TEKTRONIX CRT HISTORY

Part 4. Innovations: 1959-1961

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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. It was originally intended that Part 4 would cover the period from 1960 to 1965. It was soon found that the sheer number of innovations during that period would mean leaving out too much interesting information in order to keep it to a manageable length. This installment now covers the CRTs for the first transistorized oscilloscope and some of the more specialized instruments of the late vacuum tube era.

The following describes these tubes in approximate chronological order spanning the years of 1959 to 1961. Bear in mind that introduction dates may vary by a year so depending on information source. Sometimes instruments might be announced prematurely to meet a trade show deadline or unforeseen bugs would appear when an instrument or CRT was introduced into manufacturing. Also, product development times could differ greatly dependent on design complexity. Two products with the same introduction date might have begun design engineering a year or two apart. This might be especially true if one used an existing CRT and the other needed one having untried innovations. This applied as well to how much existing circuit design could be reused in a new instrument.

One thing is apparent from some of the descriptions below; the CRT had stringent requirements placed on it and it was often the limiting factor for the final instrument performance specifications. There were many trade-offs possible in CRT design. These necessitated close working relationships and performance compromises between the CRT design engineers and the circuit design engineers. Examples include deflection sensitivity, deflection plate capacitance (limits bandwidth), brightness, writing rate, spot size, pattern distortion, power requirements, tube length, and cost. Another problem is that if you build a new circuit and it doesn't function properly, you make component value and connection changes until you obtain the desired performance. Corrections could often be made in minutes. With a new CRT, if it didn't work properly, you threw it away and started building another, a process measured in days and dollars. This was particularly true for the T519 described in this article and even more so for the T564 storage tube to be covered in a forthcoming article in this series. And there were often hidden defects such as shorts, opens, misalignment, contamination, foreign particles, or gas, most of which weren't obvious until you tried to operate the tube. I have even seen an unlucky housefly that was inadvertently sealed in a CRT.

T581

The T581 of 1959 probably fits better in Part 3 but didn't fit the two-digit

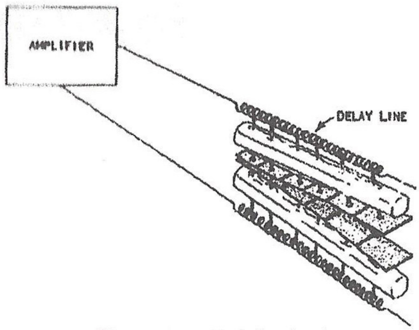

Fig. 1A Distributed deflection system

tube type numbers that article was limited to. The T581 was used exclusively in the Model 581 and 585 oscilloscopes which had a 100 MHz bandwidth (specification reduced to 95 MHz in 1962), and their replacements, the 85 MHz Model 581A and 585A of 1963 (reduced to 85 MHz in 1964). All four were fundamentally similar to the 30 MHz Models 541 and 545.

The T581 was another outgrowth of the original T51 with a couple notable exceptions, both of which were necessary to meet the wide bandwidth specification. The most notable innovation was the distributed vertical deflection system (Figure 1A). This consisted of a series of deflection plates connected sequentially with coils. The capacitance of the deflection plate pairs combined with the inductance of the coils to form a delay line terminated at the screen end (Figure 1B). The velocity of the electron beam matched that of the signal traveling down the delay line, thus reinforcing the deflection over the entire length. The deflection plates were effectively lengthened for more deflection sensitivity. If the plates had merely been combined to make longer ones of equivalent physical length the capacitance would have been prohibitively high and bandwidth severely limited. The T581 was also approximately 2-1/2 inches longer than the T54 CRT to obtain a greater "throw" distance and also allow for the longer vertical deflection system. This further allowed the deflection at the screen to be greater. Even with all that, useful scan area was limited to 4 x 10 cm, equivalent to that of the T54.

Several thousand 581s and 585s were manufactured but they never gained the wide appeal of the classic 530 and 545 series instruments. This probably is due to the fact that while the 80-series plug-in vertical amplifiers were physically the same size as the letter-series plug-ins, a Type 81 plug-in adaptor was necessary to use the widely available letter-series plug-ins of the 530 and 540 series instruments. The adaptor extended the plug-ins out about two inches from the front panel and always looked like an afterthought. Despite that, all letter-series met their full specs in the 580-series instruments.

