Tektronix 11000 Series

The Last Great Plug-in Laboratory Oscilloscopes

Giovanni Becattini

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A Note on the Illustrations

Most of the oscilloscope screenshots reproduced in this book have been digitally enhanced using AI tools to improve their clarity, sharpness, and readability.

Although their visual appearance has been improved, care has been taken to preserve the original technical content, including waveforms, measurements, menus, and instrument settings.

The purpose of these enhancements is not to alter what the instruments displayed, but simply to make it easier for the reader to see and appreciate it.

References

The following references are used in this book (from Quacktech Editions unless otherwise note

- [TEO] Tektronix Epic Oscilloscopes – Elektor Books – Sold Out
- [7KS] Tektronix 7000 Series – Mainframes – Elektor Books
- [7KPI] Tektronix 7000 Series – Plug-ins
- [TREG] Tektronix Oscilloscopes Restoration Guide – Elektor Books – Sold Out
- [HP1] Hewlett-Packard and its Voltmeters and Oscilloscopes
- [HP2] Hewlett-Packard Signal Sources
- [HP3] Hewlett-Packard Counters and Spectrum Analyzers
- [HP4] Hewlett-Packard Calculators, Computers and HP-IB
- [VRE] Vintage Radio Equipment – Elektor Book
- [MAC] Apple Macintosh – History, Engineering, and Restoration – Elektor Books
- [QT602] The Good Giant – Tektronix DSA 602A Oscilloscope
- [QT11KP] The Last Plug-ins – Tektronix 11000-Series Plug-ins
- [SCLI] Strumentazione Vintage – Edizioni C&C
- [QTCOL] Collins Classics – KWM-2, 30L-1 and 51S-1: History, Engineering, and Restorat
- [QT324] Two Giants and a Shorty – Tektronix 323/324
- [QTBYOP] Become Your Own Publisher
- [DAB] Digital but Analog
- [TG7] When Machines Learned to Write
- [PDP-8] DEC PDP-8 – The Minicomputer That Anticipated Microprocessors
- [OTTO] Build Your Own Educational PDP-8 Clone Using an FPGA
- [TUB] The Tubes That Changed the World
- [TRC] Tektronix, The Round Corners – From Vacuum Tubes to Early Solid State
- [HEPS] Tektronix, 7000 Series Power Supplies – History, Design and Restoration

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Tektronix 11302
Brighteye Technology

Preface

The last great plug-in laboratory oscilloscopes had, until now, appeared rather piecemeal in my books. The 11400 Series and some plug-ins were covered in the now out-of-print *Tektronix Epic Oscilloscopes*, while the 11300 Series, the DSA 600 family, and the plug-ins received their own separate volumes.

When I thought of bringing all this material together, I told myself, *"This shouldn't take much."* Most of it was already written. Surely a little copying and pasting would do the job.

But, just as it had with *Tektronix: The Round Corners* and the older 500-Series instruments, things got out of hand. I ended up rewriting practically everything. It is remarkable how many things you discover could have been explained better when you return to a subject a second time, with a few more years of experience behind you. After all, *Tektronix Epic Oscilloscopes* was my very first book.

The result is the largest book I have ever written—and one I found myself writing with even greater enthusiasm than the first time.

Perhaps that was inevitable. These were some of the largest and most complex laboratory oscilloscopes ever built: the last monsters of the plug-in era, fascinating dinosaurs that somehow forgot to become extinct when their time was up. The more closely I looked at them, the more I wanted to understand—and share—the ingenuity hidden inside.

After the two volumes on the 7000 Series and *The Round Corners*, the Tektronix saga continues.

Giovanni Becattini

01

An Ambitious Project, a Difficult Journey

In the early 1980s, Tektronix still dominated the high-performance oscilloscope market. But digital technology was advancing rapidly, and competitors were challenging its supremacy.

The response was one of the most ambitious projects in Tektronix history: a new family of oscilloscopes combining extraordinary performance with a radically different approach to measurement.

Four years of brilliant engineering, unexpected difficulties, and inevitable compromises followed. The result was the 11000 Series. But the road had been anything but easy.

The 11000 Project

Two extraordinary families, analog and digital, born from one of the most ambitious engineering projects in Tektronix history.



Tektronix®
COMMITTED TO EXCELLENCE

A Project for the Nineties

I Didn't Even Know They Existed

Until just a few years ago, I didn't even know they existed.

Considering that, for a fairly long period of my life, I traveled extensively through the engineering departments of many electronics companies, this probably says quite a lot about the Tektronix 11000 Series.

Although I had owned or used several oscilloscopes over the years—and oscilloscopes have always been something of an obsession of mine—I had never even heard of these 11000 instruments.

An Alien Species: the First Encounter

So, when I first came across an advertisement for a 11403, I paid little attention. The photograph was rather small, and I couldn't even figure out exactly what I was looking at.

But after seeing that same advertisement, more or less absentmindedly, for several months, curiosity finally got the better of me. I decided to buy this strange relic, pretty much blindly, knowing almost nothing about it.



Not Entirely Favorable

My first impressions were not entirely favorable.

To begin with, its dimensions and weight were, I would say, decidedly excessive. The front panel was rather disappointing, too. Instead of all those wonderful knobs, switches, and controls that I love so much, this member of the 11000 family offered just eleven buttons and two large knobs.

Worse still, the display quality was dreadful. This was certainly a defect of my particular unit, but I couldn't help suspecting that even when new, the appearance of that curved-surface CRT hadn't been especially impressive.

The touchscreen was also a long way from today's standards, and it took some practice before I could use it with anything approaching reasonable efficiency.

Nor was the 11403 particularly brilliant when it came to capturing single-shot events. With a maximum real-time sampling rate of just 20 MSa/s, it was easily outperformed in this respect by the much less expensive, contemporary 100 MSa/s Tektronix 2430.

Difficult to Understand

The fact is that the 11000 Series is not particularly easy to understand, and it is surprisingly easy to fall into a trap when trying to analyze and evaluate it. I must admit that, at first, I fell straight into it.

The **11400** instruments, which were my first introduction to the family, are particularly difficult to appreciate if we approach them with today's mentality.

In my studies of vintage electronic equipment, I have often encountered products whose purpose and success were immediately understandable. They almost explained themselves, because they responded so perfectly to the needs of their time. Many Tektronix oscilloscopes of the Round Corners and 7000 Series belong to this category.

But my 11403 required considerably more effort.

After decades of *digital oscilloscopeness*, we are almost conditioned to judge a digital instrument primarily by its real-time sampling rate, memory depth, and ability to capture unexpected events.

And so we look at the 11403 and wonder: all that enormous amount of electronics, just to achieve a miserable 20 MSa/s? But that is the wrong way to look at it.

In the early 1980s, the world of oscilloscopes was emerging from decades of *analog oscilloscopeness*, during which engineers had become accustomed to examining primarily repetitive signals. Capturing isolated events was a much more difficult matter, often requiring photographic recording, analog storage CRTs, or other specialized techniques.

Perhaps the original concept behind the 11400 was therefore not so much to create a digital storage oscilloscope as we understand the term today, but to build an extraordinarily sophisticated **analog** oscilloscope **in digital form**.

An instrument intended primarily to analyze repetitive signals at very high frequencies, offering measurement and processing capabilities that conventional analog technology could hardly provide, together with exceptional accuracy.

Viewed from this perspective, many apparently strange design decisions begin to make sense.

Faced with the trade-offs imposed by contemporary technology, the designers clearly placed great emphasis on vertical resolution and measurement accuracy, choosing, among other things, a 10-bit analog-to-digital conversion system.

Fast 10-bit converters were still challenging components at the time, and the acquisition system ultimately offered a maximum real-time sampling rate of only 20 MSa/s. Capturing high-frequency single-shot events was therefore not among the instrument's strongest capabilities. But perhaps it was never intended to be.

Yet, in the end, this is little more than **a misleading detail**, because hidden inside our 11400 lies the disruptive power of genuine innovation. Within a few years, virtually all oscilloscopes would begin to follow the path it had opened, and once again, we would end up taking for granted what Tektronix had worked so hard to teach an entire industry.

All this makes the investigation ahead considerably more interesting. The more complicated and mysterious the hidden chambers of an ancient pyramid, the more fascinating they become to us archaeologists of technology. And in this particular pyramid, I suspect we have found more than enough to keep us busy.

Leaving my personal experience aside and returning to a more general analysis, the container labeled 11000 Series held two almost immiscible liquids: the 11300 and 11400 families.

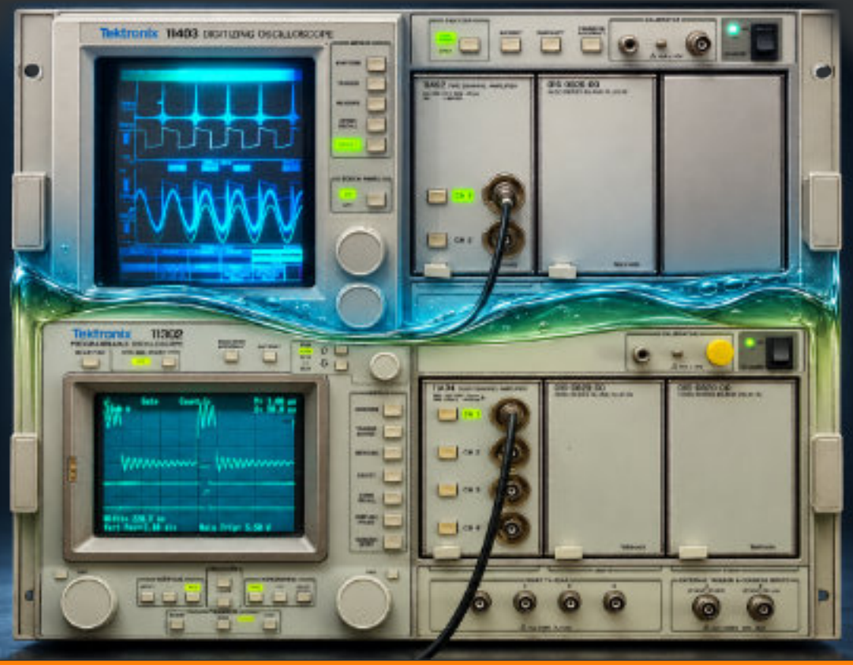
Both were true "monsters" of electronic engineering, yet they had remarkably little in common beyond the first two digits of their names. They shared most of their plug-ins and some hardware technologies, but their architectures, operating principles, and user interfaces were profoundly different.

