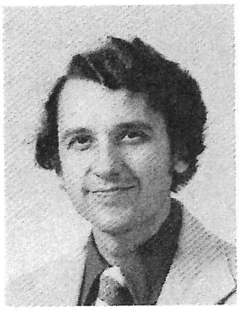
A 400-MHz dual-beam oscilloscope



Murlan Kaufman

One of the things an oscilloscope does best is show us tiny bits of history, events that occur in microseconds, nanoseconds or picoseconds. But the vast majority of shows pictured on oscilloscopes are re-runs – events that are just like many others that occurred just moments before. It means you can take a look at the crt screen and see a steady display because similar events are happening so quickly and repeatedly that persistence of vision lets you think only one graph is displayed.

Oscilloscopes also let us conveniently *compare* bits of history. Waveform comparisons are often just as important as waveform measurements. There is no better way to judge the similarities and differences between two waveforms than to place them side by side. Scope users choose dual-channel scopes and plug-ins over single-channel varieties by a great margin, simply to be able to compare two signals.

A one-shot event may be an event that is unlike any that has ever happened before or will happen again. Capturing such a unique bit of history can be pretty important and require the help of a fast-writing, wideband oscilloscope plus a high speed camera. You can have a special problem, though, when you want to capture *and* compare two simultaneous, or nearly simultaneous, events. Capturing two such events is either done with two separate oscilloscopes and cameras, or with one camera and one dual-beam oscilloscope. A dual-trace scope operated in the chopped mode can only do a good job if the event lasts longer than about 100 μsec.

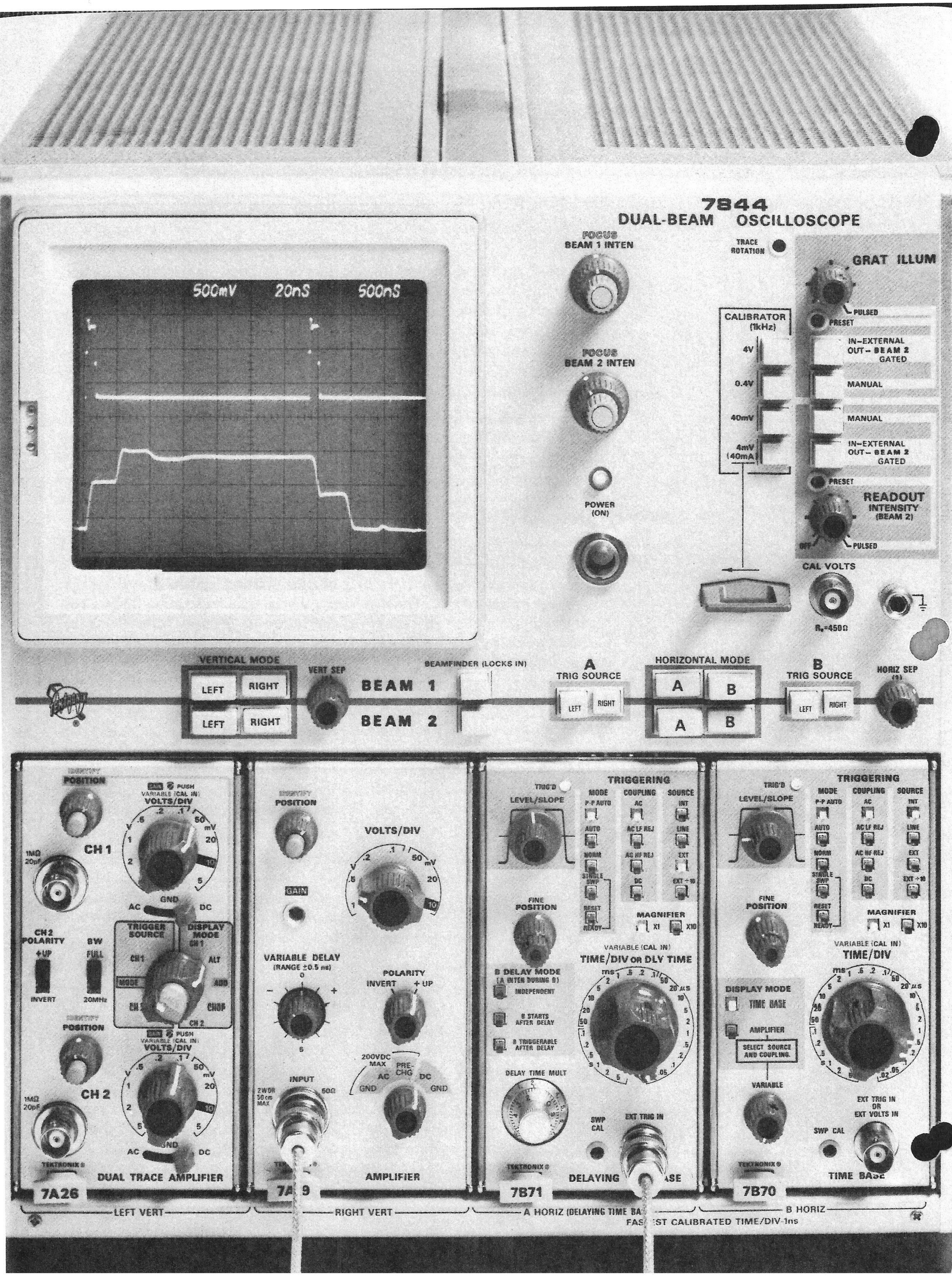
When you capture two one-shot events using a dual-trace or dual-beam scope, comparing the two waveforms is no problem because they both appear on one photograph. Critical comparison of two signals on separate photographs is more difficult. And it is more difficult to successfully take pictures of two simultaneously triggered, and equally delayed, sweeps on separate scopes.

