TEKTRONIX CRT HISTORY

Part 5. The Hybrid Years: 1961-1964

Peter A. Keller
Aloha, Oregon

Part 1 described the situation leading to the decision in 1951-52 for Tektronix to begin design of cathode-ray tubes for its own use. Part 2 discussed the development of the first Tektronix CRT, the T51, in two different versions. Part 3 covered the classic Tektronix vacuum-tube oscilloscope CRTs during the period of about 1955 to 1959. Part 4 covered the innovative period from 1959 to 1961. This installment discusses more innovative CRTs for the first Tektronix storage oscilloscope and several other instruments using hybrid technology, which combined solid-state circuitry with the tail-end of vacuum-tube technology. At this time, there were still a number of functions that could be performed better and/or cheaper with vacuum tubes.

A few early semiconductors, particularly diodes, gradually began to be employed before this time period for some functions to save power consumption, reduce heat, and save space. This trend greatly accelerated during the early 1960s, as more reliable and higher performance semiconductors became available in production quantities.

CERAMIC ENVELOPES

Among the many advances in CRT technology during this time period was the development of the ceramic envelope (also referred to as a funnel) pioneered by Tektronix in 1961. Until then, CRTs were traditionally constructed using glass or metal envelopes. The unique Tektronix ceramic envelope was first developed in 1961 by William Wilbanks et al. (US Patent 3,207,936) and was applied with particular success in 1963 to the five-inch rectangular T5640 storage tube discussed below. Several reasons have been expressed for the use of ceramic rather than glass for the funnel. These include better utilization of excess capacity of the Tektronix ceramic plant, used to manufacture ceramic terminal strips, which were becoming obsolete as printed circuits came into use; lower cost; the ability to produce new shapes and sizes rapidly and relatively inexpensively; the ease of making the multiple electrical contacts necessary for storage tubes; the ability to fabricate designs that are impossible with glass; high shear and tension strengths; and reduced dependence on outside glass vendors and their occasional labor disputes. In all probability it was the combination of several of the above that prompted the use of ceramic envelopes. The use of ceramic was practical for CRT production runs of just a few hundred funnels per year, whereas the glass companies tended to require a few hundred thousand per year to justify tooling. A side benefit was that it became possible to print higher visibility internal graticules on the separate plate-glass faceplates used for the screens of ceramic CRTs. This faceplate was frit-sealed to the ceramic envelope, using techniques developed by the color picture-tube industry. Ceramic CRTs have been produced in many sizes and shapes, from the two-inch T2110 to the eleven-inch T6110 and many of the best selling Tektronix CRTs were converted to ceramic envelopes. Eventually, all later-designed Tektronix CRTs smaller than 11-inch used ceramic envelopes produced in-plant.

RECTANGULAR SCREENS

Also during this period of time, rectangular screens became the norm for laboratory oscilloscopes. A few basic rectangular screen CRTs became available during the 1950s, around the time that rectangular picture tubes displaced round tubes for television. Other than a few tubes of relatively low volume, the rectangular oscilloscope CRT did not displace the round tube overnight as it had in television.

The rectangular CRT offered two advantages. First, it made smaller oscilloscopes possible, which became a matter of greater importance in the 1960s as solid-state electronics displaced the vacuum tube and, second, scan was often limited in newer CRTs as a trade-off for bandwidth and deflection sensitivity. High-sensitivity round tubes had large wasted areas at the top and bottom of the screen which the electron beam could not reach. The first rectangular-screen CRT at Tektronix was the non-registered T503RS in 1962, which later evolved into the T5031 and T5032. Tektronix soon after began to use the rectangular screen in almost all new instrument designs, even those using a spiral accelerator, by use of a cylindrical portion of the funnel containing the helix which gradually changed to a rectangular cross-section near the screen.

