SERVICE SCOPE

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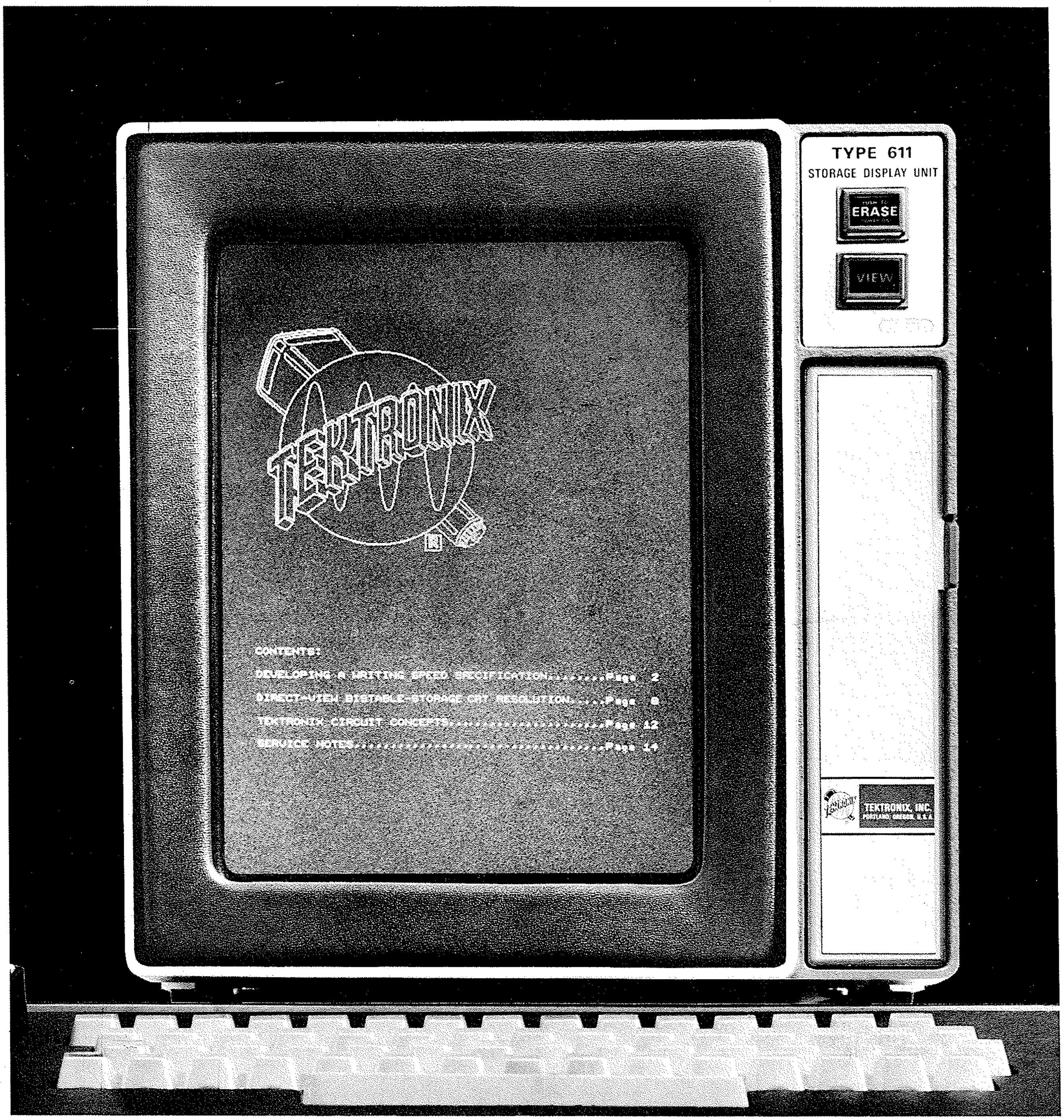


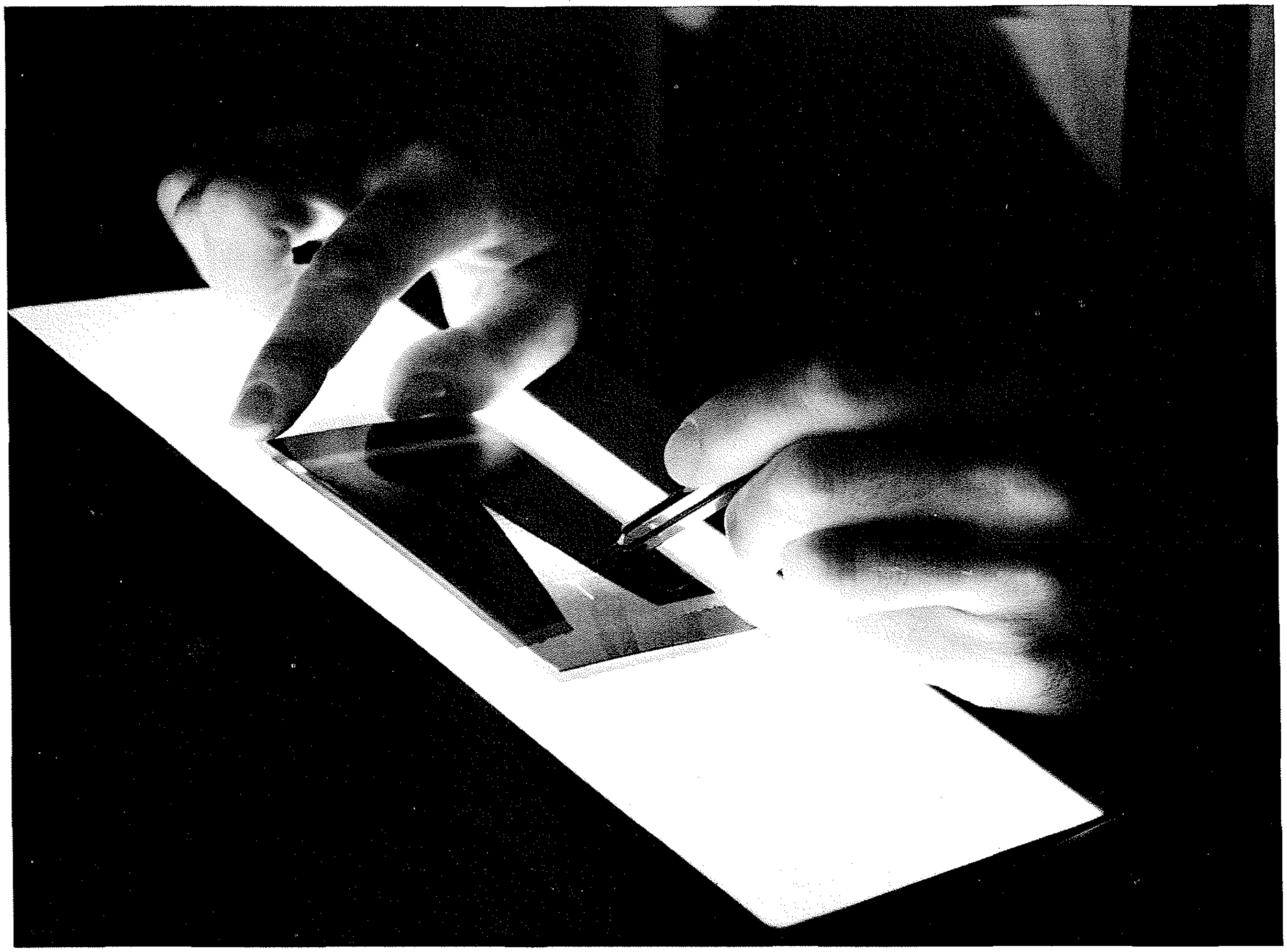


Fig 1 Determining writing speed from a backlighted photograph. Note the use of a mask to cover the peaks of the waveshape.