Two **Immiscible** Fluids

Although they shared the same series designation, a certain family resemblance, and most of their plug-ins, the 11300 and 11400 seemed to me like two almost immiscible fluids.

Their operating principles, architectures, and user interfaces were so different that they appeared to have surprisingly little in common. Yet both emerged from the same ambitious Tektronix program. How did two such different machines come into existence?

Our aim is not merely to describe two extraordinary machines, but to understand how they came into being—and what their stories tell us about Tektronix at a turning point in its history.



As we shall see, the 11300 Series represented the final and most sophisticated expression of the great analog plug-in laboratory oscilloscope—a magnificent technological achievement that would never have a true successor.

The 11400 Series, on the other hand, represented almost the opposite: the first, still relatively immature realization of a new generation of digital instruments, whose concepts and technologies would continue to evolve for decades.

In other words, those two digits, 11, marked the meeting point between two eras.

But to understand how these extraordinary machines came into existence, we must, as usual, travel back in time. Our destination is 1980, six years before the 11000 Series was officially introduced.

At the Beginning of the Eighties

The Tektronix Catalog

The 7000 Series had marked a major turning point in the evolution of oscilloscopes, and its success was extraordinary. Introduced in the October 1969 issue of *Tekscope*, the family would remain in the Tektronix catalogs for more than twenty years, with its latest members still appearing in the 1990 general catalog.

Let's pick up the 1981 Tektronix catalog, for example. The 7000 Series was still riding the crest of the wave, with some truly remarkable instruments:

- The **7104**, a real bombshell, with its 1 GHz bandwidth and almost science-fiction-like Micro-Channel Plate (MCP) CRT, providing an exceptionally high visual writing speed. Even very short, single-shot pulses could be observed at fast sweep speeds, in ordinary daylight.
- The **7834**, a 400 MHz analog storage oscilloscope, capable of preserving transient waveforms directly on its CRT.
- The **7854**, the *Waveform Processing Oscilloscope*, a remarkable 400 MHz instrument combining analog and digital technology within a 7000-Series mainframe. In addition to a conventional real-time analog oscilloscope, it incorporated a 10-bit digitizer, a programmable waveform processor, and a GPIB interface.

And shortly afterward, another remarkable product would join the family:

- The **7D20**, a two-channel, triple-width digitizing plug-in capable of transforming a compatible 7000-Series mainframe into a programmable Digital Storage Oscilloscope (DSO), complete with waveform memory and a GPIB interface.

An impressive lineup indeed. Few competitors could offer anything comparable.

Where Was the Market Going?

But where was the market heading?

Something fundamental was happening. Digital technology was rapidly spreading into almost every field of electronics, and oscilloscopes could hardly remain untouched by this revolution.

By the beginning of the 1980s, 100 MHz bandwidth was already common among professional analog oscilloscopes. Yet the emerging digital technology could not even approach such performance when acquiring signals in real time.

The advantages of digitizing waveforms were obvious: once converted into numbers, signals could be stored, processed, measured, compared, transmitted, and analyzed in ways that traditional analog instruments could hardly offer. The problem was getting those numbers in the first place.

The first generations of Analog-to-Digital Converters (ADCs) were simply too slow to compete with the bandwidth of serious laboratory oscilloscopes. But semiconductor technology was advancing rapidly, and new converter architectures were steadily pushing the limits of sampling speed.

It was becoming increasingly clear that digital acquisition would eventually transform the oscilloscope. What was much less clear was when—and how.

Tektronix and Digital Technology

Despite its extraordinary products, Tektronix's offering was still somewhat fragmented.

You could have very high bandwidth, analog waveform storage, digital acquisition, sophisticated waveform processing, or extensive programmability. But you couldn't have all these capabilities, at their best, in a single instrument. The magnificent **7854** illustrates the situation particularly well.

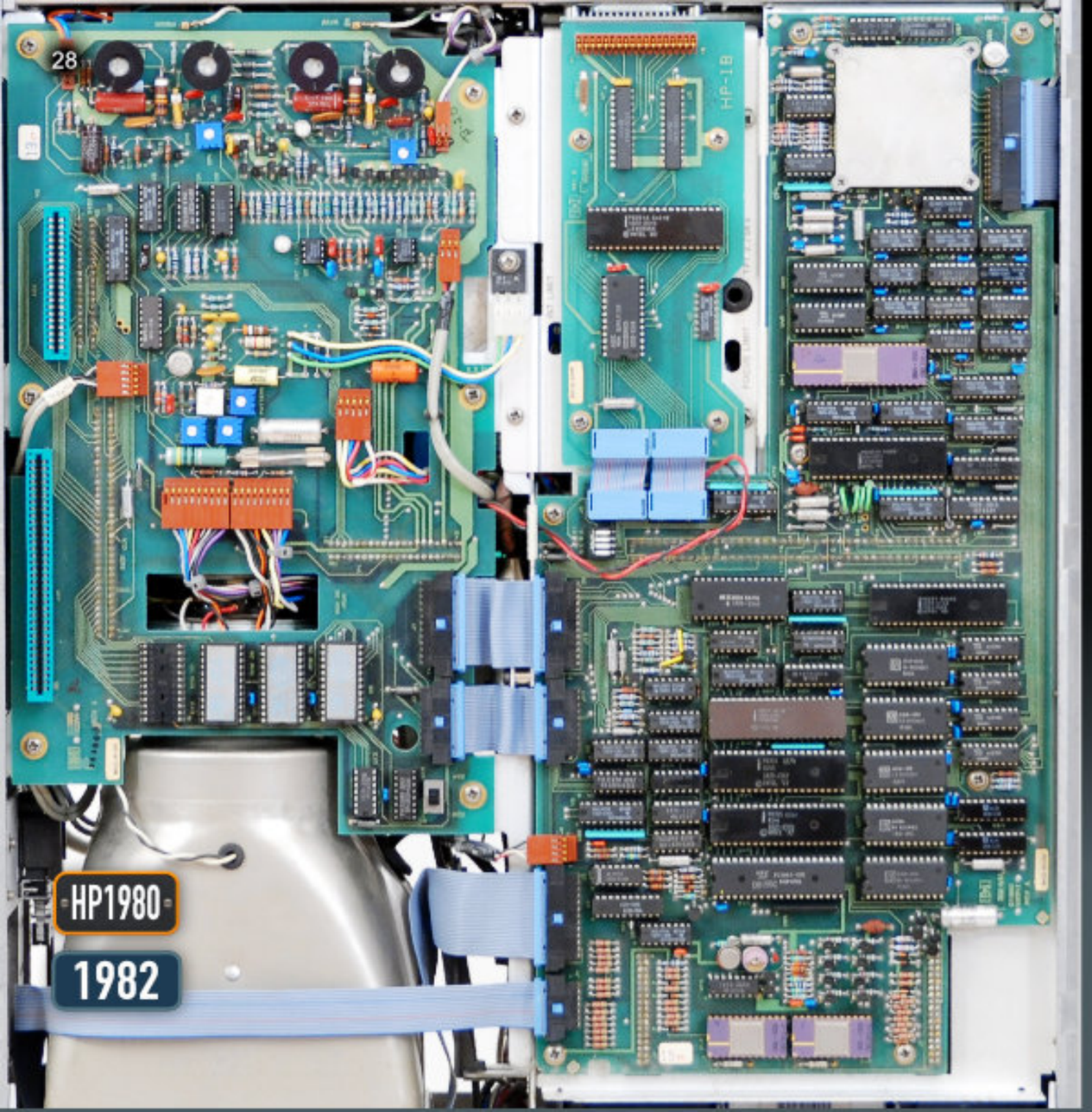
Its analog and digital sections could communicate, acquire, process, and display waveforms, but the integration was still far from complete. Apart from the signal path itself, part of the communication between the two worlds relied on an ingenious trick: reading the characters generated by the analog readout system. A remarkably clever solution, but hardly what we would call a fully integrated architecture today. Above all, the digital intelligence had very little authority over the analog circuitry. The processor could perform sophisticated mathematical operations on acquired waveforms, but it couldn't reach out and turn all those lovely knobs. That job was still firmly in the operator's hands.

The **7D20** approached the problem from another direction. It offered a genuine digital storage oscilloscope within a plug-in, but its maximum real-time sampling rate was only 40 MSa/s. It was an ingenious way to bring digital capabilities to existing 7000-Series instruments, although its limited single-shot bandwidth made it unsuitable for many high-speed applications.

In short, Tektronix had already developed much of the technology needed for the future oscilloscope. But the pieces had not yet come together. And there was another problem.

Tektronix was the undisputed leader of the oscilloscope market. This is a wonderful position for any company, but also a potentially dangerous one. Success can create the illusion that the good years will never end, particularly when a company has dominated its field for so long.

And technological revolutions rarely announce themselves politely.



In its basic configuration, it offered two 100 MHz analog channels with sensitivities down to 2 mV/div, two independent time bases reaching 5 ns/div, main and delayed sweep capabilities, and automated voltage and time measurements.

It also offered something that would soon become indispensable: **Autoscope**, an automatic setup function that could examine the input signals and select suitable vertical, horizontal, and triggering conditions. No more painstaking adjustment of half a dozen controls merely to obtain a useful trace.

Through its HP-IB interface, the instrument could be integrated into automated test systems. Measurement routines could be programmed, stored, and executed repeatedly, while instrument settings and measurement results could be exchanged with an external controller.