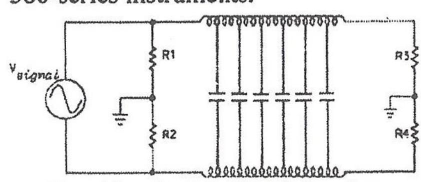

Fig. 1B. Deflection delay line

The T581 became the T5810 with the 1963 tube type number changes. P2 phosphor was originally the standard phosphor supplied, with P31 replacing it in 1962 because of its higher brightness and writing rate. P1, P7, P11, P16, P20, and P32 were also available for the T581 (see Table 1).

T321

The first all-transistor Tektronix oscilloscope was the battery-operated portable Model 321 in 1960. I can well remember the Albuquerque Field Engineer, Dean Butts, walking into my lab in Alamogordo carrying an operating 321 scope shortly after they were publicly announced. It was a real eye-opener in those days when many oscilloscopes would briefly dim the lights at turn-on. Ten D-cell flashlight or rechargeable batteries powered the 321. Alternatively, AC power or external DC power could be used where appropriate.

The CRT used in the 321 was the T321P2 that physically closely resembled the T317 CRT used in the Model 317. A low-power heater drawing only 2 watts, compared to the usual 4 watts of almost all other CRTs of that time period, was used to reduce power requirements. The heater voltage was the customary 6.3 volts. A 4-kV overall acceleration potential gave a fairly bright trace even in outdoor field applications. The principal design problems to be overcome were to keep voltage swings to a minimum for deflection amplifiers and retrace blanking. The early transistors used had low collector breakdown voltage ratings, and of course, Tektronix was usually very conservative with their designs. The 321 operating temperature range was specified as 30 to 120 deg F and altitude to 20,000 feet. Another factor was cost, as higher-breakdown-voltage transistors were markedly more expensive in 1960.

To minimize the deflection amplifier output voltage required, several means were used. First, the acceleration voltage through the deflection region of the CRT was about half of that of the T317. This automatically doubled the deflection sensitivity. A spiral post-deflection accelerator provided the final 4 kV acceleration for a brighter trace while maintaining good deflection sensitivity. Second, the deflection plates were made as long as possible consistent with low capacitance to meet the 5 MHz bandwidth specification. Lastly, the deflection plates were spaced together as closely as possible for maximum sensitivity at the sacrifice of some scan area due to beam intercept by the plates. The specification for scan area was 6 x 10 divisions, each division being ¼". The viewable screen area was masked to that size by the instrument bezel.

Retrace blanking is used in all but the simplest of oscilloscopes to eliminate visibility of the beam as it returns to the left side of the screen prior to its next scan. If the beam is not blanked during that time, a spurious trace will be displayed on the screen. Normally, a pulse of up to -100 volts is applied to the control grid or +100 volts applied to the cathode for cutoff of the beam during retrace. The T321 employed a novel approach to the problem. The first anode region is split and two pairs of cross-connected blanking plates are inserted between anode apertures (Figure 2). The beam passes between the plates much the same as it does the deflection plates. If the plates are at the same voltage as the anode apertures, the beam will pass unimpeded to the screen. Applying a differential voltage to the plates will deflect the beam off-axis and it will be intercepted by the second aperture thus preventing it from reaching the screen. It would appear at first glance that a single pair of blanking plates would be adequate but some electrons in the first anode region are divergent and will result in a spot shift at the screen during the blanking transition

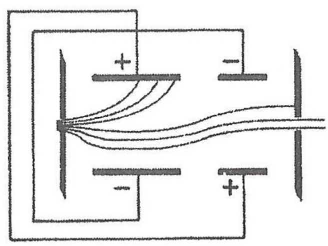

Fig. 2. Blanking plates

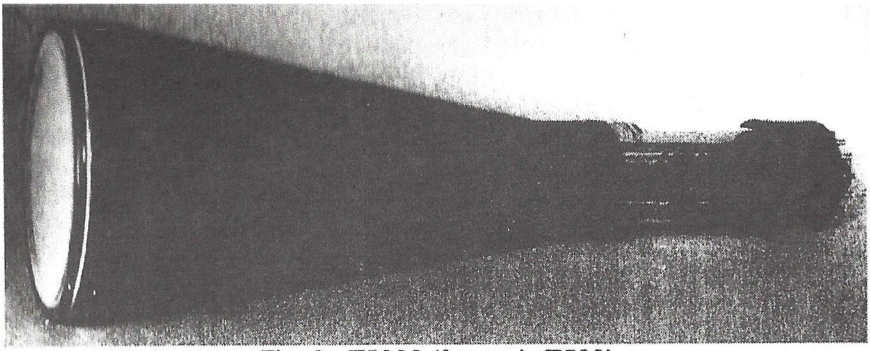

Fig. 3. T5030 (formerly T503)

times. The second pair of plates and cross-connection eliminates the problem. Only about 25 volts, well within the capability of the 1960-era transistors, was required for full blanking.