Developing a Writing Speed Specification

(2.5 cm/nanosecond)

COVER

The Type 611 Storage Display Unit is featured on this issue of SERVICE SCOPE. The familiar Tektronix trademark display was programmed from a disk memory unit and the table of contents entered from the accompanying keyboard. The Type 611's unique storage CRT eliminates the need for display-refreshing memories and provides excellent display resolution without flicker. For information on resolution of Tektronix Direct-View Bistable-Storage CRT's, *see the story on page 8.*

For some years now various groups at Tektronix have been striving to specify writing speed for new Tektronix instruments. The problem is difficult because of the number of variables entering into it. Table 1 illustrates the factors that can enter into specifying writing speed. If such a parameter is specified, then each factor must be carefully examined to determine its contribution. The subjective nature of some of these factors, plus the lack of control over others, (for example film history), all contribute to the problem.

Various approaches were taken in an attempt to control this parameter more completely and consistently. Photomultiplier and microdensitometer techniques, while appropriate for lab correlation, were not considered appropriate for customer use. An important consideration was that the customer be able to duplicate the test conditions at a reasonable cost. Without this requirement, much of the value of specifying writing speed would be lost, for many customers could not measure it.

The effort was then directed toward refining the techniques and controlling the factors that enter into the conventional determination of writing speed. To reduce the effect of variations in film sensitivity from roll to roll and frame to frame, five Polaroid* backs were used. Each contained Polaroid Type 410 film, and one exposure was made using each back. The results of the five pictures were then averaged and this value recorded.

The photographs are viewed while backlighted and masked as shown in fig 1. The use of backlighting (transillumination) tends to standardize the reading of recorded wave shapes. When determining writing speed, it is important that the photograph be well illuminated as the contrast sensitivity of the eye is a function of brightness. Backlighting is the preferred method of obtaining adequate illumination (approximately 1 foot-lambert) without the harsh glare that may accompany reflected light. This technique does not apply to Polaroid pack films as the plastic base is too opaque. Although the surface is glossy and harsh to the eye, adequate reflected light will achieve the same results as backlighting.

Using a mask to cover the peaks of the damped sine wave is important when making the measurement. The vertical velocity of a sine wave is zero at the peaks and maximum at the midpoint, so there is a considerable range of brightness on the photo. Without a mask there will be the illusion of seeing the complete trace, as the viewer will tend to connect the area between the bright peaks. Because of this he will tend to read a writing speed that is higher than the correct one. A line chosen as discernible without a mask may very well not be discernible when the peaks are covered with a mask.

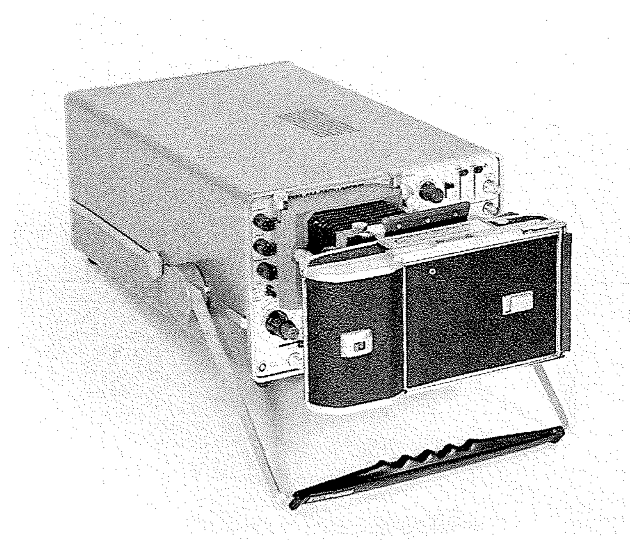


Fig 2 Shown above is the Tektronix Type 454 150-MHz Oscilloscope with the Type C-31 high writing speed camera system. The combination has a specified writing speed of 3200 div/μs with P11 phosphor.

To acquire enough information from which to compile a specification, a group of 74 instruments (Tek-

*Registered Trade-Mark, Polaroid Corporation

FACTORS INFLUENCING WRITING SPEED

Oscilloscope Controls and Circuitry

- Focus misadjustment
- Astigmatism misadjustment
- Intensity setting
- Unblanking pulse height and shape
- Heater regulation
- Calibration
- Accelerating potential

CRT Gun

- Mutual conductance (Beam current vs. Grid drive)
- Spot size
- Edge defocus
- Plate intercept

CRT Screen

- Phosphor efficiency
- Uniformity of phosphor efficiency across the screen
- Spectral distribution
- Persistence
- Phosphor graininess
- "Sticking" of phosphor

Camera and Lens

- Graticule transmission
- Dichroic mirror transmission
- Effective aperture
- Lens transmission (spectral response and transmission efficiency)
- Lens shading (vignetting)
- Magnification (object-image ratio)

Film

- Sensitivity (including change with age and environment)
- Spectral response
- Processing
- Uniformity
- Reciprocity

Interpretation of Photographs

- Film fog level
- Trace contrast
- Trace width
- Viewing conditions
- Human judgment

Table 1 Major factors that affect writing speed.

tronix Type 454, 150-MHz Oscilloscopes) were used as a sample. The instruments were composed of 6 different groups taken over a 6 month period, and selected from manufacturing on a random basis.

The 74 instruments were read by the various readers subject to the following controls:

1. Intensity—adjusted to point of visual extinction with the oscilloscope in the single sweep mode.
2. Focus and Astigmatism—adjusted to produce a sharp trace on both horizontal and vertical axes during low repetition rate displays of a damped sine wave.
3. Phosphor dormant—5 minutes allowed between each exposure to allow decay to a consistent low level.
4. Camera System—Tektronix Type C-40 (f/1.3 lens with 1:0.5 object to image).
5. Exposure—5 seconds.
6. Film Type—Polaroid Type 410 (ASA 10,000).
7. Film Development—10 seconds.
8. Repeat Steps 3, 4 and 5 with 5 different rolls of film.
9. Mask photographs and view backlighted.
10. Record first central segment that is just discernible on each photo.
11. Calculate writing speed from formula—
    ws = 3.14 fA.
12. Average results and record.

Two readers were initially used: Reader 1 with no previous experience in determining writing speed; Reader 2 with considerable experience. The chart below shows the data taken by Reader 1. Note the mean of 1671 div/μs. Reader 2 consistently read higher and the mean value of readings was 1875 div/μs. Photos were then sampled from each of the 6 groups and given to 3 additional readers with no previous experience. This data when correlated with the other, resulted in a group average of 1656 div/μs. This then gave assurance that a specification based on Reader 1's data would be meaningful and repeatable. Note that only one of the 74 instruments fell below the specification of 1250.

In addition, studies were made with P11 phosphors. These studies confirmed that the Tektronix P11 phosphor had 100% more photographic writing speed than the Tektronix P31 Phosphor.