Internally, a microprocessor coordinated the various functional sections through a common bus architecture. This made possible extensive programmability, autoranging, automatic calibration, and expansion through additional hardware and firmware.

Digital waveform storage was also available, although its maximum single-shot sampling rate was only 50 kSa/s, one tenth of the Tektronix 7854's rate. The HP was certainly not winning the acquisition-speed race.

But that was not the point. The real innovation lay in the architecture. The instrument's controls were no longer necessarily direct mechanical extensions of its analog circuits. Instead, they became commands interpreted by a computer, which could then configure the instrument.

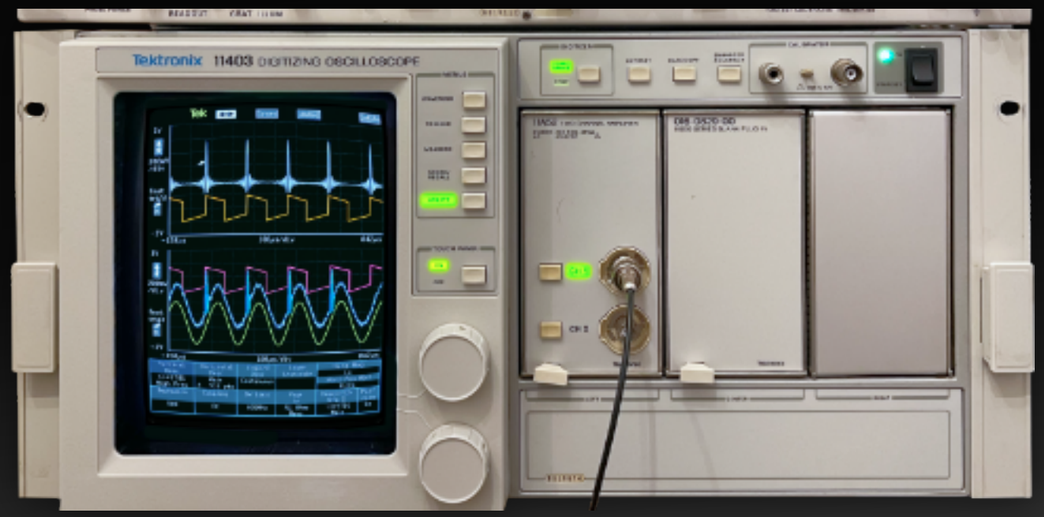
And the front panel made this philosophy immediately apparent: rather than the familiar forest of knobs, there was just **one rotary control**, used for many different functions. It was a glimpse of the future.

> *If I had been sitting in Tektronix's management offices, what would have worried me most was not the HP 1980's performance specifications. It would have been the photograph on the facing page. Look at its internal construction. Everything appears carefully organized, rationally arranged, and designed with manufacturing in mind. It gives the impression of an instrument that could be produced efficiently, without excessive complexity or cost. Now compare that philosophy with the extraordinary electronic monster Tektronix was about to develop, as we shall soon see.*

The HP 1980 was not yet the instrument that would dethrone the great analog oscilloscopes. But beneath the canopy of the old giants, a new tree was growing.

And it was growing in a very different direction.

02 | Part 1



The 11400 Series

Discovering the 11400

A closer look at the remarkable digital instruments that brought a new philosophy of measurement to the laboratory.

Behind its apparently simple front panel, the 11403 concealed a remarkably complex instrument, where high-speed sampling, digital processing, stored waveforms, and advanced measurements came together in a single laboratory tool.

This part introduces the 11400 family, its distinctive appearance, its remarkable capabilities, and the design philosophy that made it one of the most unusual oscilloscope families of its time.

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of the signal preceding the trigger only by using an analog delay line.

In this mode, however, the 11400 could acquire a maximum of just **20 million samples per second** (one sample every 50 ns), a rather modest figure even at the time. The HP 54100A already offered twice that sampling rate, while the contemporary, much smaller Tektronix 2430 reached 100 MSa/s. Their vertical resolutions were lower, however: 7 bits for the HP and 8 bits for the 2430, compared with the 11400's 10 bits.

We have already discussed this relatively modest sampling rate, probably one of the weakest aspects of the original 11400 project. It may simply not have been considered a primary design objective. But in practice, things were even worse.

The maximum 20 MSa/s rate applied only when acquiring a single channel. With two channels selected from different plug-ins, the sampling rate dropped to 5 MSa/s per channel. With three channels, one from each plug-in compartment, it fell to just 2.5 MSa/s per channel.

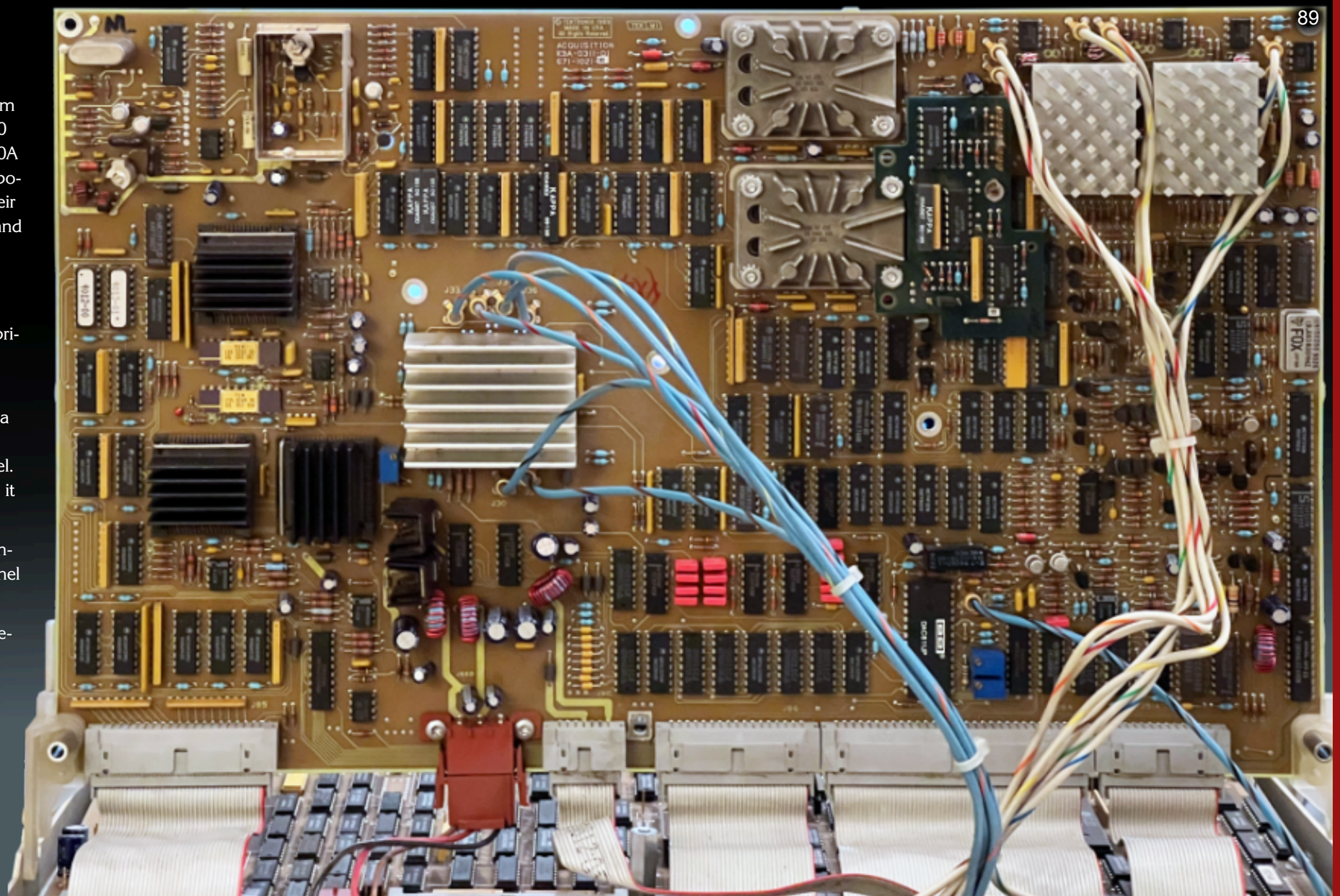
Interestingly, the three plug-in compartments could be sampled simultaneously, but this did not mean that each channel could operate at the maximum sampling rate.