A giant step in bandwidth

For the last nine years the fastest dual-beam oscilloscope available has been the TEKTRONIX 556, a 50-MHz instrument. The new 7844 Dual-Beam scope from Tektronix will replace it. The 7844 has eight times the bandwidth, 400 MHz, and bandwidth is extended to 1 GHz using one or two 7A21N plug-ins with direct-access to the vertical deflection plates.

Less weight, power, rack space

The 7844, and its rackmountable counterpart the R7844, are very similar in performance to two 500-MHz TEKTRONIX 7904 scopes placed in one cabinet and made to share the same crt screen. The volume of the 7844 is, however, the same as that of *one* 7904. Both are four-hole mainframes. The front-panel height of the R7844 is only 7 inches, one-half that of the rackmountable R556. You can put two R7844's where one R556 was used before. The 7844 weighs only 36 pounds, less than half that of the 556, and power required is 235 watts, less than one-third that of the 556. Because the 7844 has a DC fan it will operate from a power line having a frequency from 48 Hz to 440 Hz.


500mV 20nS 500nS
7844
DUAL-BEAM OSCILLOSCOPE
FOCUS
BEAM 1 INTEN
FOCUS
BEAM 2 INTEN
TRACE ROTATION
GRAT ILLUM
PULSED
PRESET
CALIBRATOR (1kHz)
4V
0.4V
40mV
4mV (40mA)
IN–EXTERNAL OUT– BEAM 2 GATED
MANUAL
MANUAL
IN–EXTERNAL OUT– BEAM 2 GATED
PRESET
READOUT INTENSITY (BEAM 2)
OFF
PULSED
POWER (ON)
CAL VOLTS
VERTICAL MODE
LEFT
RIGHT
LEFT
RIGHT
VERT SEP
BEAM 1
BEAM 2
BEAMFINDER (LOCKS IN)
A TRIG SOURCE
LEFT
RIGHT
HORIZONTAL MODE
A
B
A
B
B TRIG SOURCE
LEFT
RIGHT
HORIZ SEP
POSITION
VOLTS/DIV
CH 1
AC GND DC
TRIGGER SOURCE
DISPLAY MODE
CH 2 POLARITY
+UP
INVERT
BW
FULL
20MHz
CH 1
ALT
ADD
CHOP
MODE
CH 2
POSITION
VOLTS/DIV
CH 2
AC GND DC
TEKTRONIX®
DUAL TRACE AMPLIFIER
7A26
POSITION
VOLTS/DIV
GAIN
VARIABLE DELAY
(RANGE ±0.5 ns)
POLARITY
INVERT
+ UP
INPUT
50Ω
200VDC MAX
AC
PRE-CHG
DC
GND
GND
AMPLIFIER
TRIG'D
LEVEL/SLOPE
TRIGGERING
MODE
COUPLING
SOURCE
P-P AUTO
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SINGLE SWP
RESET
READY
AC
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X1
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VARIABLE (CAL IN)
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B DELAY MODE
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INDEPENDENT
B STARTS AFTER DELAY
B TRIGGERABLE AFTER DELAY
DELAY TIME MULT
SWP CAL
EXT TRIG IN
TEKTRONIX®
DELAYING
7B71
TRIG'D
LEVEL/SLOPE
TRIGGERING
MODE
COUPLING
SOURCE
P-P AUTO
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MAGNIFIER
X1
X10
VARIABLE (CAL IN)
TIME/DIV
DISPLAY MODE
TIME BASE
AMPLIFIER
SELECT SOURCE AND COUPLING.
VARIABLE
EXT TRIG IN OR EXT VOLTS IN
SWP CAL
TEKTRONIX®
TIME BASE
7B70
LEFT VERT
RIGHT VERT