In a discussion of writing speed it is important to discuss briefly ASA exposure ratings as they are the accepted method of specifying negative speed in this country. ASA exposure ratings are measured at 1/50-second exposure to light of normal daylight spectral characteristics. Oscilloscope exposures are different in 2 very important aspects. First, most oscilloscope recordings are a very short exposure and so the normal relationship of exposure and density is subject to failure (reciprocity law failure). In addition, the spectral

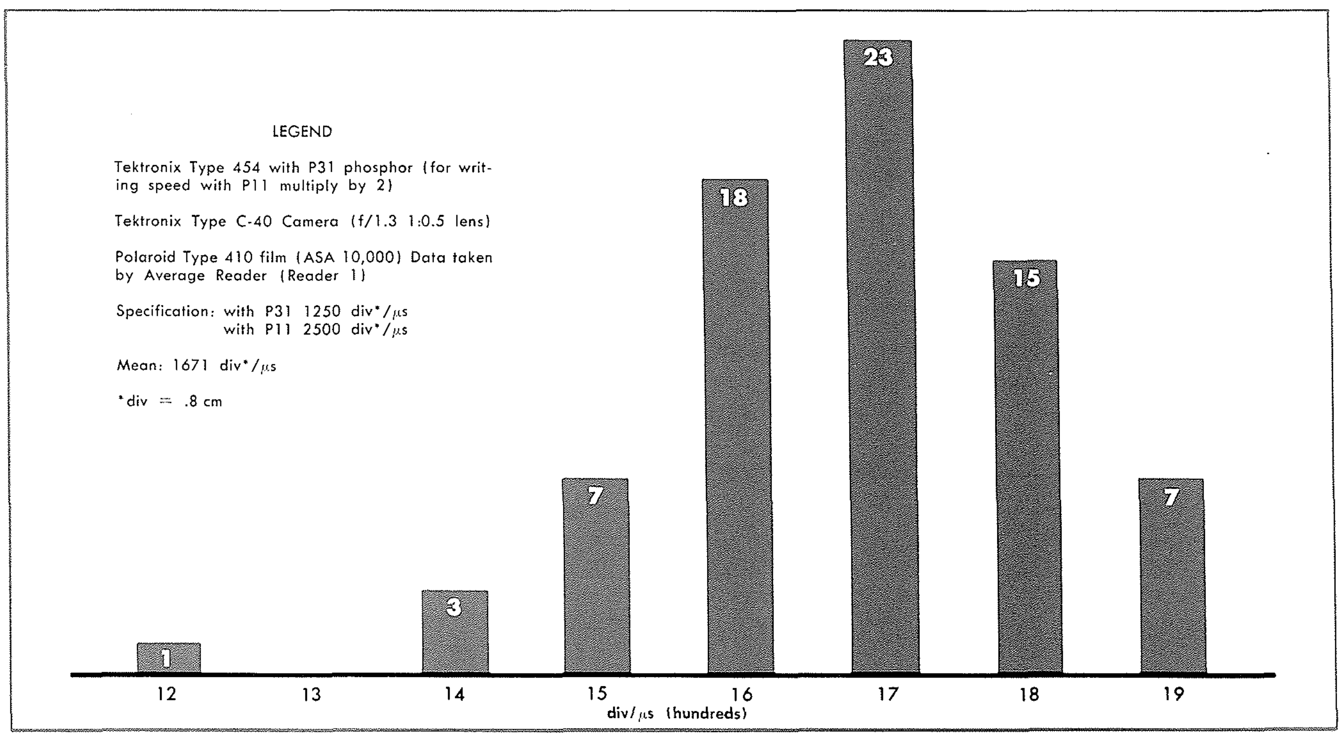
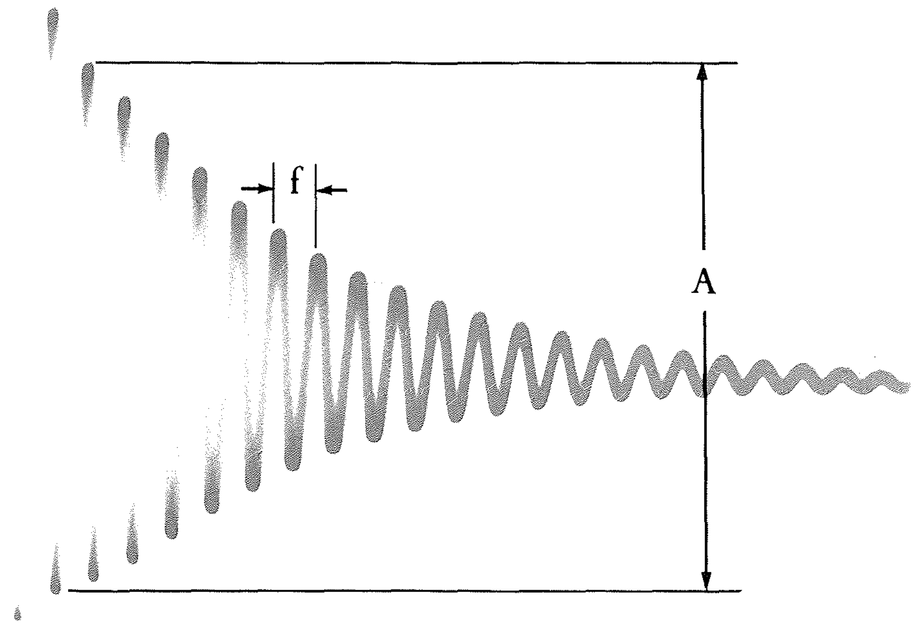


Fig 3 Writing speed distribution of Tektronix Type 454/C-40 (74 instruments).