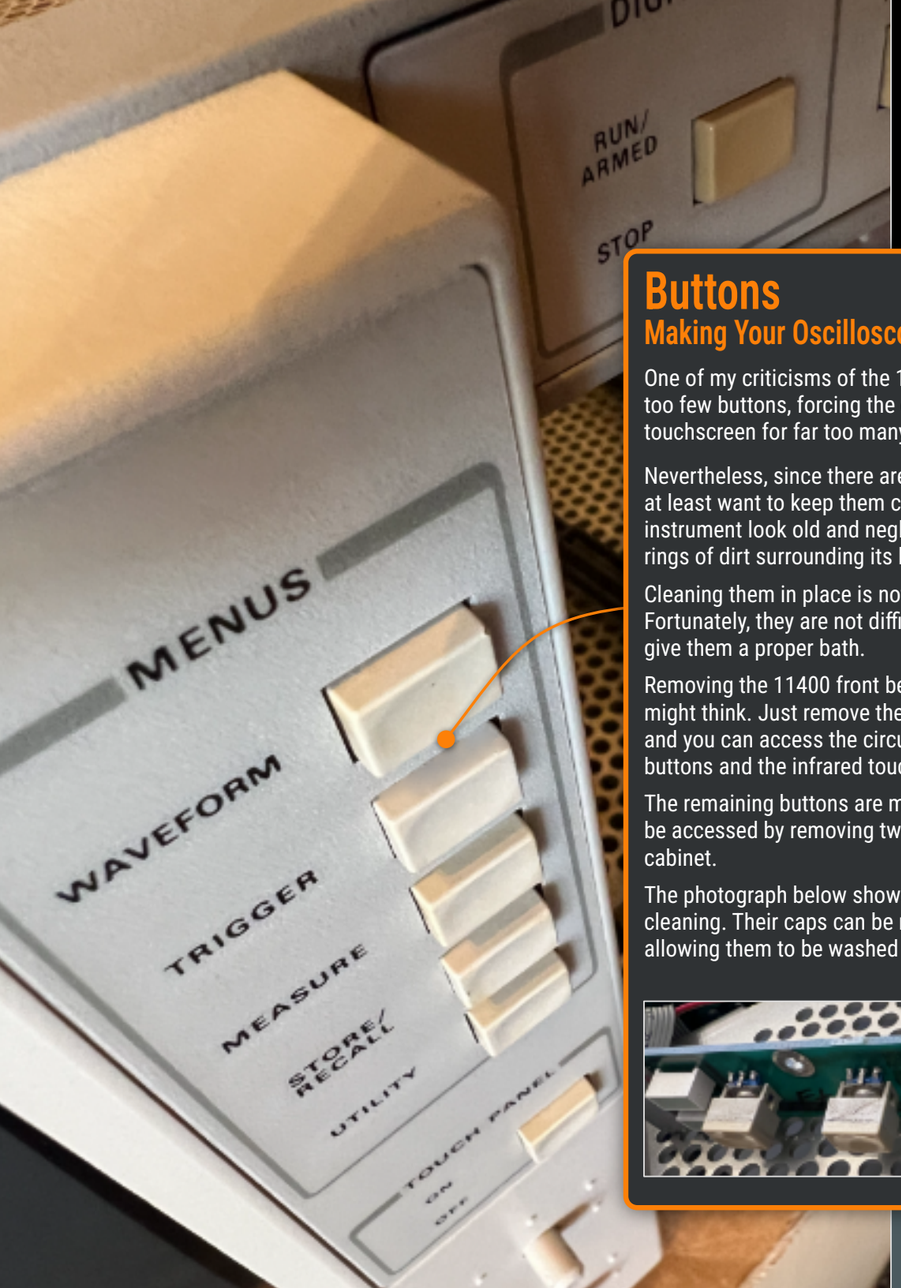
And when several channels within the same plug-in were selected, the limitations became even more severe.

The Digitizer

The photograph shows the digitizer module of the 11403, certainly one of the most complex parts of the entire oscilloscope and one of the greatest challenges of the project, as confirmed by several historical accounts.

The “hearts” of the module were hybrid circuits, designed and manufactured by Tektronix itself, ensuring high quality, repeatability, and, not least, easier maintenance. Note the high-frequency signal paths implemented with coaxial cables and the familiar PCB connectors already used in the 7000 Series.





Buttons
Making Your Oscilloscope Shine

One of my criticisms of the 11400 Series is that it has too few buttons, forcing the operator to resort to the touchscreen for far too many operations.

Nevertheless, since there are so few of them, we might at least want to keep them clean! Few things make an instrument look old and neglected quite like those ugly rings of dirt surrounding its buttons.

Cleaning them in place is not particularly easy. Fortunately, they are not difficult to remove, so we can give them a proper bath.

Removing the 11400 front bezel is easier than you might think. Just remove the two screws underneath it, and you can access the circuit board carrying the buttons and the infrared touchscreen components.

The remaining buttons are mounted separately and can be accessed by removing two screws from inside the cabinet.

The photograph below shows the buttons before cleaning. Their caps can be removed quite easily, allowing them to be washed separately.



Returning to Tektronix, the new approach dramatically reduced front-panel clutter. More importantly, the interface could be reconfigured or extended through software, without corresponding modifications to the hardware.

The designers nevertheless decided to retain two large rotary knobs, considering them more practical than the industry's emerging tendency—particularly evident at HP—to reduce physical controls to one knob or even none.

By the summer of 1983, a simulation of the proposed interface was already running on an Apollo workstation. This allowed the engineers to evaluate and refine their ideas long before the actual oscilloscope hardware and firmware were ready.

Would users understand and accept such a radical departure from familiar operating habits? The designers must surely have asked themselves this question. They could not know that, in the decades to come, touchscreen interaction and context-sensitive menus would become familiar features of professional oscilloscopes. They were helping to write the future, without knowing how readily the world would accept their vision.

The 11000 Human Interface

The final solution was to move almost the entire user interface onto the display itself, precisely where the operator's attention was already concentrated. No longer would the operating procedure be *look at the screen, then find the knob to adjust*. Instead, it became *look at the screen and touch what you want to change*.

The resulting front panel was remarkably simple and clean: just **eleven buttons**, including the power switch, and **two large knobs**. The most conspicuous innovation was the **large monochrome display** equipped with a **touchscreen**, later replaced by a color display in the 11403.

The two **rotary knobs** were an important part of the concept. Unlike conventional oscilloscope controls, they had no permanently assigned functions. Depending on the selected menu, they could adjust vertical position, sensitivity, cursor position, or other parameters.

Tektronix went a step further by allowing certain commands to be initiated directly **from the probe**. The probe interface incorporated additional communication capabilities, supporting functions such as service requests and other forms of automatic interaction with the instrument.

In most cases, an FRU is a circuit board. Two notable exceptions are the CRT/CRT Driver assembly and the Power Supply Module, which are treated as complete replaceable units.

The procedure is straightforward: run the instrument's diagnostics, identify the reported error index code, and cross-reference it against the FRU Guide tables to determine which assemblies are most likely responsible for the failure.

After replacing the defective FRU, some recalibration of the instrument is normally required.

Component-level repair is simply outside the scope of this procedure. The manual does not attempt to guide the technician through individual circuits or components: the objective is to locate the faulty assembly, replace it, and return the instrument to service. It is difficult to imagine a clearer illustration of the new servicing philosophy.

My Own Experience

I experienced exactly the same transition in my own company, and we eventually reached very similar conclusions.

Our service technicians continued repairing simple faults, particularly recurring ones that could be identified and corrected quickly. More complex failures were handled by replacing the entire board, while defective assemblies were returned to the factory for testing on the same automated equipment used in production.

But even this approach eventually became troublesome. Returning, tracking, testing, and repairing defective boards introduced considerable logistical complications, particularly when several hardware revisions were in circulation.

A repaired board might be perfectly functional, yet belong to an obsolete revision that could no longer be installed in a newly manufactured product. After all, you could hardly sell a new machine containing an old version of a circuit board.

Eventually, we found ourselves discarding a surprising number of assemblies that, from a purely technical standpoint, might still have been repairable.

It was a difficult lesson: technical repairability and economic recoverability are two very different things.

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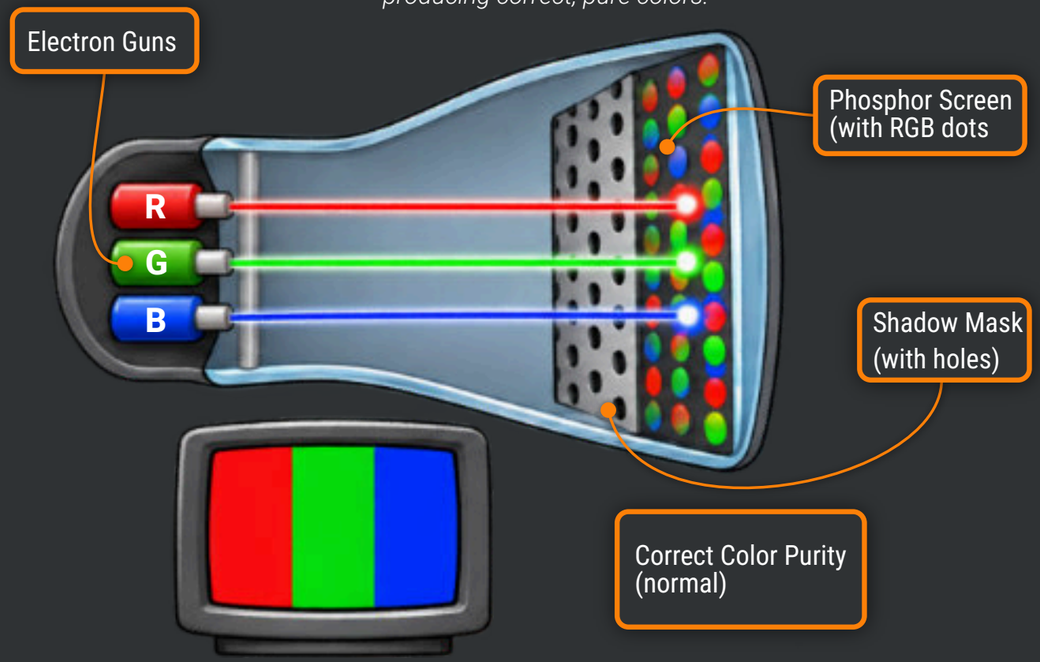
Magnetization Problem In Color CRT Displays

Unlike monochrome CRTs, color tubes must direct three electron beams precisely onto their corresponding red, green, and blue phosphors. A magnetized shadow mask can deflect the beams just enough to make them strike the wrong phosphors, producing unwanted patches of color.

Even the Earth's magnetic field can affect color purity, particularly when the instrument is moved or rotated. Fortunately, residual magnetization can usually be corrected by a process called degaussing, which we will examine separately.