A HORIZ (DELAYING TIME BA
B HORIZ
CALIBRATED TIME/DIV-1ns

Single-shot photos simplified

The 7844 brings crt readout to dual-beam scopes for the first time. Since the 7844 will be used with a camera frequently, the alpha-numeric crt readout characters are especially valuable. They document the sweep speed and vertical deflection factor automatically for each beam displayed.

A pulsed mode of illuminating both the readout characters and the edge-lit crt internal graticule lines greatly simplifies the job of consistently taking good one-shot photographs. Although the pulsed graticule mode is available as an extra-cost option on one other TEKTRONIX single-beam scope (R7903), the feature is standard in the 7844.

In the pulsed mode the graticule illumination lamps are turned off and the crt readout character generators deactivated until a pushbutton is pushed, an external switch is closed, or the awaited one-shot sweep occurs. When controlled by the sweep, each character is generated and displayed once in a rapid sequence immediately following the sweep. Then the graticule lamps are pulsed once briefly.

Front-panel screwdriver adjustments are provided to set the brightness of the readout characters and internal graticule lines to match the camera film speed and f-stop. Each photograph will then have correctly exposed readout characters and graticule lines independent of the time the camera shutter remains open.

Front-panel pushbuttons permit manually pulsing the graticule lines or readout, independently. This is helpful in setting the screwdriver adjustments and getting optimum exposure of the graticule and readout when photographing repetitive sweeps.

A rear-panel connector on the 7844 allows remote pulsing of the readout characters and graticule by a switch closure to ground. Two more rear-panel connectors provide power for remote lamps to indicate when each of the one-shot sweeps is armed or has been triggered. Still another connector allows you to reset the one-shot sweeps remotely.

Built-in film fogging

The 7844 is available with an option that provides a new, automatic way to fog the films for enhancing photographic writing speed. The method allows using cameras not compatible with Tektronix Writing Speed Enhancers. No additional equipment is required; everything is built-in. A one-shot crt raster is generated which illuminates the entire crt faceplate by a preset amount, fogging the film through the camera lens. The raster is produced by one beam (Beam 2) as soon as the sweep for that beam ends. In the automatic pulsed mode the crt readout characters are generated and written on the screen by the same beam (Beam 2) as soon as the raster scan is completed.