INTERNAL GRATICULES

It was very difficult to make accurate measurements from the screens of the older blown-glass curved-face CRTs due to parallax between the scale or "graticule" overlay because of the non-uniform distance between the graticule and the phosphor plane. The flat-face tube had greatly improved the situation; however, the spacing between the plane of the graticules, which was usually illuminated, and that of the phosphor - due to the thickness of the glass faceplate between - still resulted in parallax errors and the resulting difficulty of having the eye lined-up in the same relative position for each measurement. Hewlett-Packard overcame this, beginning with their model 120-B oscilloscope in 1961, by forming the graticule internally on the glass faceplate before applying the phosphor screen. A finely ground black-glass powder which was fused to the glass faceplate was used to withstand the acid rinses and high-temperature baking associated with CRT processing. The only drawback of this graticule was the difficulty of photographing the graticule and the display simultaneously, since the black lines would not show unless backlit with "flood" electrons or the entire screen was illuminated with ultra-violet light to silhouette the graticule. H-P used both techniques. In 1964, Tektronix introduced illuminated, titanium dioxide, photo-deposited internal graticules, which allowed the use of conventional incandescent edge-lighting like that used for external graticules. A plexiglass combination light-pipe and implosion shield was laminated to the CRT faceplate to conduct the light to the graticule markings. The use of a separate faceplate frit-sealed to the funnel in the early 1960s allowed a considerable improvement in the visual appearance of the graticules. It lent itself well to the application of screen-printed, illuminated graticules using colored frit applied to the inner glass surface.

T310

The T310 was merely a Tektronix-produced version of the purchased 3WP- used in the 310A oscilloscope and 360 indicator unit. Improved quality and tightened specs, not cost, were likely the reasons for Tektronix to develop it, since the purchased 3WP-s were produced by several competing companies in fairly large quantities. Physically, the T310 had a larger neck diameter and longer phenolic base than the 3WP-. The T310, soon to be redesignated T3100, was available with P31 phosphor as standard and P1, P2, P7, P11, and P32 optionally.

T503RS/T5031

The RM561, a rack-mount version of the 561, used a space-saving rectangular version of the T503 that had been used previously in the Models 560 and 561. The acceleration voltage was 3.5 kV with no aluminizing or internal graticule.

The T503RS was normally supplied with P31 phosphor, and P1, P2, P7, P11, and P32 were cataloged as options. It soon became the type T5031 as the four-digit CRT numbering system took hold.

T561/T5610/T5032

The first ceramic-envelope CRT was the rectangular T561 (Figure 1) introduced in 1962 for the model 561A oscilloscope. It was lightly aluminized for improved brightness and operated at 3.5 kV. An illuminated internal graticule was standard.

The T561 was normally supplied with P31 phosphor, while P1, P2, P7, P11, and P32 were cataloged as options. The T561 became the T5610 and, in January 1965, was discontinued with the all-glass T5032 (Figure 2) replacing it.