Photographic Writing Speed

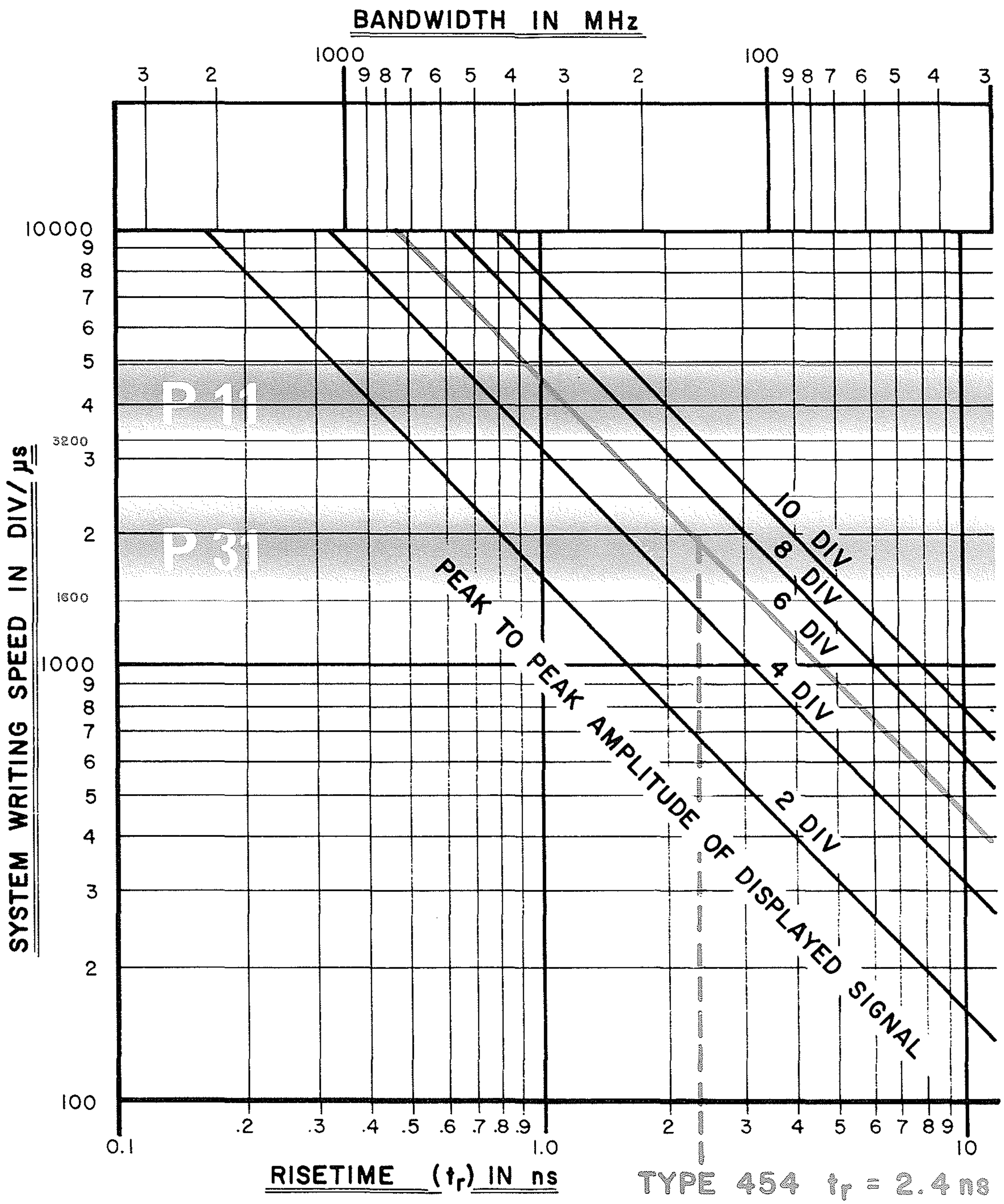


Photographic writing speed is a figure of merit which describes the ability of a particular camera, film, oscilloscope, and phosphor to record a fast moving trace. This figure expresses the maximum single-event spot velocity (usually in centimeters per microsecond) which may be recorded on film as a trace just discernible to the eye.

The results achieved are a function of the combined system performance of the oscilloscope, camera, film, recording technique, and the ability of the film reader to make a consistent interpretation of the results. Prefogging and postfogging of the recording film improve the apparent photographic writing speed of a particular system but the results are unpredictable and difficult to repeat. Because of this fact, Tektronix specifications are made without using fogging techniques. Should the user employ fogging, then the writing speed will be increased according to his skill. Writing speed figures 50-100% higher are possible with controlled techniques on Polaroid Type 47 and Type 410 film.

The illustration above shows the way in which writing speed is measured. Display a single trace of a damped sine wave whose frequency and amplitude is such that the rapidly rising and falling portions of the first cycle or two fail to record. The peak-to-peak amplitude of the sine wave should be three to four times as great as the horizontal distance occupied by one cycle. This is necessary to insure that the horizontal velocity component is small compared to the vertical velocity component.

The writing speed capability of the oscilloscope is determined as follows: mask out the sine-wave peaks on the photograph leaving the central one-third visible. View the photograph while backlighted. Starting from the left, find the first rapidly rising or falling portion of the damped sine wave which is discernible. Let A represent the vertical distance in centimeters between the peaks which are connected by this portion and let f be the frequency of the damped sine wave in megahertz. Since the maximum vertical velocity of a spot moving in simple harmonic motion is equal to fA, the writing speed in centimeters per microsecond may be calculated by:
photographic writing speed $= 3.14\,fA$



NOMOGRAPH: Writing speed VS. displayed signal amplitude

Blue figures indicate specification points

Fig 4 Type 454/C-31 Nomograph

distributions of the different phosphors used are all different from that of normal daylight. As a result the ASA ratings of film do not apply accurately to oscilloscope photography. There is usually some relationship between ASA rating and maximum writing speed, however. Thus, it would be safe to assume that a film with a very high ASA speed rating would probably have a higher maximum writing speed than a film with a lower ASA speed rating. For example, ASA 10,000 has approximately 2—2.5 the writing speed of ASA 3000.

What does the specification of writing speed mean to the oscilloscope user? First, the user may now determine whether an oscilloscope will meet his needs in single-shot applications. An oscilloscope with a stated risetime is one thing. To know that an oscilloscope is adequate to photographically record a single event is another thing entirely. The chart in fig 4 illustrates this. With P11, the Type 454 is capable of presenting 10 divisions of data with a pulse of 2.4-nanoseconds risetime being applied. Since the instrument has 6 divisions of vertical scan, the Type 454 has a comfortable margin of performance.

The other area where writing speed is of major concern is in marginal viewing applications of repetitive events. Oftentimes, a user will want to observe a specific pulse of a pulse train and examine it in detail. If the pulse of interest is, for example, the 30th one, then the effective repetition rate has been decreased by 30, since that time has been used to delay the sweep. Therefore, viewing may be quite difficult. In addition, ambient light may contribute to a marginal viewing condition. If marginal viewing is a continuing problem then an instrument with additional writing speed should be considered and evaluated.

Since the eye is more responsive to the yellow-green than to the blue-violet region*, visual writing speed and photographic writing speed have definite characteristics of their own. Most photographic film used in oscilloscope recording is more responsive to blue light, and a phosphor such as P11 peaked in this region will give excellent results. The eye will respond best to a phosphor such as P31 because its spectral characteristics are peaked in the green area. To concern ourselves with the two most commonly used phosphors, P11 has twice the photographic writing speed of P31, while P31 has nearly 7 times the luminance (spectral response corrected to that of the average eye) of P11.

The nomograph shows the relationship between writing speed, frequency, risetime and display size. In addition colored bands have been used to illustrate the writing speed distribution of the 74 sample instruments. These bands take into consideration the recently introduced Tektronix Type C-31 Camera. This camera has

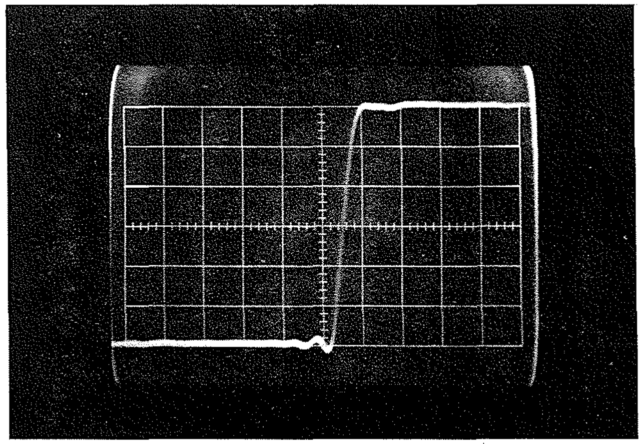


Fig 5 The Type 454/C-31 displays a single-event pulse with 2.4-ns risetime.

an f1.2 lens, a 1:0.5 object-to-image ratio and improves writing speed nearly 30% over its predecessor the Type C-40. The Type 454/C-31 with P11 phosphor has a writing speed of 3200 div/μs (2560 cm/μs). The P31 distribution is the one used in the control group. The P11 band is applicable because the photographic writing speed of P11 is twice that of P31. To use the chart, find the risetime or bandwidth of interest and follow the line until the display size desired is intersected. At this point read on the left axis the writing speed required to adequately record this information on a single event basis.

A significant step has been taken by incorporating writing speed into the Tektronix Type 454 Oscilloscope catalog specification. In addition, a considerable safety margin has been provided the oscilloscope user because of the following:

1.) No film fogging is relied upon. Skillful fogging techniques may allow up to 100% additional writing speed.

2.) Writing speed specification is based upon minimal performance not average.