Room for special plug-ins

Many dual-beam applications require only a single time base for both beams. This leaves room for one of the specialty 7000-Series plug-ins. The 7M13, for example, may be used to generate additional crt readout characters of your choice. You can include date, test number and other such data when you like. In fact, by double exposure, you can insert a 7M13 in place of one of the plug-ins and record its crt characters at a later time. The manually-operated pulsed mode for generating the characters makes this job simple.

The 7D11 Digital Delay plug-in is another example. It can be used to generate long, very precise trigger delay intervals, with the numerical value of delay displayed on the screen. When you wish to photograph two one-shot events that occur after a main trigger signal, the 7D11 can be used to great advantage. The delay interval will be unmistakable when written on the crt.

Full dual-beam sometimes essential

Although two one-shot events are usually displayed using the same sweep speed, with both sweeps starting at the same instant, you sometimes need to compare two one-shot signals that don't occur simultaneously. A full dual-beam scope is usually called for in this application. Two sweep generators are needed, one that sweeps one beam, and another that sweeps the second beam a little later. The 7844 provides maximum flexibility through four pushbuttons that permit sweeping either Beam 1 or Beam 2 from either time base unit without interchanging the units. We call this feature full horizontal crossover.

A similar feature is provided for the vertical channels. The signal from either channel may be displayed on either beam without interchanging vertical plug-ins. We call this full vertical crossover. One of the advantages of vertical crossover is the ability to display the same signal on both beams using only one probe. This eliminates loading the circuit with a second probe. A typical application is measuring both the risetime and duration of a wide, fast-rise pulse. Both sweeps are initiated simultaneously, but one is set to run much slower than the other.

When only one plug-in is used in this way the single vertical position control on that plug-in does not allow the two beams to be separated vertically. The VERT SEP control on the front-panel positions accomplishes this. The HORIZ SEP control lets you position the beams horizontally to assure that they start together when only one time base unit deflects both beams.

Reliability

The prospect of putting nearly twice as many parts into a 7844 as you will find in a 7904 called for special attention to assuring instrument reliability. Every conceivable reliability factor was scrutinized from the beginning of the project. Components with conservative voltage and power tolerance ratings were selected and air flow from the fan carefully controlled to limit temperature rise in all areas. Exhaustive reliability testing has taken place at all design stages and long term reliability testing is continuing. We are confident that reliability will be exceptionally good.

Serviceability

A help to people who will calibrate and service the 7844 is the fact that many of the circuits are merely duplicates of each other for the two beams. Some circuit boards are identical for both beams. For those already familiar with the popular 7904, learning the 7844 will be very simple since many circuits are similar. The high-efficiency power supply is merely a beefed-up version of that used in the 7904.

State of the art dual-beam crt

Keeping the 7844 small was a design goal from the start. That placed a premium on the space normally required for a dual-beam cathode ray tube. The crt used in the 7844 is much smaller than that used in the 556. Figure 3 shows a comparison. Crt design hurdles were overcome that not only saved space but did some other, more valuable things.

Both beams write full screen

In a dual-beam crt built with two guns, a straight, centerline shot from each gun should converge at the center of the crt screen. How much the gun centerlines miss the center depends on the length of the crt, the angle of convergence, and how far apart you place the cathode-end of each gun. In the 556 crt the upper beam centerline hits the screen one centimeter above center and the lower beam one centimeter below center. Because each beam in the 556 is restricted to a vertical deflection range of 6 centimeters (for optimum bandwidth) only the middle four centimeters of the crt can be shared by both beams. The 4 x 10 centimeter area is called the overlap area. In the 7844 the entire 8 x 10 centimeter screen is shared by both beams, giving twice as much overlap area.