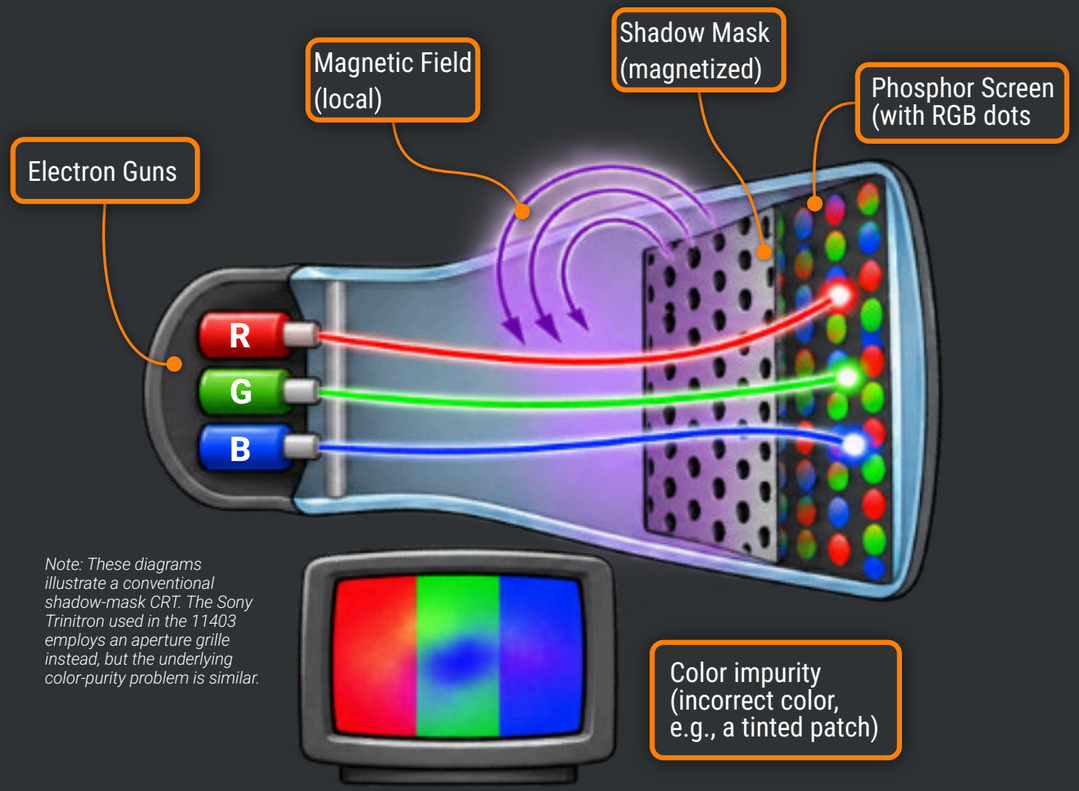
1 Normal Operation

Electron beams hit their matching phosphors, producing correct, pure colors.

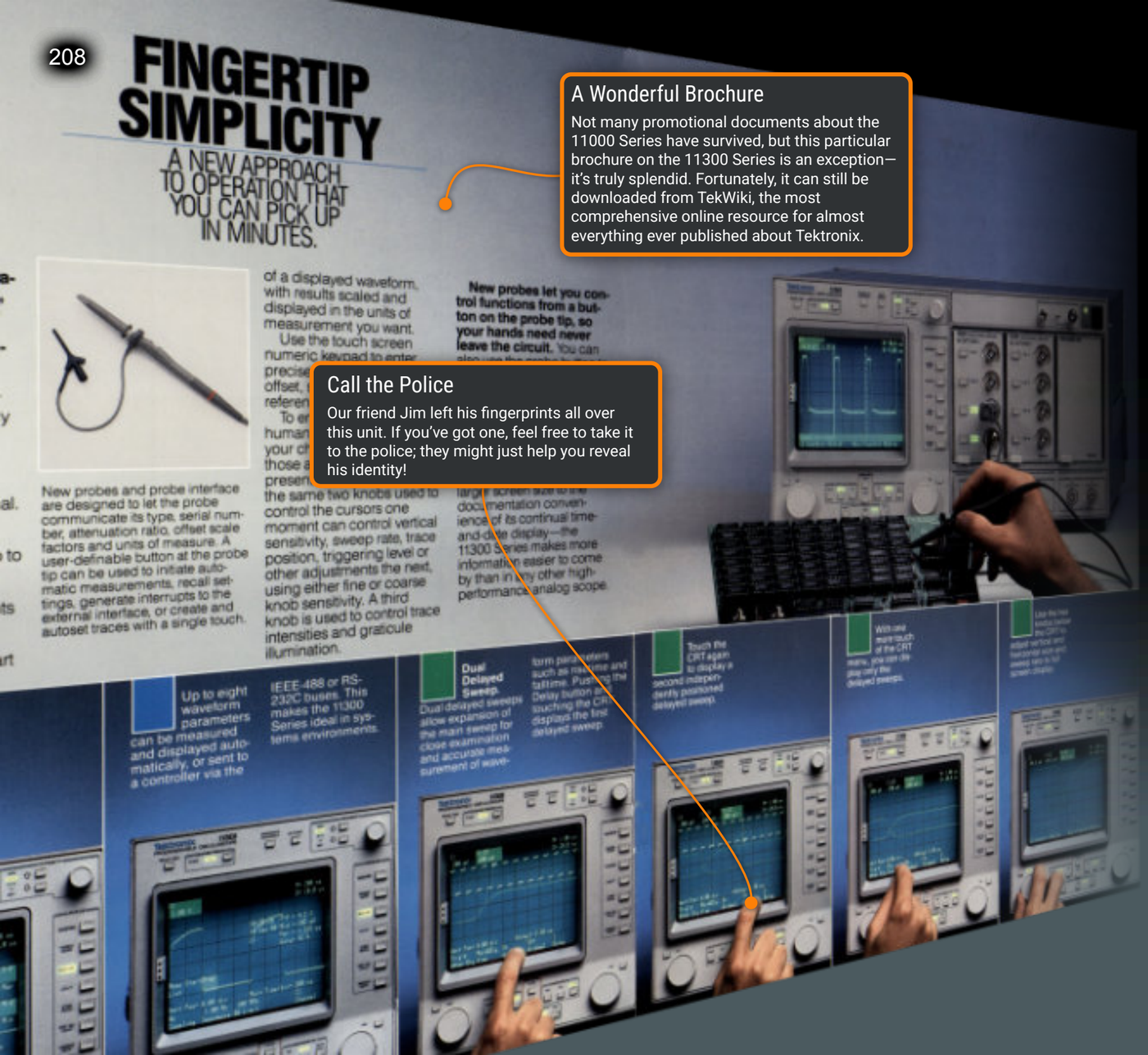


2 Magnetized Mask / Color Impurity

A residual magnetic field (e.g., a magnetized shadow mask) deflects the electron beams, so they hit the wrong phosphors, causing color impurity (tinting, blotches, or discoloration).



Note: These diagrams illustrate a conventional shadow-mask CRT. The Sony Trinitron used in the 11403 employs an aperture grille instead, but the underlying color-purity problem is similar.



A Wonderful Brochure

Not many promotional documents about the 11000 Series have survived, but this particular brochure on the 11300 Series is an exception—it's truly splendid. Fortunately, it can still be downloaded from TekWiki, the most comprehensive online resource for almost everything ever published about Tektronix.

Call the Police

Our friend Jim left his fingerprints all over this unit. If you've got one, feel free to take it to the police; they might just help you reveal his identity!

The Oscilloscope Becomes Intelligent

Looking at the front panel of an 11302, the first surprise is the almost complete disappearance of the traditional forest of knobs and switches. Instead, we find a relatively small number of pushbuttons, two assignable knobs, and a touchscreen interface.

The instrument presents menus directly on the CRT, allowing the operator to select functions simply by touching the appropriate areas of the screen. The two knobs can then be assigned to the parameters being adjusted.

This was a radical departure from the operating philosophy of the 7000 Series. Yet, unlike the 11400, the 11300 retained a somewhat richer set of physical controls, resulting in what I personally consider a particularly successful compromise between traditional operation and the new digital interface.

The CRT also served as an information center. The advanced readout system displayed operating settings, plug-in configurations, measurement results, and other information alongside the waveforms themselves.

Automatic measurements of time and amplitude reduced the need to count graticule divisions or estimate positions between them. The selected signals could be displayed automatically, greatly simplifying the preparation of complicated measurements.

And then there was a feature that I find particularly remarkable: **a built-in 500 MHz universal counter/timer**.

This was not a simple frequency counter added as an accessory. It was integrated into the oscilloscope's operating system and could perform a wide range of measurements, including frequency, period, pulse width, and time intervals.

Even more interesting was the **Counter View** function, which allowed the operator to see directly on the displayed waveform the portion involved in the counter measurement. A brilliant idea, and one that deserves a closer examination later.

In fact, the combination of a high-performance oscilloscope, sophisticated automatic measurements, and an integrated universal counter/timer made the 11300 a remarkably complete laboratory instrument.



Logical Architecture

After discussing some of the main features of the 11300 Series, it's time to explore the architecture of these formidable oscilloscopes—from both an electrical and a mechanical standpoint.