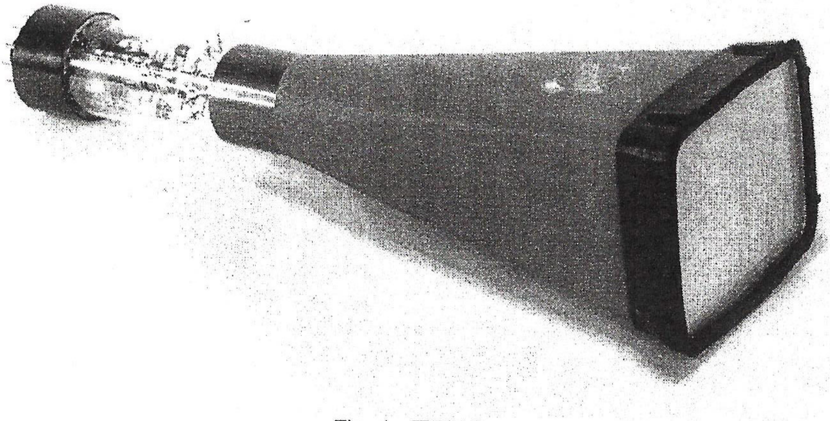

Fig. 1. T5610

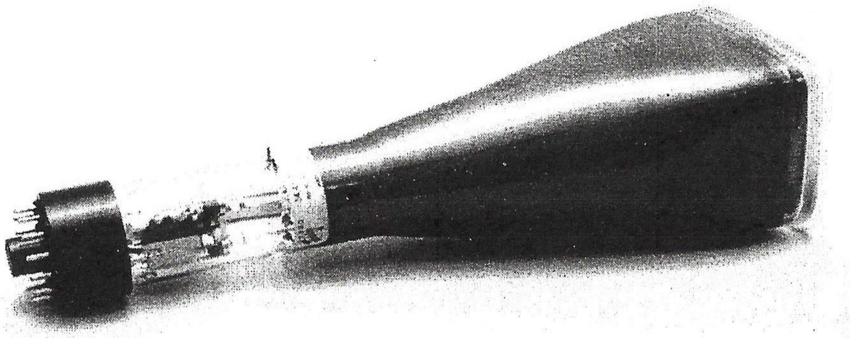

Fig. 2. T5032

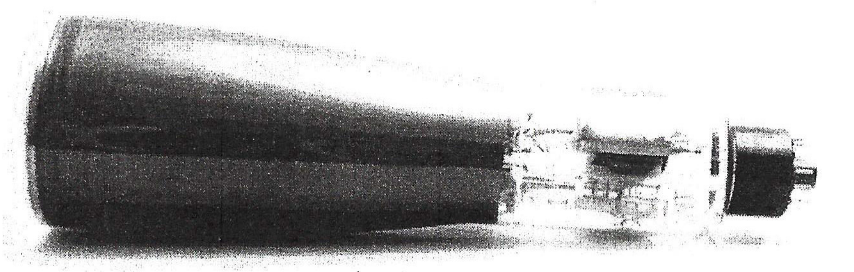

Fig. 3. T565

T565/T5650

The dual-gun, round, glass T565 (Figure 3) was essentially two T503s in one envelope. It was used only in the Model 565 and RM565 oscilloscopes introduced in 1962. An acceleration potential of 4 kV was used with no aluminizing and, at introduction, no internal graticule.

The T565 became the type T5650 in the new CRT numbering scheme. Illuminated internal graticules were added in 1965. P2 phosphor was standard, with P1, P7, P11, and P31 available on special order.

T5640

The Model 564 storage oscilloscope introduction was the big event of 1963 for Tektronix. Until then, the Hughes oscilloscopes using their Memotron storage CRT were about the only option for applications requiring viewing of low-frequency repetitive waveforms or single-shot events. The Memotron was easily damaged, expensive, and not particularly easy to operate. The simplified, bi-stable, direct-view storage tube (DVST) was invented by Robert Anderson at Tektronix in the late 1950s. Much effort was devoted over the next few years to making it a practical device and a commercial success. Unlike the fragile magnesium-oxide (MgO) coated storage mesh of the Memotron, the DVST used the phosphor screen itself to store the charge pattern of the displayed waveform. Both devices employed the secondary-emission characteristics of the MgO or phosphor respectively to store the charges. The high-voltage writing gun deposited the charges while the low-voltage "flood" guns maintained the charges in equilibrium until the user initiated erasure. Erasure of the screen involved suddenly raising the flood gun voltage to overwrite the entire screen, followed by a rapid drop in voltage to near-zero and gradual return to the "ready-to-write" voltage.

The Model 564 used the T5640 storage CRT. Other than the CRT and associated circuitry required for the storage functions, it was mechanically and electrically similar to the 561A and used the same series of vertical and horizontal plug-ins. The screen used P1 phosphor due to its similarity in secondary-emission characteristics to MgO and good visual properties. The phosphor was deposited as a decal on a flat glass faceplate having a transparent conductive film of tin oxide just under the phosphor. Voltages applied between this layer and the flood-gun cathodes established the ready-to-write and erase conditions of the screen. Additionally, the conductive film was split horizontally in the center of the screen to form two distinct screen areas that could be written and erased together or separately to allow comparison of two waveforms. The glass faceplate was frit-sealed to a ceramic funnel (Figure 4). Here, the ceramic envelope facilitated the forming of several conductive gold wallbands that comprised the collimation system used to control the uniformity of flood electrons at the screen. Each wallband had a separate conductive feedthrough connection to the outside of the funnel. From those points conductive silver stripes extended to the rear, where contact to the flood gun control circuitry was made with phosphor-bronze springs.