New design yields smaller size

A couple of rather radical design departures made it possible to build the 7844 crt with centerline convergence at center screen. And this was accomplished without making the crt longer or separating the cathodes further than in the 556 crt. In fact the crt was made

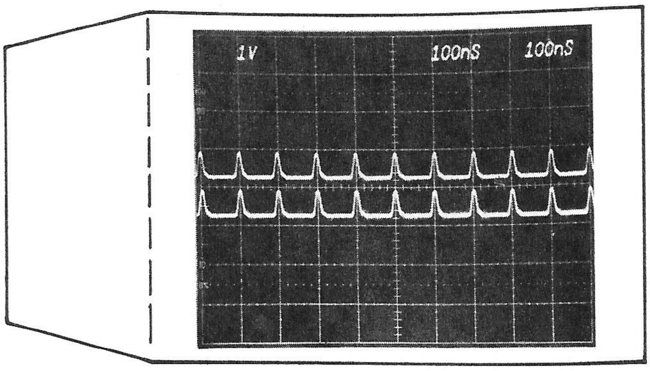

Fig. 1. Excellent crt deflection linearity of both beams shown with 10-MHz time markers.

shorter and the cathodes placed closer together. The first major difference is that the two gun-structures are made parallel and laid side by side instead of placed one on top of the other. This permits the gun structures to be placed closer together, reducing the diameter of the neck of the crt.

This kind of construction gives us a left and right beam instead of an upper and lower beam. It also helps keep the two undeflected beams closer together as they emerge from the last pair of deflection plates, reducing the overlap problem. Having a left and right gun instead of an upper and lower gun changes the vertical overlap problem to a horizontal overlap.

The horizontal overlap problem was solved by placing a pair of small auxiliary horizontal deflection plates between the vertical and horizontal pairs of deflection plates of each gun. By applying a dc voltage between each pair of these plates both normally undeflected beams will be aimed at the center of the screen.

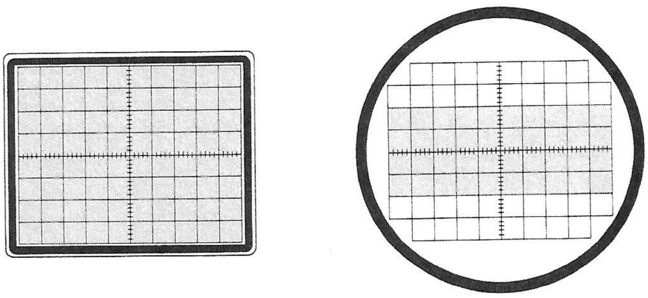

Fig. 2. Each beam in the 556 scans a 6 by 10 cm area providing a 4 by 10 cm overlap area. In the 7844 each beam scans the full 8 by 10 cm area providing twice as much overlap.

One of the reasons dual-beam crt's have traditionally been constructed with one gun above the other is that a deflection linearity problem called keystoning may be easily corrected. Keystoning is an effect which tends to make a trapezoidal pattern instead of a rectangle when a set of raster lines is displayed on the screen. It is caused by a given angle of deflection causing more deflection on one part of the screen than on

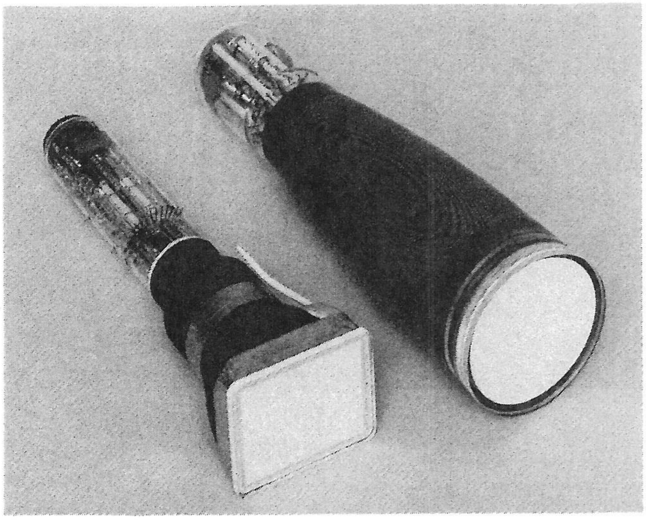

Fig. 3. 7844 crt is shorter than 556 crt and has much less volume.