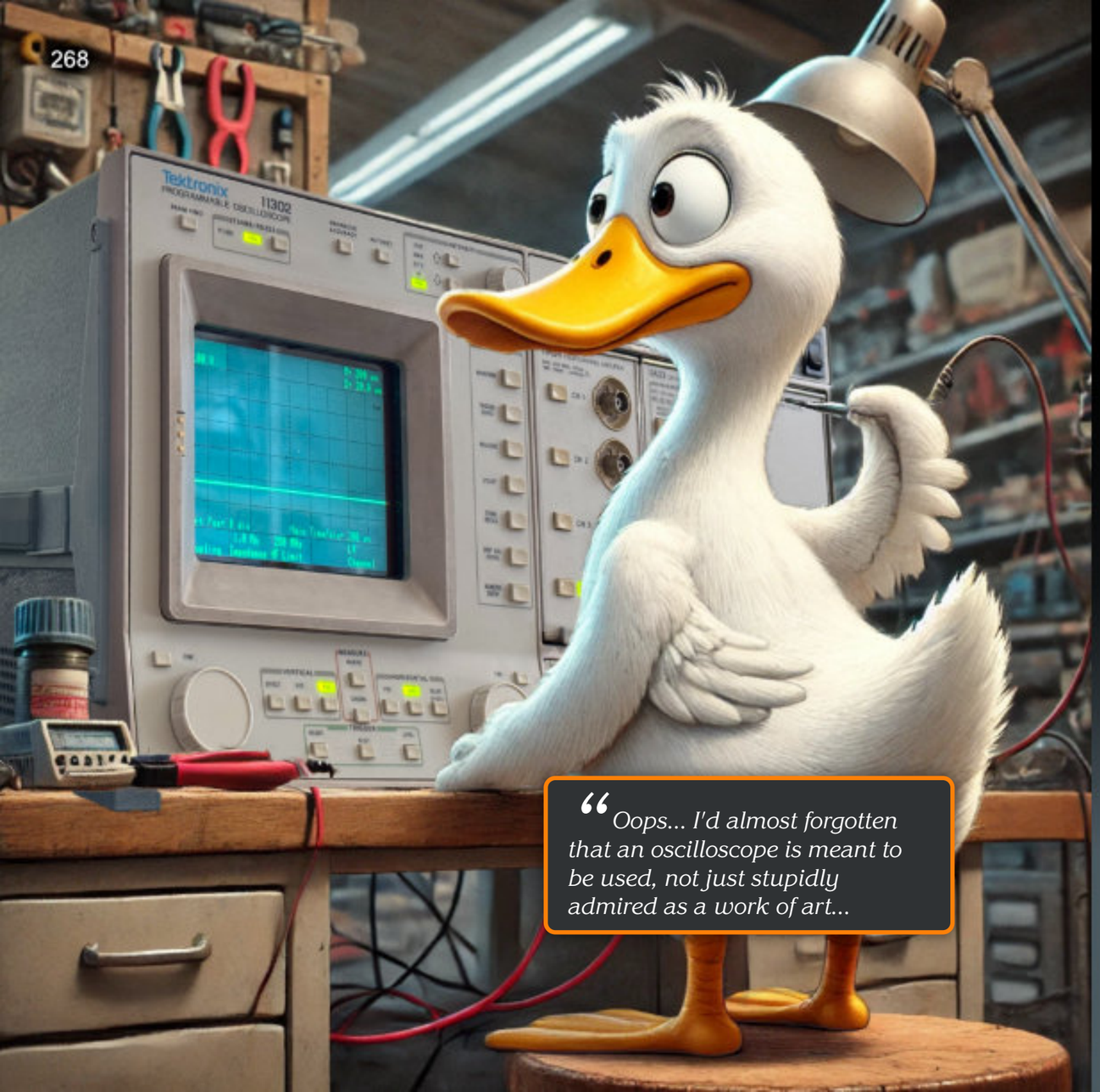
Let's begin from the outside.

New Form Factor

If you're used to the 7000 Series, the first thing you'll notice is the different form factor of the 11000 Series: wider and lower, more horizontal than vertical.

The days when Tektronix offered separate tabletop (vertical) and rackmount (horizontal) mainframes were essentially over. The new instruments adopted a common, low-profile format, suitable for both benchtop use and rack mounting.

Increasing costs and the growing complexity of the internal electronics certainly encouraged this consolidation, although each family—the 11300, 11400, and later DSA 600—implemented its own internal architecture.



“Oops... I'd almost forgotten that an oscilloscope is meant to be used, not just stupidly admired as a work of art...

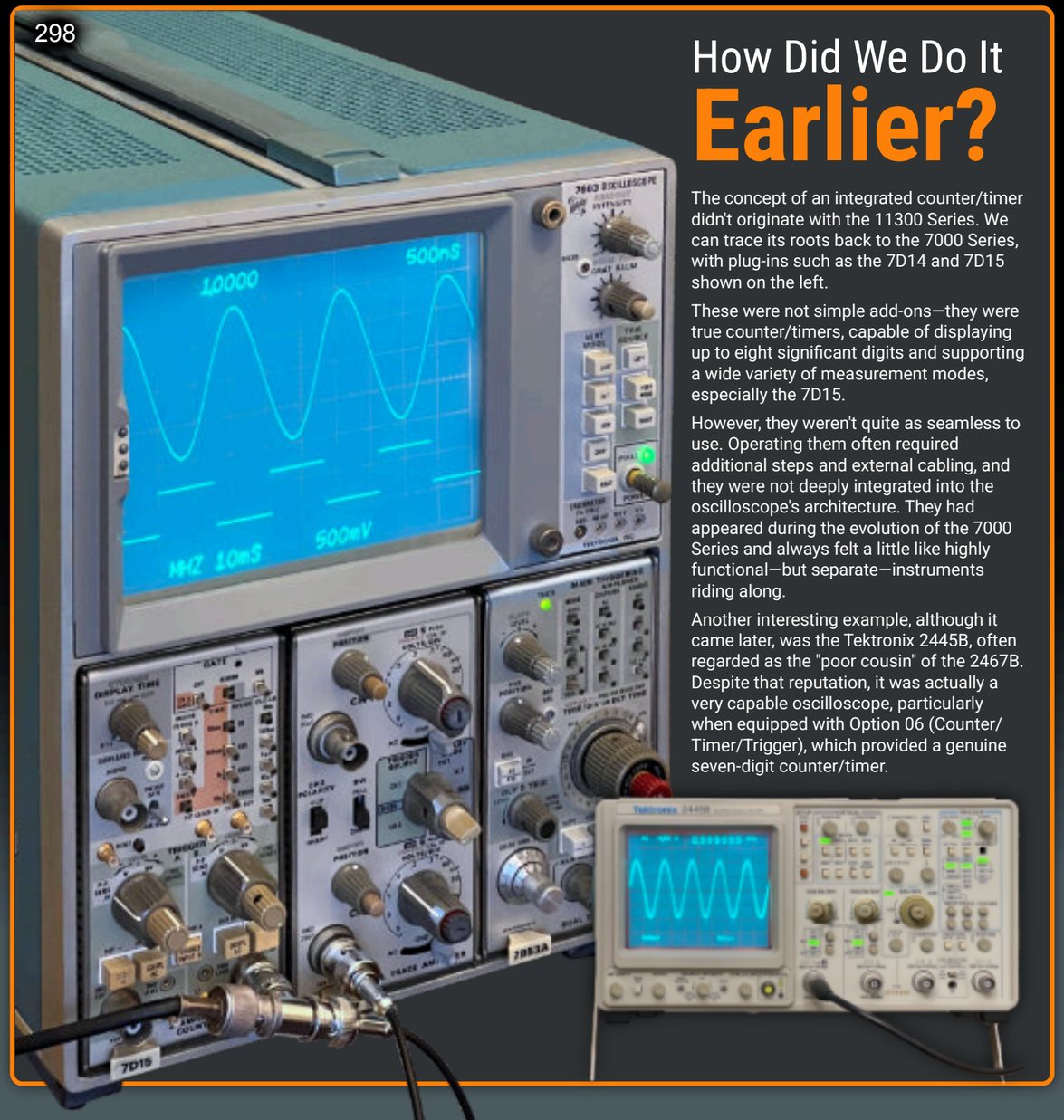
Using an 11302 Oscilloscope

After reviewing the **specifications** of the 11300 Series oscilloscopes and exploring the key elements of their architecture, it's time to see how to use them, with some practical examples whenever possible. These will not only demonstrate the most intriguing features of the 11302, but also give us an opportunity to introduce further technical details along the way.

In my opinion, the official user manual—though thorough—is sometimes confusing and lacks a clear overall picture. I hope this more hands-on, example-driven approach will make it easier to understand what these extraordinary instruments are truly capable of.

By the way, the 11300s are the **only analog oscilloscopes** I've ever encountered with a **touchscreen** interface. In that sense, they represent a fascinating technological crossroads, combining two worlds that would rarely meet again: the waning age of electrostatic-deflection CRTs, refined to near perfection after decades of evolution, and the birth of touchscreen technology, still in its infancy but already pointing toward a very different future.

This unlikely coexistence gives the 11302 a sort of timeless charm. On one side, we have the elegance and precision of analog signal rendering, drawn by the remarkable MCP CRT that makes the invisible visible. On the other, an interface concept that would soon become ubiquitous in smartphones, tablets, and modern instruments. It's as if the 11302 managed to shake hands across generations of technology—bridging the past and the future.



How Did We Do It Earlier?

The concept of an integrated counter/timer didn't originate with the 11300 Series. We can trace its roots back to the 7000 Series, with plug-ins such as the 7D14 and 7D15 shown on the left.

These were not simple add-ons—they were true counter/timers, capable of displaying up to eight significant digits and supporting a wide variety of measurement modes, especially the 7D15.

However, they weren't quite as seamless to use. Operating them often required additional steps and external cabling, and they were not deeply integrated into the oscilloscope's architecture. They had appeared during the evolution of the 7000 Series and always felt a little like highly functional—but separate—instruments riding along.

Another interesting example, although it came later, was the Tektronix 2445B, often regarded as the "poor cousin" of the 2467B. Despite that reputation, it was actually a very capable oscilloscope, particularly when equipped with Option 06 (Counter/Timer/Trigger), which provided a genuine seven-digit counter/timer.

Worse yet, there are situations—such as burst signal analysis—where you need to restrict the counting window to a very specific time interval. Doing this with a standalone counter can be cumbersome and sometimes unreliable. While some advanced counters provide internal signal outputs for monitoring purposes, using them isn't always intuitive and requires additional cabling, setup, and screen real estate.