The electron gun was similar to that of the T561 except for the addition of two flood guns which were mounted near the deflection plates with their central axes inclined to point at screen center. The accelerating voltage was 3.5 kV. Aluminizing was not used, since low-voltage flood electrons would be unable to penetrate it. There was some loss of brightness compared to the T561, since the screen thickness and density were optimized for their storage characteristics. The tin-oxide layer also absorbed some light from the phosphor. Still, it was an excellent compromise for both storage and conventional applications. With the phosphor in good thermal and mechanical contact with the glass faceplate, it was very rugged and not easily burned through misuse. Conversely, the Memotron with its coating of MgO for storage on a fine mesh mounted behind the phosphor screen was easily damaged.

Two versions of the T5640 were available. The first, intended for general use, used just P1 for the screen decal. The tube designation was T5640-200. The second contained a few percent of MgO added to the P1 phosphor, which improved the sec-

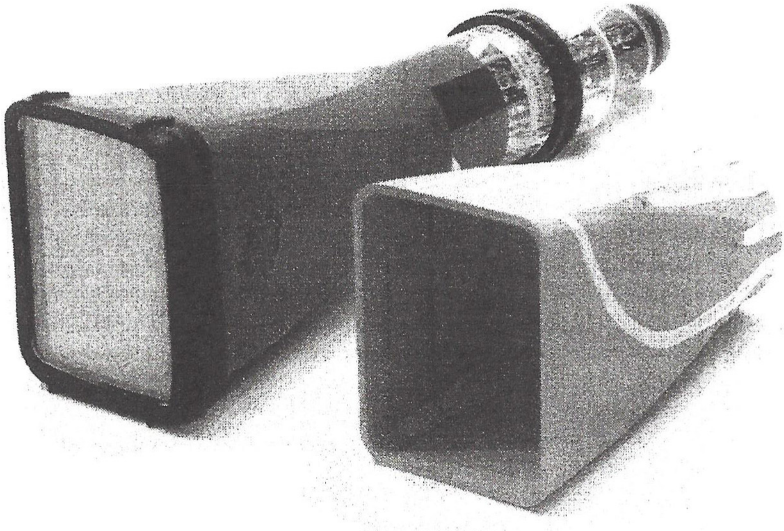

Fig. 4. T5640 storage CRT and ceramic envelope

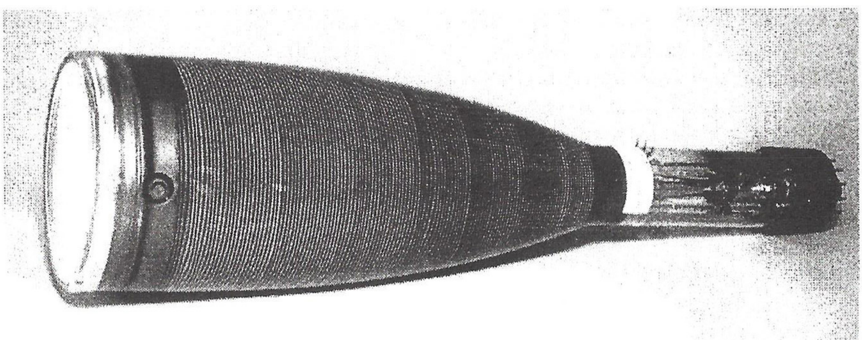

Fig. 5. T5470

TYPE	P1	P2	P7	P11	P31	P32
T310	154-0362-00	154-0363-00	154-0364-00	154-0365-00	154-0366-00	154-0382-00
T503RS	154-0319-00	154-0320-00	154-0321-00	154-0322-00	154-0355-00	154-0388-00
T5031	154-0319-00	154-0320-00	154-0321-00	154-0322-00	154-0355-00	154-0388-00
T5032		154-0454-00	154-0455-00	154-0456-00	154-0449-00	
T5470 Early		154-0450-00	154-0451-00	154-0452-00	154-0429-00	
T5470 Later		154-0478-01	154-0478-02	154-0478-03	154-0478-00	
T561	154-0396-00	154-0397-00	154-0398-00	154-0399-00	154-0400-00	154-0401-00
T565	154-0357-00	154-0358-00	154-0359-00	154-0360-00	154-0368-00	
T5650 Early		154-0426-00	154-0439-00	154-0440-00	154-0441-00	
T5650 Later		154-0477-00	154-0477-01	154-0477-02	154-0477-03	

Table 1. CRT part numbers

ondary-emission characteristics for higher writing speed. The tradeoff was lower brightness. It was designated T5640-201. The DVST was a resounding success. It ultimately led to a series of data terminals, desk computers, and data displays with screen sizes up to 25".

T5470

In the author's opinion, the T5470 CRT (Figure 5) and its associated instruments, the 543B, 544, 545B, 546, and 547, comprised the finest of the classics. This series of instruments began in 1964 as replacements for the 540-series scopes that had become the leading instruments in the Tek product line. They featured a very fine spot-size (under 10 mils), 50-MHz bandwidth, hybrid circuitry, illuminated internal graticule, and larger 6-by-10-cm scan area, while retaining the familiar appearance and layout of the 530/540-series instruments. This resulted in an instrument by which all others are often judged by those of us who spent many hours working with them.