P1, P7, and P11 phosphors were also available in the T321. The standard phosphor was changed to P31 in 1962 for higher brightness. The T321 became a T3210 in the 1963 type renumbering and evolved into the T3211 used in the Model 321A oscilloscope. The T3211 was a direct retrofit replacement for the T321 and T3210. The reverse is not true since at some point between the original T321 and the T3211 a deflection-plate shield connected to pin 9 was eliminated. It is not clear exactly when but it appears to have been at 321 s/n 4720, coincident with the T3211 introduction.

T503

A pair of low-cost oscilloscopes was introduced in 1960. These, the Model 503 and 504, were basic instruments intended for the education market where Du Mont and other lower cost oscilloscopes were entrenched. The 503 and 504 retained the "Tek look and feel" but had a bandwidth of only DC to 450 kHz.

The 503 and 504 both used the T503 (Figure 3) which physically had a strong resemblance to the Du Mont 5AMP- except for being a little shorter and having Tektronix-style neck pins instead of the Du Mont small ball caps. Normally, neck deflection lead connections are not necessary for the 450-kHz bandwidth of these instruments but the tube was also to be used the following year in the Model 560 and 561 moderate-cost plug-in oscilloscopes that had wider bandwidth. The T503 was an unaluminized monoaccelerator CRT operated at 3 kV in the 503 and 504 and 3.5 kV in the 560 and 561. The tube was not particularly noteworthy except that it used blanking plates like the T321.

Both instruments were normally supplied with P2 phosphor manufactured by General Electric. This particular P2 had much better brightness and a very pleasing bluish-green color. It was a marked improvement over previous P2s. Because of its excellent long decay properties and the low frequency applications emphasis of the 503 and 504, it remained the standard phosphor long after most other instruments changed to P31 phosphor. P1, P7, and P11 were catalogued as optionally available. CRTs with P16, P19, P31, and P32 (see Table 1) were eventually part numbered and available through Customer Service on special order. The T503 became the T5030 and was later produced in rectangular versions as the T5031, T5032, and T5033.

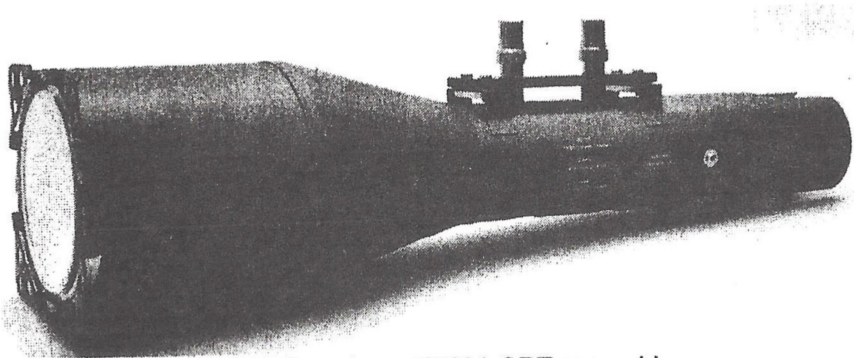

Fig. 4. Completed T5191 CRT assembly

T519

In 1961, the 519 oscilloscope was introduced. With a bandwidth of DC to 1 GHz and a risetime spec of less than 0.35 ns, it was state-of-the-art for viewing and photographing high-speed events. Extensive nuclear testing during the 1960s provided a high-end niche market for the 519 to record sub-nanosecond pulses from nuclear events. Legends abound of trailers containing rows of 519s with C19 cameras affixed to record just a single pulse from each of various aspects of the nuclear explosions. It was rumored that they often became contaminated and bulldozed into the ground, thus ensuring a great replacement market at about $3800 a pop (or should I say boom?). The 519 was produced until about 1973.

The 519 used the T519 CRT that was a major departure from other Tektronix CRTs. Many unique features were incorporated in this CRT. It resembles previous Tektronix CRTs only in its use of a spiral accelerator.

Mechanically, the T519 used a bulb and spiral accelerator similar to the other five-inch tubes except for having another small-cavity anode button to connect to the low-voltage end of the helix. Also, larger diameter neck tubing was used to provide adequate space for the complex deflection system. The base was the first "hard-pin" type used on Tektronix CRTs. Instead of the usual Bakelite base cemented to the tube with the wire leads from the header soldered to the base pins, heavier leads used as feed-throughs became the actual pins. A plastic guide / protector slipped over the pins and was secured with RTV silicone rubber. It is possible that the hard-pin stem was used to reduce capacitance for the fast blanking pulses required. The entire tube was permanently mounted in a blue mu-metal magnetic shield (Figure 4).