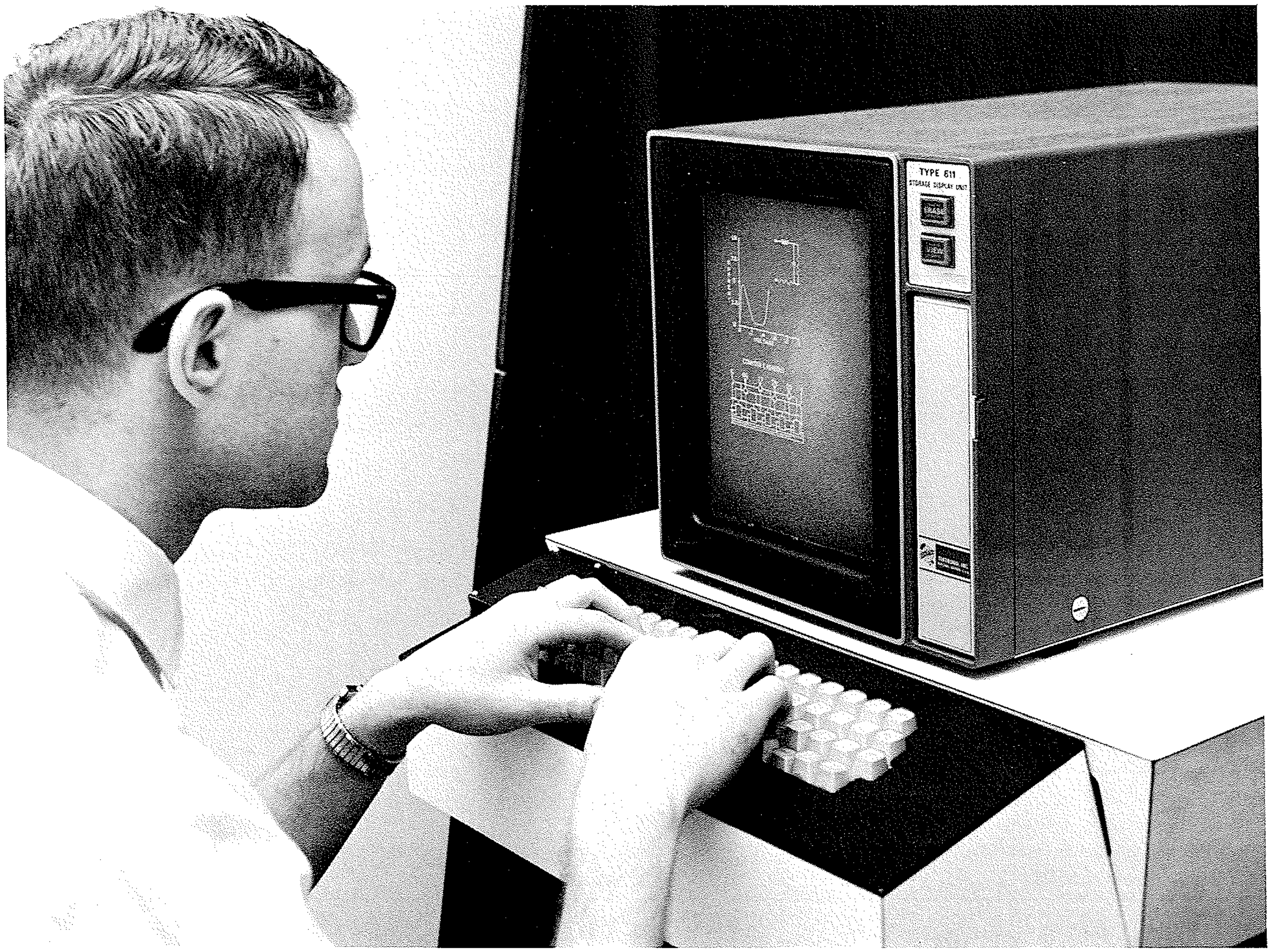
3.) There is sufficient writing speed to write 10 divisions vertically (CRT is 6 divisions vertically).

4.) Data is based on average of several inexperienced readers. Studies indicate that as readers become more experienced they are able to attain higher readings.

The oscilloscope user can now select his instrument, *knowing in advance,* the minimum writing speed he may expect. He is assured of having sufficient writing speed to record a single event at the risetime (or bandwidth) of the system.

For further information on the Type 454 Oscilloscope and Type C-31 Camera contact your local Field Engineer. Complete Type 454 specifications are given on pages 43-47 of Tektronix Catalog 27 (1968).

*See Human Eye Response, P13



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.

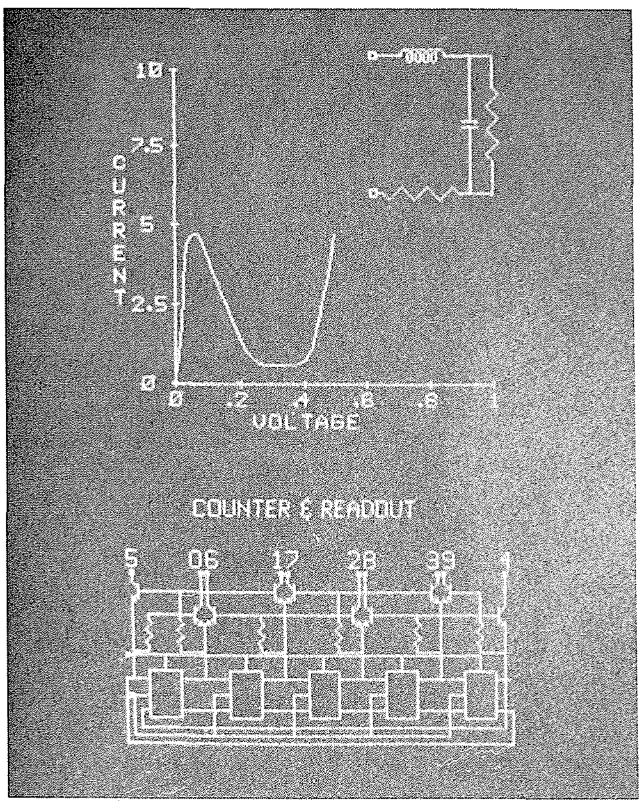
The design objective for the Type 611 required enough resolution to make a set of 4000 alphanumerics unambiguously legible (well-spaced for clarity), based upon a 7 x 9 dot matrix of nominal 10-mil dots. For the Type 601, the resolution objective was to get as much resolution as practical using a conventional 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 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.

*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.



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

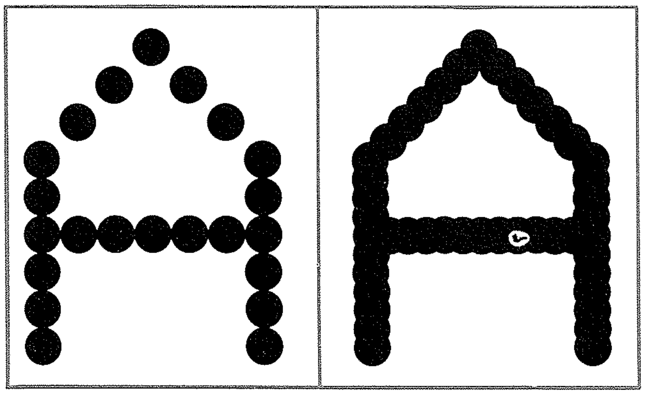


Fig 2a Letter A—9 x 7 matrix   Fig 2b Letter A—½ spot width steps

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 x 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.

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.