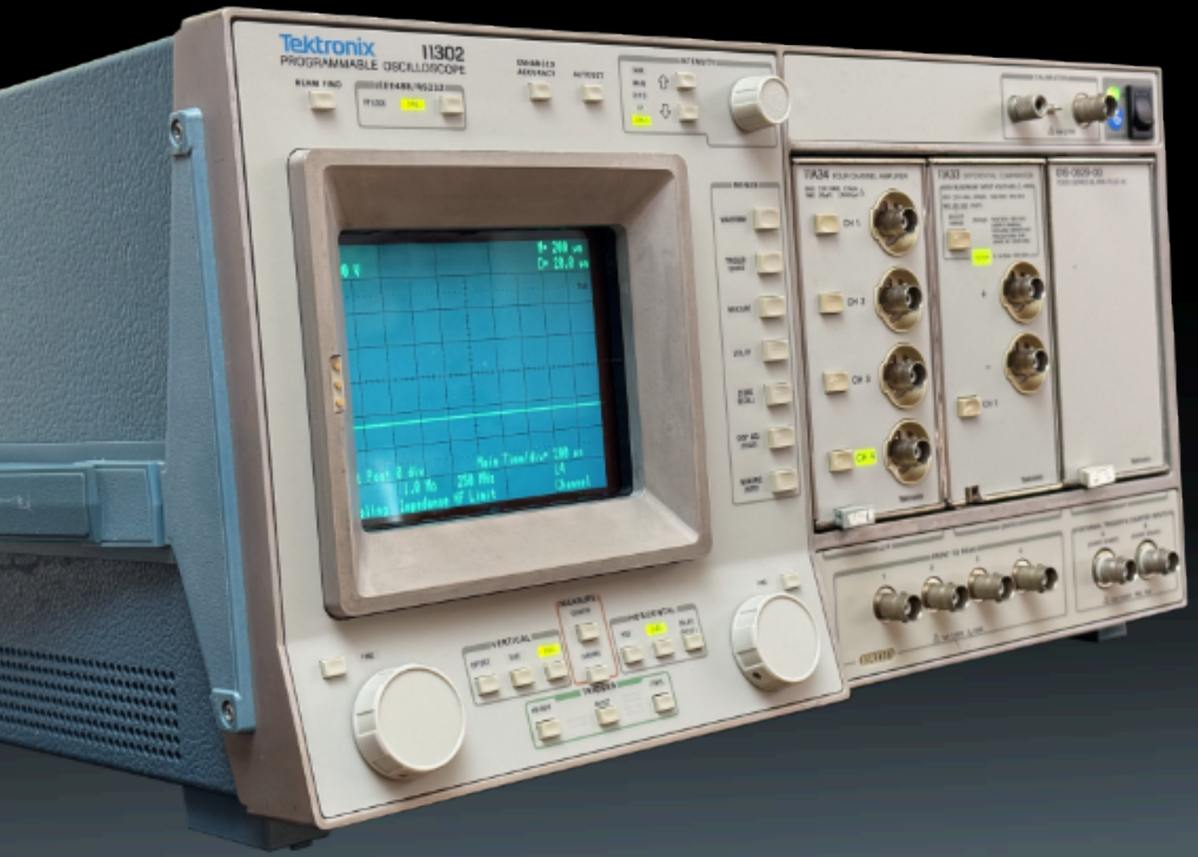
Full Integration

Tektronix marketing once asked: *"Is it a scope with a built-in counter/timer, or a counter/timer with a built-in scope?"* In truth, by integrating a high-performance universal counter/timer into a high-performance oscilloscope, the 11300 Series made complex time-related measurements far simpler and more powerful. Even more impressively, it offered a combination of capabilities that standalone counters could hardly match.

This level of integration offers numerous advantages beyond the obvious convenience of having a single instrument on the bench:

- **Shared Inputs**: Both the scope and the counter/timer can access the same signal through a single connection.
- **Enhanced Triggering**: The oscilloscope's trigger system, complete with delayed sweeps and selectable sources, can be used to define precise counting windows.
- **Signal Conditioning**: Plug-ins with high-sensitivity inputs, preamplifiers, and filters can help condition the signal before counting.
- **Visual Insight**: You can actually see what the counter is doing, thanks to features such as Count View, which we'll explore in the practical section.
- **Flexibility**: Measurements can use the two dedicated external counter inputs (A and B) or any of the twelve plug-in input channels, without requiring the signals to be displayed on the CRT.

In summary, an integrated counter/timer doesn't just replace a standalone counter—it greatly expands the possibilities of measurement, helps avoid errors, and dramatically increases your confidence in the results. In the sections that follow, we'll examine real-world examples where this level of integration makes all the difference.



After the adjustments described in the following pages, my 11302 was considerably improved, especially in terms of display quality. Apart from the troublesome DIP switches and the possibility of future problems, I found no definitely defective components. Most of its "diseases" seemed to be caused by incorrect adjustments, although I cannot rule out the possibility that some of these settings had been affected by aging or deteriorating components.

In any case, the monster now seems to be working almost perfectly, and I am very happy with the result.

Diagnosing the 11300

The Nouvelle Vague

As we have already seen, the 11300 Series, despite being fundamentally analog, had one foot firmly planted in the future. And with this new generation came a new approach to maintenance and troubleshooting, one that we must learn to understand if we want to keep these remarkable instruments alive.

The basic principle is now familiar: most service procedures begin by connecting the patient—our oscilloscope—to a computer and running the appropriate diagnostic software. Of course, this does not mean abandoning our traditional instruments and methods. If something appears wrong with the power supply, for example, checking the voltages is still an excellent place to start!

In this chapter, we'll explore the tools required for computer-assisted servicing: the PC, its connection to the oscilloscope, the diagnostic software, and the procedures that make use of it.

The following chapters will then take us back to the workbench, where we'll put all this into practice through the actual repairs and investigations carried out on my 11302.

Problem Analysis

The problem could not be reproduced on demand. It appeared whenever it pleased, usually at power-up, particularly when the 11302 had been switched off for several days.

When it occurred, the display was clearly abnormal: the text appeared larger than it should have been and was noticeably out of focus, as illustrated in the photograph on the previous page.

In most cases, simply switching the instrument off and back on made the problem disappear. It would then behave normally, often until it had been left switched off for several hours or days.

The Strategy

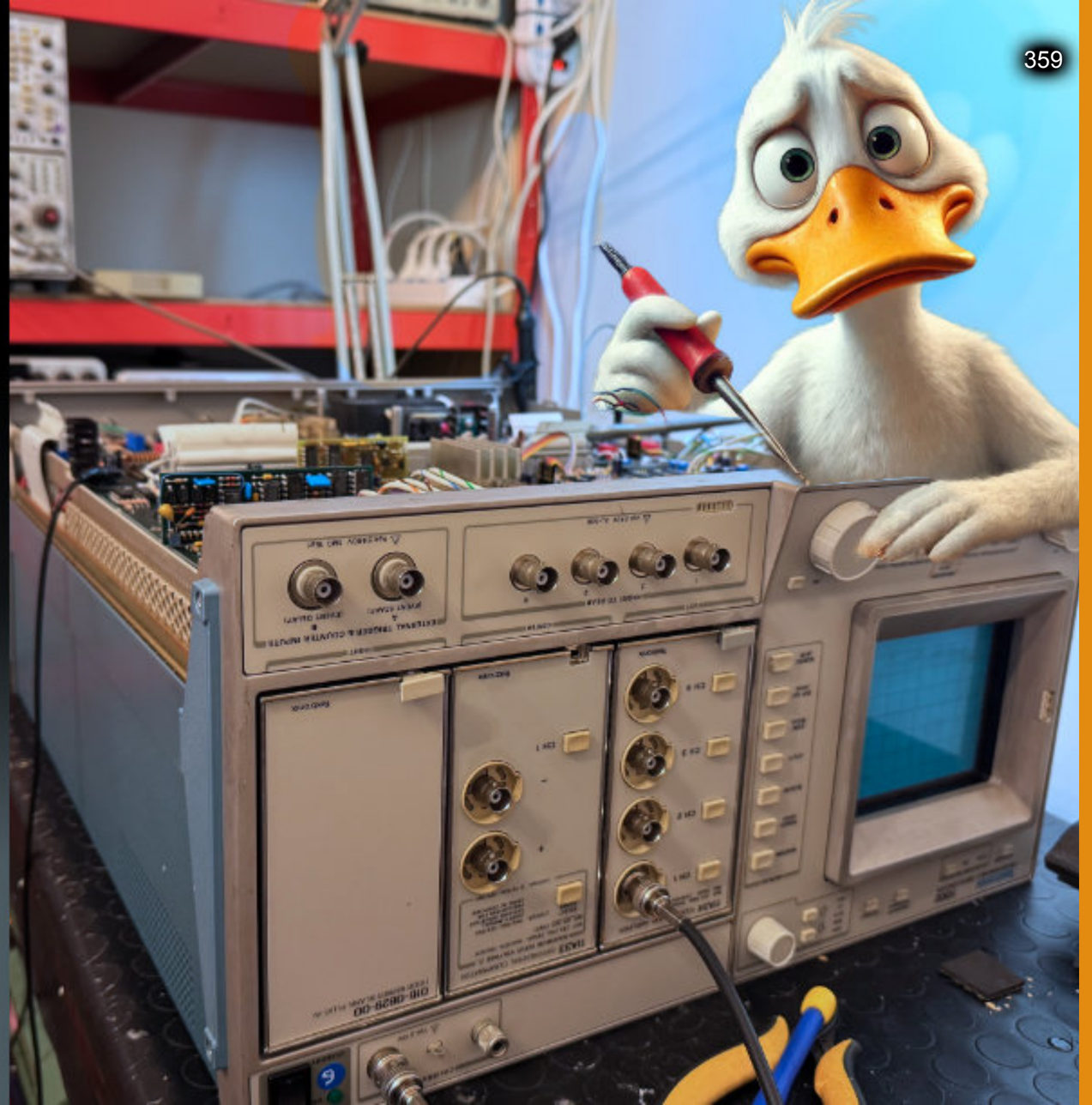
As I said, the problem seemed very difficult, and for someone still inexperienced in servicing the 11300, as I was, it certainly was. With my limited knowledge of this particular instrument, the only sensible approach was to devise a proper strategy.