The greatest difference, though, was in the 1 GHz vertical deflection system. This was constructed as a box-like assembly (Figure 5) with tuning adjustments that were aligned electrically before sealing in the tube. A stripline deflection plate created a coaxial delay line as in the T581, only for a much higher frequency. The impedance of the line was 125 ohms and General Radio GR-874 coaxial connectors were used for both the input and termination connections. The stripline formed one deflection plate with the velocity of signal propagation through the stripline matching that of the electron beam through the deflection system. The anode voltage could be adjusted to match the transit time of the beam through the deflection system to that of the electrical signal through the stripline deflector for opti-

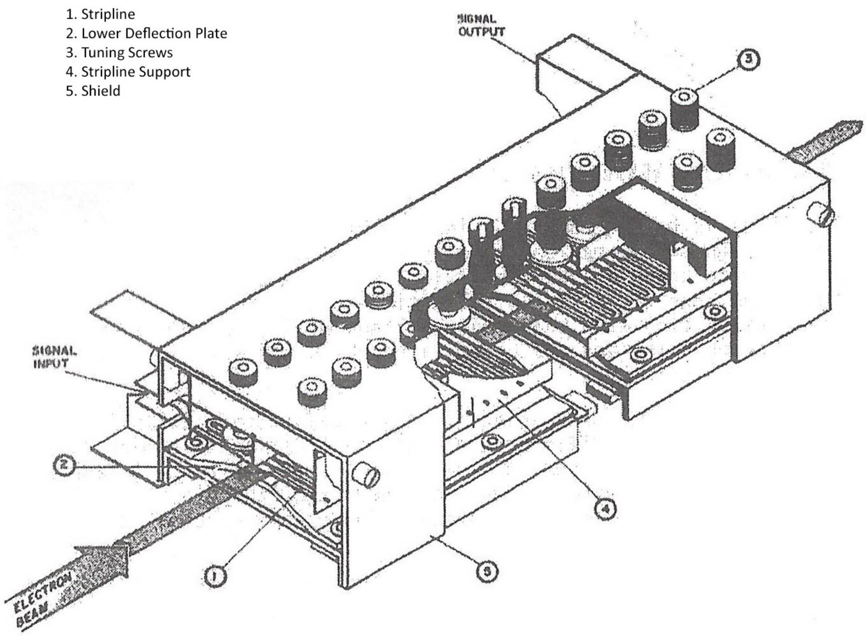

Fig. 5. T5191 stripline vertical deflection assembly

mum transient response. Since the T519 operated with coaxially-fed signals, the deflection was not push-pull and a solid plane formed the opposing deflection plate. No deflection amplifier was possible for the 1 GHz limit so signals were applied to the deflection system directly through coaxial cable. The vertical-sensitivity spec was 8 to 10 volts / cm. Horizontal deflection was more traditional, with the exception of use of a forced-air cooled Eimac 4CX250F as a sweep generator to obtain fast sweeps up to 2 ns / cm.

The overall acceleration voltage was 24 kV. Usable scan area at the screen was 2 x 6 cm and the actual calibration of the deflection sensitivity and risetime of the individual CRT was written on the bezel. Since bezels are often removed and can be lost or mixed up, later T519s had the sensitivity and risetime printed on a label attached to its shield. A very small spot size of 0.004" was obtained in the T519 through electron gun design to aid resolving pulse detail in the limited scan area. Conventional Tektronix CRTs had spot-sizes of 0.010" to 0.015" or so.

The standard phosphor for the T519 was P11 for photo-recording. No other phosphor was available. The T519 soon was renumbered T5190. At instrument s / n 244 it became the T5191, which was the same tube with a slightly degraded vertical sensitivity specification, presumably to improve production yields.

T519C

An interesting variation of the T519 was the T519C that was renumbered as the T5192 (Figure 6). It was used in a special-order version of the 519 oscilloscope designated 519 Mod 795. It is believed to have been developed for Lawrence Livermore Laboratory, a major 519 user. The T519 was built in the Tektronix Engineering Tube

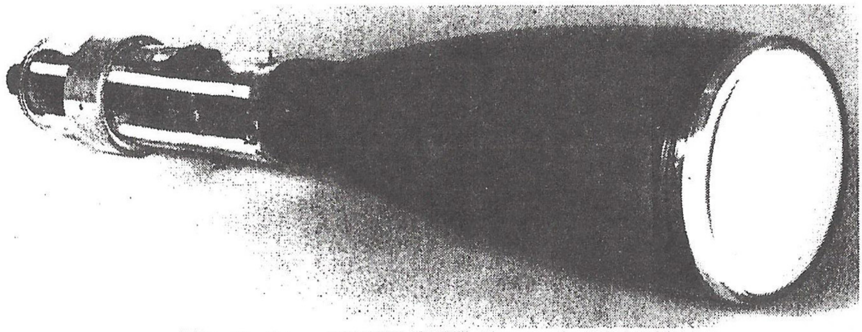

Fig. 6. Raw T5192 CRT (formerly T519C)

Lab. As with the T519, the only phosphor supplied was P11 for photo-recording.