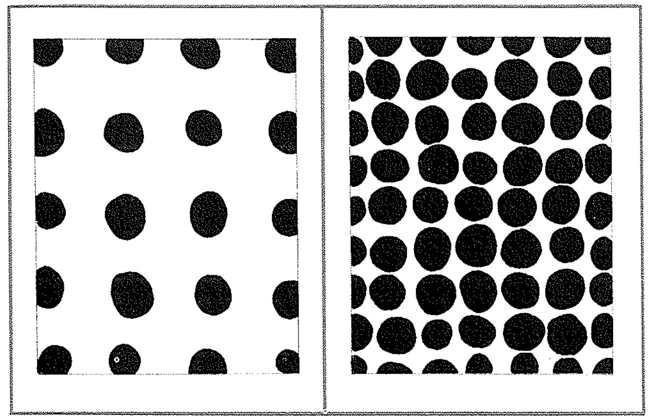


Fig 3a Coarse grid—few dots   Fig 3b Fine grid—many dots

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.

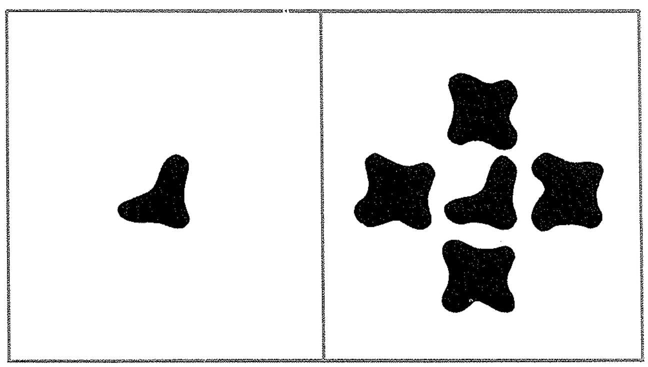


Fig 4a Single dot   Fig 4b "Period" composed of 5 dots

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

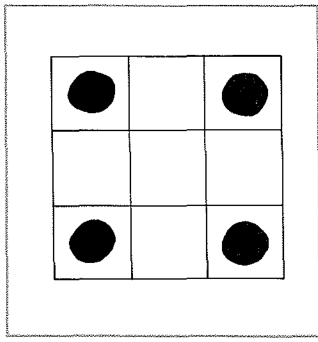


Fig 5a Center dots

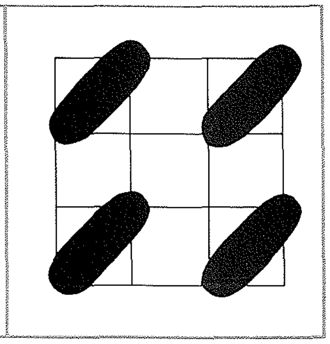


Fig 5b Corner dots

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).

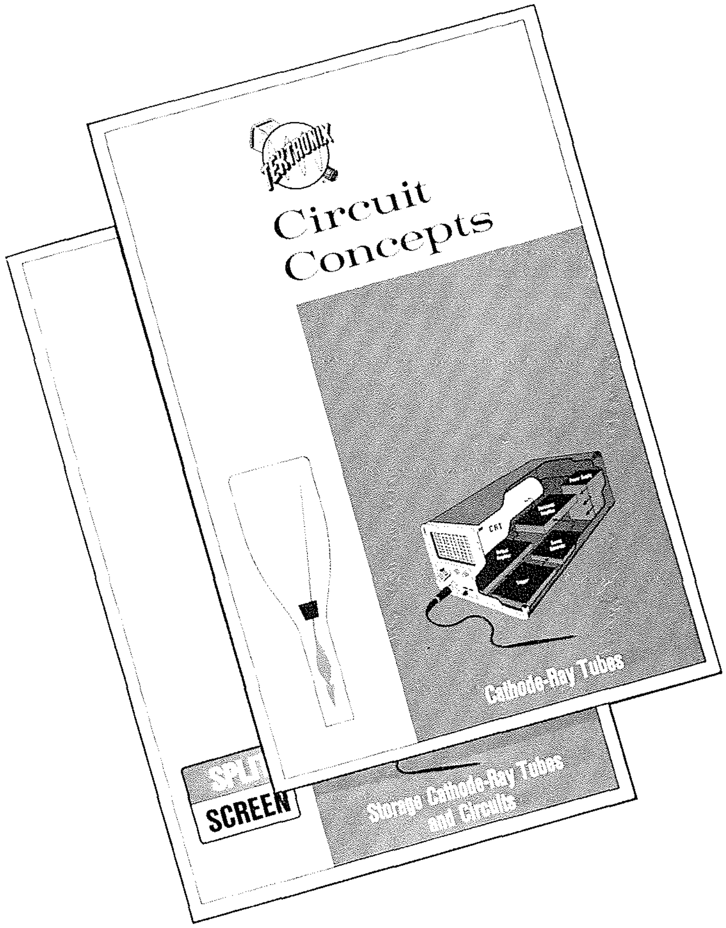
The "bridging" specification and specifying the acceptable size and number of spots which may appear bright takes care of the first two considerations. Drop-out is covered by specifying the number of dots that may be missing. Specifying contrast ratio after 15 minutes takes care of the last consideration.

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.



Circuit Concepts from Tektronix

The Circuit Concepts Program at Tektronix was initially established to fulfill an internal training need. A body of literature was needed to assist in the training of Field Engineer Trainees. As the program evolved, the material developed appeared excellent for customer use. As a result, a series of Tektronix Circuit Concept books are being created which will be helpful to many customers.

The intent was to develop a format that would be a reference book for various categories of information. The book is a convenient size (6 x 9) and is indexed for quick reference. Should you wish further information on Tektronix Circuit Concepts, contact your local Field Engineer.

The material on pages 13 and 14 is taken from "Cathode-Ray Tubes" and is indicative of the content. The other title currently available is "Storage Cathode-Ray Tubes and Circuits".

TRACE WIDTH

The term "trace width" has been used in a general sense without definition. A line or spot on a CRT is not uniform in brightness but is brightest in the center and decreases in brightness toward the edges. The distribution of the electrons in the beam causing the trace or spot are concentrated in the center and the density decreases toward the edges. This variation in brightness presents a problem in answering the question, "How wide is the trace?"

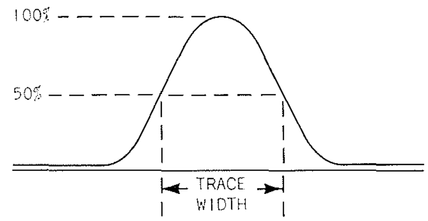


Fig 8-4. Gaussian distribution of trace width.

A solution (though not the only one) is to assume the distribution is Gaussian (fig 8-4) and use a shrinking raster method of making the measurement. This method requires a raster (our example uses 11 lines—fig 8-5). The measurement is made by shrinking the raster down until the 50% points of brightness on two adjacent lines merge. This 50% point is achieved when the dark line between the traces first disappears. The width of the

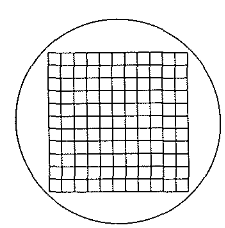


Fig 8-5. Raster to measure trace width.

raster is measured and the resultant trace width is 1/11 of the width. This yields a trace width measured between the 50% brightness points (fig 8-6). All CRT data is taken by this method.

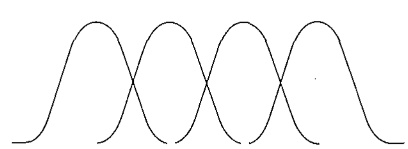


Fig 8-6. Trace width measurement using 50% brightness points.

HUMAN EYE RESPONSE

An important factor in selecting a phosphor is the color or radiant energy distribution of the light output. The human eye responds in varying degrees to light wave length from about 400 to 650 nanometers or from deep red (650 nanometers) to violet (400 nanometers). The human eye is peaked in its response in the yellow-green region at about 555 nanometers and falls off on either side in the orange-yellow area to the right and the blue-violet region to the left (fig 10-1). The eye is not very receptive to deep blue or red.