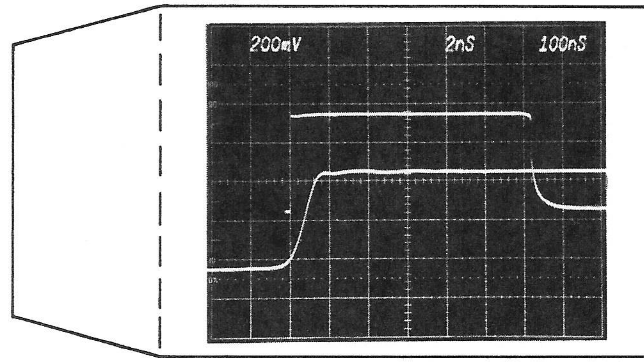

Fig. 4. Two views of the same pulse using two beams. Bottom graph shows risetime and top graph shows duration. Only one input of one vertical plug-in was used. Top sweep was set for 100 ns per division, the bottom for 2 ns per division.

another. For example, the upper gun in a conventional dual-beam crt tends to produce a trapezoid having parallel upper and lower edges with a longer lower edge than upper edge. The effect is corrected for the top gun by mounting the horizontal-deflection plates so the top edges of the plates are closer together than the bottom edges. In effect that equalizes the horizontal-deflection sensitivity across the screen, correcting the keystoning.

When electron guns are placed side by side the inherent tendency to keystone still exists. The difference is that the left and right edges tend to be of different length instead of the top and bottom edges.

This distortion can't be corrected by tilting the deflection plates as with dual-beam crt's having upper and lower guns. Instead it is corrected by applying a dc voltage to an additional plate that lies outside, but adjacent and parallel to, each horizontal-deflection plate. Two additional plates are added for each gun. One edge of these plates extends a little bit further toward the crt screen than the corresponding edge of the adjacent deflection plate, allowing its electric field to extend into the deflection region and correct distortion. Shielding between the two guns increases the horizontal deflection plate capacitance slightly, restricting the top linear speed to 1 ns per division compared to 0.5 ns per division in the 7904.

The crt for the 7844 is not only smaller in diameter than the one used in the 556 but it is shorter. Placing a dome-shaped metal mesh between the deflection plates and the crt screen provides a scan-expansion effect allowing the screen to be brought closer to the deflection plates. The mesh is primarily used to increase crt sensitivity — a necessity for wideband scopes. The penalty is that spot-size is increased and some beam current is intercepted. An accelerating voltage of 24 kV compensates for the beam intercept and yields a writing rate of 1.7 cm per nanosecond (using P11 phosphor, a C51R camera with Type 47 Polaroid® film, and without film fogging.) The 7844 crt is the first dual-gun crt using a dome-shaped scan-expansion mesh.

In summary

The 7844 represents a giant step forward in dual-beam oscilloscope performance. Bandwidth is increased from 50 MHz to 400 MHz and the screen area covered by both beams increased 100% from 4 centimeters to 8 centimeters.

Size, weight and power consumption are substantially reduced. The rack space needed for the R7844 is only 7 inches, half that of its predecessor. A dc fan permits operation from any power line frequency between 48 and 440 Hz.

One-shot photography is simplified with a standard feature that provides pulsed graticule illumination and crt readout characters. Built-in film fogging by a one-shot raster scan is available as an option.

Add to these features the unmatched versatility provided by over thirty 7000-Series plug-ins, with four holes to put them in, and you have a dual-beam oscilloscope suited to almost any application.

Acknowledgments

The excellent crt design was done by Conrad Odenthal and Ken Hawken. On the circuit design team, Chuck Scott, Dick Anderson, Keith Taylor and Bob White deserve special recognition. Mechanical designers Mark Anderson and Joal Davis did a top notch job of packaging two scopes in one. My thanks go to these people and to the many others in support groups who were a pleasure to work with and who contributed to the project's success—Murlan Kaufman, Project Mgr.