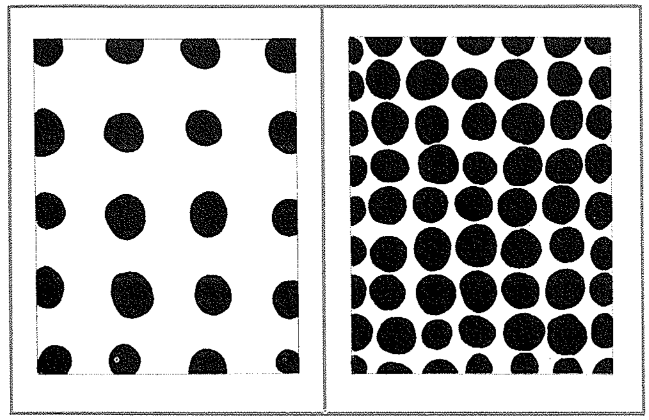


Fig 3a Coarse grid—few dots   Fig 3b Fine grid—many dots

This non-uniformity of the written dots is the major reason for most of the problems in measuring resolution. There will inevitably be "noise" on a dot's dimension at the resolution limit. Thus for a quality display, the size of a "period" must be greater than the minimum dot size that can be written. Figure 4 illustrates a group of five dots written at the nominal spot size for spacing. Note that the effect of noise on the dimension of the written period has been substantially reduced. This means at normal viewing distances all the 5-spot periods look substantially uniform although the individual spots do not.

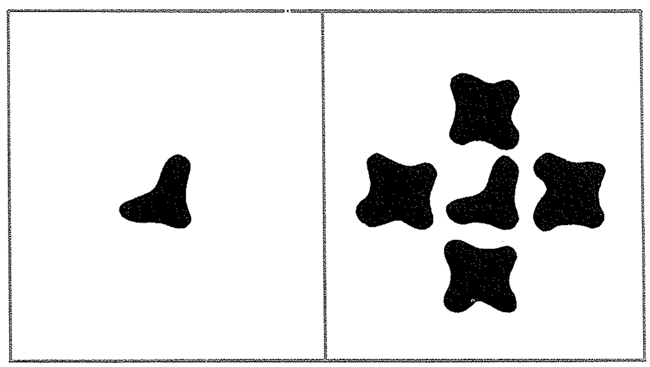


Fig 4a Single dot   Fig 4b "Period" composed of 5 dots

Dotted Line Resolution

By writing the Type 611 screen with a 300 x 400 dot matrix the problem is simplified. Under ideal conditions there would be uniform round dots spaced one diameter apart. Actually, at the center of the CRT, the dot is generally smaller than nominal and not uniformly round with more than a diameter's spacing between dot edges. In the corners, the dots are generally elliptical and have less than nominal spacing. If the written dots in the center are not too small (for example, not less than half nominal size) and the dots in the corners do not touch (for example, less than 70% over size), then a written message should be clearly legible. The uniform nominal distance separating the dot centers is easy to set up and is consistent with computer grid usage. In addition, by looking for the areas

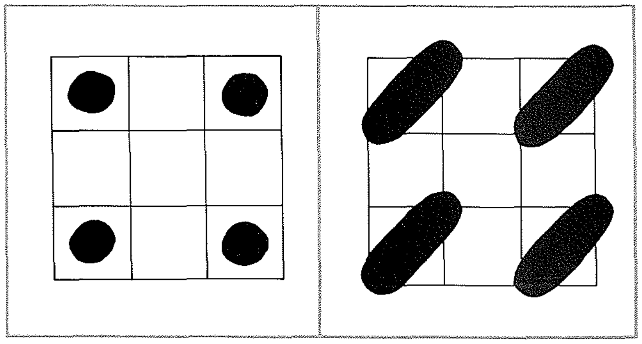


Fig 5a Center dots   Fig 5b Corner dots

that appear brightest and dimmest, the places where measuring is worthwhile are easily seen. A quality criterion which might be applied in "in any group of 10 x 10 dots no more than 10 shall be missing, and no more than 10 pairs of bridging shall occur." The "missing" specification accounts for too small a dot and the "bridging" specification takes care of too large a dot. A further advantage is that with the dotted line method, the screen is approximately 25% written. This is closer to the percent of the screen which is written in an ordinary alphanumeric message. Using line pairs the screen is nominally 50% written.

Interpreting Resolution

There are many methods of ascertaining resolution, but the following factors should be kept in mind:

(1) A **total resolution** may be derived from the center specific resolution multiplied by the length of the display. This is usually an optimistic value, because the resolution is usually poorer off-center.

(2) Sometimes **total resolution** is derived from the integral of the various specific resolutions across the tube, multiplied by their respective distances over which they apply (sum of the actual maximum number of lines of varying width that can be fitted across the tube). This is hard to do, since the lines must be generated one at a time, and tried for "fit", to observe if the defocused width put it at the correct spacing from the preceding line, etc. This method, because of averaging, is close to a realistic number.

(3) **Total resolution** is derived from the worst case specific resolution multiplied by the length of the display. In a computer driven display this usually results in an overly conservative value.

Noise

When discussing noise consideration, let us note a general principle. A single written spot is not considered appropriate for an "unambiguously written" message. More than one dot is needed to have an economically sensible signal-to-noise ratio. For example, 15 to 25 dots are required to make up well-formed alphanumeric characters. A "dash" on a graph would seldom be shorter than 5 dots in a row.

In any system the effects of noise should be considered. If noise is defined as "anything which is not the message", then there are four outstanding noise sources to consider. These are discussed as they relate to direct-view bistable-storage tubes:

(1) Random noise on a recorded trace width due to the phosphor agglomerate variations.

(2) Spots on the CRT which remain written even after erasure. Since most messages use less than 10% of the CRT area, the probability is high a permanently written spot won't coincide with a desired written spot.

(3) Spots on the CRT which remain unwritten after the spot was excited properly with the writing gun (drop-out).

(4) Spots which appear after the message has been written for a period of time (fade-up).

The "bridging" specification and specifying the acceptable size and number of spots which may appear bright takes care of the first two considerations. Drop-out is covered by specifying the number of dots that may be missing. Specifying contrast ratio after 15 minutes takes care of the last consideration.

Summary

Defining resolution in terms of line pairs has some advantages. Because the term has a history from the field of optics, it is less ambiguous than lines, which then raises the questions: TV lines? Kell effect corrected? etc. Line pairs implies that there are written and non-written lines laid down on a uniform grid where the center-to-center spacing of the written lines is uniform, and the space between written lines (unwritten lines) is equal to the nominal written line width. The actual width of the line and the line space sections vary somewhat but the line pair width is constant. Because of flood-gun collimation considerations, Tektronix tests with dotted lines rather than continuous line pairs. This results in a nominally 25% written field and allows testing under conditions similar to those encountered in information display usage.

The Tektronix Type 601 and 611 Storage Display Units employ new direct-view bistable-storage tubes. These instruments are designed specifically for information display and resolution is specified in terms of the number of line pairs resolvable in the X and Y axis. Defining resolution by this method appears to provide the most meaningful information to those concerned with this application.

For further information on Tektronix Display Units refer to pages 231-236 of Catalog 27 (1968) and consult your Field Engineer.