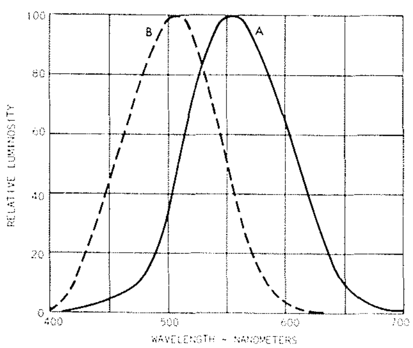


Fig 10-1. Standard luminosity curve.

If the quantity of light falling on the eye is doubled, the brightness "seen" by the eye does **not** double. The brightness of a color tone as seen is approximately proportional to the log of energy of the stimulus.

The response of the eye to various colors is believed to be due to the construction of the eye. One theory is that the cones of the retina respond to color stimuli and that each cone consists of three receptors. Each receptor is believed to respond to a different wave length of visible light; a yellow-blue, a red-green and a black-white receptor. An average can be taken of the color response of many people and a "standard" response curve for an average person, as shown in fig 10-1, can be compiled.

The term **luminance** is the photometric equivalent of brightness and is based upon measurements made with a sensor having a spectral sensitivity curve corrected to that of the average human eye. The unit commonly used for luminance measurements is the foot lambert. The term **luminance** implies that data has been measured in a manner, or has been so corrected, to incorporate the CIE standard eye response curve for the human eye. CIE is an abbreviation for "Commission Internationale de l'Eclairage" (International Commission on Illumination). The luminance graphs and tables are therefore useful **only** when the phosphor is being **viewed visually**.

PHOSPHOR BURNING

When a phosphor is excited by an electron beam having an excessively high current density, a permanent loss of phosphor efficiency may occur. The light output of the damaged phosphor will be reduced and in extreme cases complete destruction of the phosphor may result. Darkening or burning occurs when the heat developed by electron bombardment cannot be dissipated rapidly enough by the phosphor.

The two most important and controllable factors affecting the occurrence of burning are **beam-current density** (controllable with the Intensity, Focus and Astigmatism controls) and the length of **time** the beam excites a given section of the phosphor (controllable with the Time/Div control). Under normal conditions in CRT's with grid unblanking, the ambient voltage on the control grid will hold the tube in cutoff and no spot will be present on the screen.

When the sweep is triggered, the unblanking pulse turns on the gun and if everything else is working properly the beam can be seen as it moves across the screen. But what if the horizontal amplifier is inoperative? The horizontal plates will not receive a signal under that condition and the beam will not be deflected but it will be turned on by the unblanking pulse. Result?—possibly a burn mark on the screen!

The Intensity control can be adjusted to override the normal cutoff condition of the gun in the absence of an unblanking pulse in a CRT using grid unblanking. If this is done, a spot of reasonable intensity will be seen on the face of the CRT. If the sweep is now triggered, an unreasonably bright spot will occur. Result?—you guessed it—a burn mark.

Remember, burning is a function of intensity and time. Keeping intensity down or the time short will save the screen.

Any phosphor can be burned but some more easily than others. Phosphors may be divided into three groups when considering their burn resistance:

Group 1 phosphors are easily burned and should be used with care. Group 2 phosphors are about 10-100 times more difficult to burn than those in Group 1, so normal care should be exercised. Group 3 phosphors are about 100-1000 times more difficult to burn than those in Group 1. A P31 phosphor is quite difficult to burn. In fact, you really have to want to damage the phosphor even with a 10 kV tube.

The typical phosphor is about 10% efficient. This means that of the total energy from the beam, 90% is converted to heat and 10% to light. A phosphor must radiate the light and dissipate the heat; or as any other substance, it will burn.

Burn Resistance of Common Phosphors

Group 1	Low (easily burned)	P12, P19, P26, P33
Group 2	Medium (moderate)	P2, P4, P1, P7, P11
Group 3	High (hard to burn)	P31, P15

Service Notes

Tony Bryan of our Long Island Field Office offers this suggestion.

QUICK CHECK FOR TUNNEL DIODES

A method of tunnel diode evaluation using your Tektronix Type 454 Oscilloscope without special attachments is offered by the following setup.

Many times, in troubleshooting, substitution of components is recommended as a quick analysis of the circuit malfunction. Many times expensive tunnel diodes are not at hand to make a substitution.

A quick evaluation of the tunnel diodes' ability to switch and at what current level it does switch often helps in the troubleshooting process.

Using a Type 454, the TD may be evaluated using the sawtooth out as a current source for the TD. A 670-ohm resistor from the sawtooth out connector in series with the TD to ground will give a calibrated current/div horizontally of 1 mA/div. The sawtooth voltage goes from 0 volts to 10 volts. Therefore the horizontal display becomes current/div. Looking at the voltage drop across the diode will give a vertical display of the low voltage/high voltage states of the diode.

The display does not give an indication of switching time but confirms that the device has the ability to switch at the correct current level and will probably perform normally in its intended circuit.

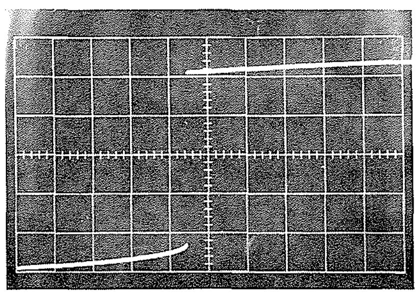


Fig 1 TD3A (4.7 mA)
horiz 1 mA/div: Vert .1 V/div

Figure 1 (photo) shows a TD measured on the Type 454 using the 10-V A SWEEP output voltage, through 670 Ω (plus 330 Ω source) to calibrate 1 mA/div horizontally.

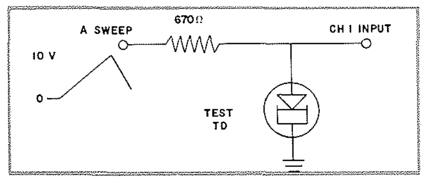


Fig 2 454 measuring circuit

DECORATIVE INSERT REPAIR

Decorative inserts or strips are used to cover certain screw and bolt heads on the outside of many of our instruments. The strips are installed with 3M EC 847, a rubber contact cement. An equivalent adhesive, such as rubber cement, will do the job when replacement is nescessary.

USED INSTRUMENTS FOR SALE

1—Type 517, SN 268; 1—Type 517, SN 483. Both in fair condition. Price: $200 each. Contact: Richard J. Pasco, Litton Industries, 1035 Westminster Drive, Williamsport, Pennsylvania 17704. Telephone: (717) 326-3561.

1—Type 561/63/67. Contact: Harold Rapp, Dialight Corporation, 60 Stewart Avenue, Brooklyn, New York 11237. Telephone: (212) 497-7600.

1—Type 531A, SN 026463; 1—Type H, SN 015488; 1—Type D, SN 025-698. Contact: G. W. Bandy Company, 3086 N. Avon, Burbank, California. Telephone: (213) 846-9020, 849-2962 or 767-6066.

1 — Type 564/3S76/3T77; 1 — Type 109; 1—Type 201-1. Been used only 4 hours. Two years old. Total package: $2700. Contact: Dr. Frank Avignone, Physics Department, University of South Carolina, Columbia, South Carolina 29208. Telephone: (803) 765-4121.

1—Type 526. Excellent condition. Price: $1325. Contact: KVOS, attn. John Price, Bellingham, Washington. Telephone: (206) 734-4101.