The T5470 was a long CRT, over 20" overall, using the same bulb as the T581/T5810. Segmented, narrow vertical deflection plates similar to those of the T581, but without the delay line, achieved good vertical deflection sensitivity with low capacitance for wider bandwidth. The acceleration voltage was 10 kV. Development of this series was forced by competitive pressure from the entry in the oscilloscope market by Hewlett-Packard, with their Model 175-A having many of the same features. The latter suffered from the unfamiliar panel layout, poor spot size, and the feeling prevailing in the market by then that if you wanted the best, Tektronix was *the* oscilloscope to buy. It had become the status symbol for the engineer.

P31 aluminized screens were standard in the T5470 but P2, P7, and P11 were available as options. The 5-inch, round, glass T5470 soon evolved into the similar T5471 which used a ceramic envelope. We extensively used 547 scopes and many T5470s built in the Engineering Tube Lab to evaluate phosphors, screen processing, and internal graticule designs during the 1960s.

Note: By early 1965, the T#### type numbering and nine-digit part numbering systems were fully in place. Many of the CRTs discussed in this article were popular for several years. Custom internal graticules and other variations resulted in too many part numbers to be completely described here. By 1968 internal graticules were designated in the tube type by a single digit following the phosphor type. Also, the "P" preceding the phosphor type was dropped. Thus a T5032 with P31 phosphor and standard 8-by-10-cm internal graticule became the T5032-31-1. The special internal graticules as well as the "no-graticule option" continued the proliferation of part numbers as well as tube type numbers. Also note the differences in CRT part numbering that occurred between the early and later T5470s and T5650s. The center four digits became the same for the basic tube type, with the two-digit suffix denoting the phosphor. The 154 prefix used for all CRTs remained the same. By this time, the availability of many phosphors on special order had begun to decline somewhat.

COMING NEXT

The final article in this series will discuss CRTs introduced by Tektronix during the mid-1960s for the beginning of the all-solid-state era (except for the CRT, of course).

REFERENCES:

Keller, Peter A., The Cathode-Ray Tube, Palisades Press, 1991.

Griffiths, Stan, Oscilloscopes, Selecting and Restoring a Classic, 1992.

Lee, Marshal M., Winning with People: The First 40 Years of Tektronix, Tektronix, 1986.

Tektronix instrument catalogs.

Tektronix, CRT Data Book, looseleaf binders, individual CRT data sheets updated as needed throughout the 1960s.

Tektronix internal publications of instrument / CRT/part number cross reference lists, 1962-1989.