A coaxial vertical deflection system replaced the stripline of the T519 for a risetime spec of 0.13 ns and about 2.7 GHz bandwidth. The increased bandwidth came at the expense of deflection sensitivity. The sensitivity specification was 180 to 240 volts/cm, about 25 times that of the T519. Useable scan area was also decreased to 2 x 4 cm. Most of the P11 phosphor on the five-inch diameter screen never saw an electron. The deflection system consisted of a coaxial transmission line entering the right side of the CRT neck and passing through the centerline of the tube to exit the left side of the neck. It was terminated with a 125 ohm load. An opening in center portion of the coaxial shield allowed the electron beam to pass through the transmission line close to the center conductor which became the active deflection "plate". An additional electrode nearby was the opposing deflection plate and provided vertical positioning with an applied DC voltage. A following grid shown in the basing diagram (Figure 7) probably was a mesh on the beam exit side of the structure to control the strong field from the subsequent 24.11 kV final accelerator to minimize pattern distortion. Jim Richardson, a retired Tektronix CRT engineer, recalls the T519C being referred to as the "knife edge tube". This was likely due to the fact that the center coaxial wire that provided vertical deflection made a very short deflection "plate" compared to conventional deflection systems. Transit time past the wire would be very short for fast response.

The T519C paragraphs have been reconstructed from the T5192 tentative data sheet and the memories of several retired Tektronix employees. The electrode configuration deduced above may not be exact, but until one of the tubes is examined or an old drawing surfaces, it will have to suffice. In any event, it should be fairly accurate.

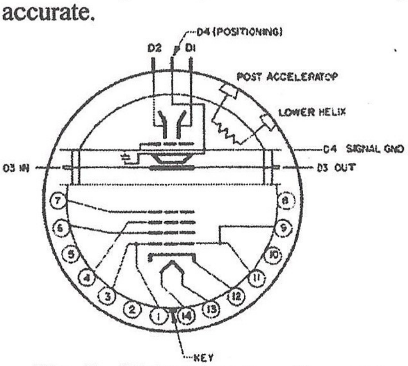

Fig. 7. T5192 basing diagram

T945

Also in 1961, the Model 945 oscilloscope was introduced. The 945 was a ruggedized and enviromentalized

TYPE	P1	P2	P7	P11	P16	P19	P20	P31	P32
T321	154-293	154-226	154-294	154-295				154-347	154-385
T503	154-264	154-265	154-266	154-267	154-318	154-311		154-341	154-387
T519 (Early)				154-356					
T519 (Late)				154-308					
T581	154-228	154-224	154-229	154-230	154-335		154-297	154-354	154-395

Table 1. CRT Part Numbers

version of the 545A for the military. It appeared only in the 1961 and 1962 instrument catalogs. The T945P2 CRT was listed in the catalogs as standard but no other information using that designation has been unearthed so far. It was basically just a militarized T543P2. By 1968, the T945 was designated T5431. The CRT data sheet for the T5431 dated April 19, 1968 describes it as follows:

> "The Tektronix Type T5431 is an aluminized 5-inch flat-faced cathode-ray tube with electrostatic focus and deflection and a helical post-accelerator. The tube features faceplate shielding to prevent radio interference; provisions for use at high altitude, over wide temperature ranges, and in high-humidity and fungus environments; and a ruggedized structure to withstand vibration and shock. The T5431 is designed to meet the applicable portions of Mil-T945A environmental specifications. The T5431 was designed for use in the Tektronix Type 945 Oscilloscope."

No Tektronix part number has been found for the T945 per se. A 1972 parts reference table lists the T5431P2 as p/n 154-0501-00 and the T5431P11 as p/n 154-0501-01. Both were listed as stocked for Customer Service only since the 945 was a discontinued instrument by then.

COMING NEXT

The next article in this series will discuss more of the innovative CRTs introduced by Tektronix during the early 1960s. Also to be discussed will be other CRTs used to expand the product line to cover diverse customer requirements.

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