1—Type 531A; 1—Type B Plug-in; 1—Type D Plug-in. Excellent condition. Contact: Ash Brown, 246 Cambridge, Kensington, California 94707. Telephone: (415) 524-3005.

1—Type 107, SN 002436; 1—Type TU2, SN 001765; 1—Type P, SN 002-517. Contact: Jack Kane, Jr., Electro Optical Systems, 300 N. Halstead Ave., Pasadena, California 91107.

1—Type 317, SN 211. Contact: Mike Croslin, International Applied Science Labs., 510 South Franklin Street, Hempstead, New York 11550. Telephone: (516) 483-5494.

USED INSTRUMENTS WANTED

1—Type 531 or 1—Type 515 or A series oscilloscope and 1—Type B Plug-in Unit. Contact party at (714) 526-5281, Fullerton, California.

1—Type 104 or 1—Type 105. Contact: Roy Lang, Jr., 1003 Reseda Drive, Houston, Texas 77058. Telephone: (713) 483-2093.

1—Type 535A, 1—Type 545, 1—Type 547 or 1 Type 647 Oscilloscope with dual-trace plug-in: Contact: Vern Baker, TAME Company, Inc., 813 S. 4th Street, La Porte, Texas. Telephone: (713) 471-3069.

REFERENCE TABLE

Reference information for Tektronix Attenuators, Terminators and Adapters has been condensed for your convenience. By cutting along the dotted lines, the table *on page 15* *can be detached for use on your bench.*

BASIC FUNCTIONS OF ATTENUATORS, TERMINATIONS, AND ADAPTERS

PERFORMANCE CHARACTERISTICS

ACCURACY OF INDICATED ATTENUATION RATIO:

TYPE	
UHF	±2% at DC; ±3% at 100 megahertz
GR	±2% at DC; ±3% at 1 gigahertz
TEKTRONIX 125-Ω	±2% at DC; ±3% at 1 gigahertz
BNC	±2% at DC; ±3% at 100 megahertz

VOLTAGE STANDING WAVE RATIO:

TYPE	
UHF	less than 1.2 up to 100 megahertz
GR	less than 1.1 up to 1 gigahertz
TEKTRONIX 125-Ω	less than 1.1 up to 1 gigahertz
BNC	less than 1.1 up to 100 megahertz

POWER RATING:

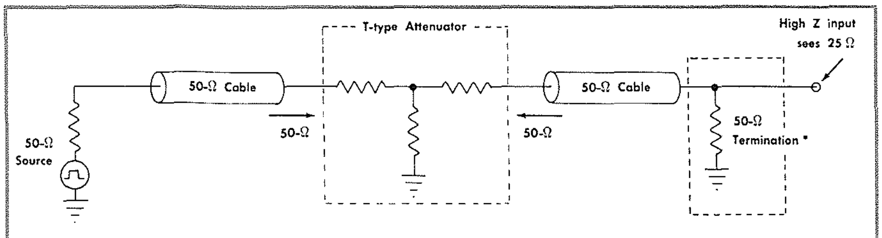
TYPE	
UHF	1.5 watts.
GR	1 watt.
TEKTRONIX 125-Ω	1 watt.
BNC	0.5 watt.

OUTPUT TO INPUT VOLTAGE RATIOS FOR MINIMUM-LOSS ATTENUATORS:

When properly terminated the E_{out}/E_{in} ratios for the various minimum-loss attenuators are as follows:

Connection	E_{out}/E_{in}
50 Ω → 75 Ω	0.63
75 Ω → 50 Ω	0.42
50 Ω → 93 Ω	0.59
93 Ω → 50 Ω	0.32
50 Ω → 125 Ω	0.56
125 Ω → 50 Ω	0.23
50 Ω → 170 Ω	0.54
170 Ω → 50 Ω	0.16

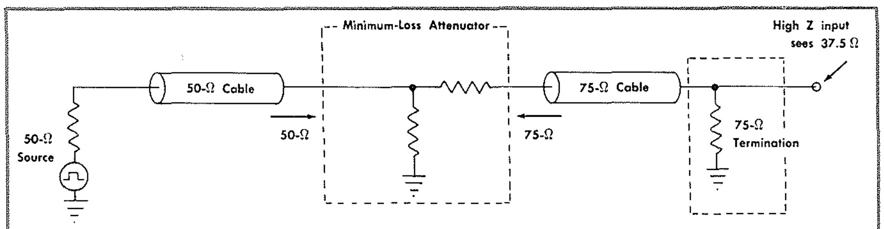
All attenuators, with the exception of minimum-loss types, are T-type attenuators.



Typical Use of a T-type Attenuator, and a Termination.

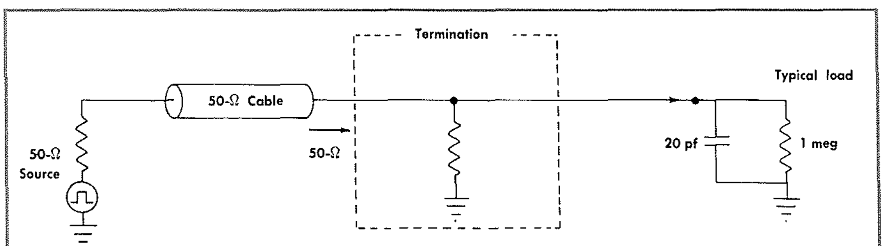
ATTENUATORS—*Two types are included under this designation, the T type and the minimum-loss type.*

T-TYPE—*Maintain the proper impedance match between the signal source and the input to an instrument while attenuating the signal by an indicated ratio. T-type attenuators must have a load of the correct impedance to give the indicated attenuation ratio.*



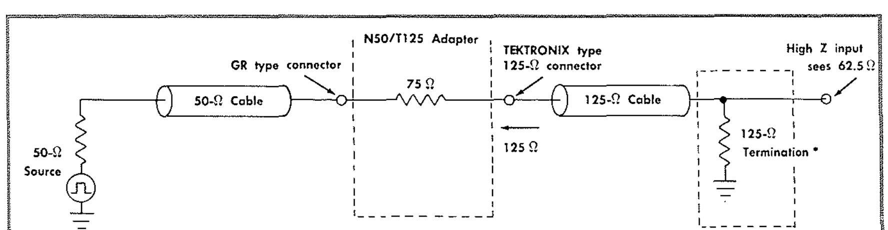
Typical Use of a Minimum-Loss Attenuator and a Termination

MINIMUM-LOSS TYPE—*Provide a convenient means of matching a source or load with cables of different characteristic impedances. Tektronix minimum-loss attenuators assure proper matching, with a minimum loss of signal strength.*



Typical Use of a 50-Ω Termination

TERMINATIONS—*Terminate a cable in its characteristic impedance. Improper termination, or no termination, can cause ringing, reflections, and other adverse effects. Tektronix 50-Ω and 125-Ω instruments have built-in terminations.*



Typical Use of a N50/T125 Adapter and a Termination

* Not necessary when instruments have built-in terminations.

ADAPTERS—*Connect cables of different characteristic impedances and different connectors. They are used only where impedance matching is not important. Tektronix adapters use the letter N to designate a non-terminated end and the letter T to designate a terminated end.*

SERVICE SCOPE

USEFUL INFORMATION FOR

USERS OF TEKTRONIX INSTRUMENTS

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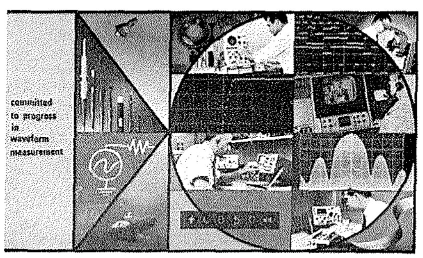

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