I started with a few assumptions, which might, of course, turn out to be completely wrong:

- The problem might be related to the **high voltage**, or more generally to the CRT circuitry. I imagined that, somehow, the beam electrons might have less energy, making them more sensitive to the deflection fields and causing the image to expand on the screen.
- When the 11302 was working, **everything else seemed to work properly**. This meant that I could record the voltages under normal operating conditions and compare them with those measured when the display failed.

The fault seemed almost *"digital"* in nature: it was either present or absent. I never observed a gradual transition between the two states. When it appeared, it did so suddenly, sometimes accompanied by little **ticks**, almost like tiny electrical discharges.

The time factor—the tendency for the problem to reappear after the instrument had been switched off for a long period—also made me wonder whether some static RAM might be involved. But in that case, I would have expected to lose the entire instrument setup, rather than just the correct display.





Bandwidth **Hidden** Limitations

Always Read the Fine Print

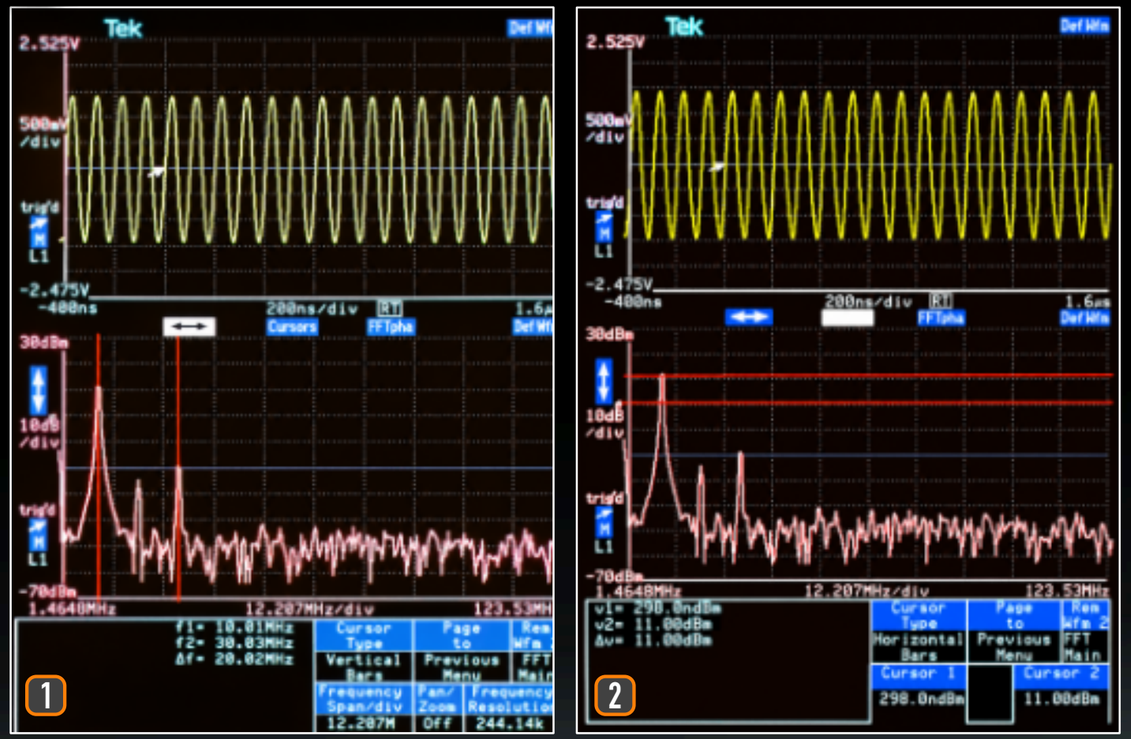
Before we move on, let's revisit a subtle point already discussed elsewhere. In the early days of digital technology, spec sheets often stood on tiptoe to look taller than they really were.

Take the Tektronix **2430** as an example. If you were coming from the world of analog oscilloscopes, you might glance at the brochure and see **150 MHz bandwidth** in bold type. Impressive! You'd be forgiven for assuming that this figure represented real-time performance, just as it would on your trusty analog scope.

But no. Although the vertical amplifier really does have a 150 MHz bandwidth, this figure can be fully exploited only when observing repetitive signals through equivalent-time sampling. When capturing a **non-repetitive, single-shot waveform**, the situation changes dramatically.

Here we encounter a much more modest specification: **Single-Event Useful Storage Bandwidth (SEUSB)**. For the 2430, it is just **40 MHz**.

So now that I've bought it... I guess I'll have to settle for that. I had hoped for more—but hey, I'll survive.



(1) Time- and frequency-domain analysis of my OCXO on the DSA 602A. Note how the cursors are context-sensitive—they "understand" which type of window they're in and automatically adjust their measurements accordingly. (2) Same signal, but this time the cursors are horizontal, measuring amplitude. For some reason, it's not possible to properly "zero" the display to 0 dBm—it insists on showing 298 ndBm (nano!), which is obviously nonsense. (3) (on the next page) For comparison, the same plot is shown on a Hewlett-Packard 8568B spectrum analyzer.

Fast Fourier Transform

More Than Just a Bonus

One of the functions that initially can seem almost miraculous is the **Fourier Transform**, a mathematical operation that converts a signal from one domain to another—from time to frequency, or vice versa. At first encounter, this ability to take a waveform and reveal its hidden spectral components feels like magic: a jumble of samples suddenly becomes an orderly set of frequencies, amplitudes, and phases. Yet the concept is far from modern. The foundations were established in 1822 by French mathematician **Jean-Baptiste Joseph Fourier**, who proposed in his *Théorie analytique de la chaleur* (Analytical Theory of Heat) that any periodic signal, no matter how complex, could be expressed as a sum of simple sinusoids. His intuition, revolutionary for its time, laid the groundwork for virtually all modern signal analysis.

In practical digital systems, however, we rarely compute the Fourier Transform in its continuous form. Instead, we use the **Discrete Fourier Transform** (DFT), which works on sampled data—the natural format produced by analog-to-digital converters. The DFT is mathematically elegant but computationally heavy: calculating it directly requires a large number of operations, making real-time processing impractical on early computers and test equipment.

This is where the **Fast Fourier Transform** (FFT) enters the picture. Developed in the 20th century, the FFT is not a different transform but a dramatically more efficient algorithm for computing the DFT or its inverse (IDFT). By exploiting symmetries and periodicities in the underlying mathematics, it reduces computation time by orders of magnitude. Only when digital processors became sufficiently powerful did FFT-based spectral analysis become feasible on oscilloscopes, spectrum analyzers, and other instruments. Today, the FFT is so ubiquitous that it is easy to forget how transformative it truly was: it opened the door to the real-time frequency-domain world that modern electronics heavily relies on.

DSA 600 and FFT

The DSA 600 Series can perform the FFT of the stored signal by leveraging its internal high processing power. Six FFT windowing functions are available: Rectangular, Triangular, Hamming, Hanning, Blackman, and Blackman–Harris. The appropriate window depends on the type of spectral information you need—for example, reducing spectral leakage or improving amplitude accuracy. The selected window is automatically applied to the acquired record by the DSA 601 and DSA 602.

Both magnitude and phase of the signal's frequency components can be displayed, and measurement cursors allow direct readouts of amplitude and frequency. Importantly, the instrument supports true single-shot acquisitions in both the time and frequency domains. The typical noise floor of the DSA 600 is around –60 dB, which can be improved to about –70 dB by averaging multiple acquisitions before performing the FFT.

The result is an instrument capable of performing substantial calculations while maintaining the responsiveness expected of an oscilloscope.

Digitizer Controller

The Digitizer Controller acts as the coordinator of the acquisition and processing system. It receives instructions from the Executive Processor, translates them into the appropriate acquisition and processing settings, and supervises the movement of waveform data from local processing memory into the instrument's waveform memory.

In other words, while the processing hardware performs the mathematical work, the Digitizer Controller makes sure that the right operations are performed on the right data.

Sharing and Displaying the Results

Memory Management Unit

Several subsystems need access to the instrument's memory, sometimes at the same time. The **Memory Management Unit (MMU)** acts as an arbiter, coordinating memory requests from three principal subsystems: the Executive, the Digitizer, and the Display.

This shared-memory arrangement allows acquired and processed data to move through the instrument without requiring each subsystem to manage the others' memory operations.

Display Control

Eventually, the processed waveform data reaches the Display Control block. Its responsibilities extend well beyond drawing traces. It also generates the graticule, axes, annotations, menus, and the graphical elements used by the touch-panel interface.

The DSA uses a custom **vertical raster-scan display**, an arrangement particularly well suited to presenting both waveform information and text.

Before generating the image, the display circuitry reduces the waveform data to **512 horizontal pixel positions** and converts it into the format required by the raster display.

The result is the familiar DSA screen: a combination of waveforms, measurements, and interactive controls, all presented on the same CRT.

Who Runs the Show?

Executive Processor

So far, we have followed the signal. But who tells all these blocks what to do? That is primarily the responsibility of the **Executive Processor (EXP)**.

The EXP interprets the user's commands and coordinates the corresponding operations throughout the instrument. It controls and monitors the boards connected to the Executive system bus and, through them, communicates with the other DSA subsystems. It is also responsible for initiating the built-in Self-Test diagnostics, both during power-up and when requested by the user.

In the A-series instruments, its responsibilities also extend to controlling the floppy disk drive.

Although the EXP is essential to the operation of the instrument, it is worth distinguishing its role from that of the TriStar processing hardware: **the EXP manages the instrument; the waveform-processing system handles the signal calculations**.

Memory

The Memory block provides the resources needed to store waveforms, preserve instrument settings, and hold the program instructions required by the Executive Processor.

It includes RAM and EPROM devices, together with supporting and diagnostic circuitry. Provision was also made for optional nonvolatile waveform storage.

Access to these resources is coordinated through the instrument's memory-management system.

Powerful! Maximum Power Consumption **585 W!**

Power Supply Section

A4 Voltage Regulator Board

Option 1C Loop Through BNC's

Warning

Don't be fooled by the hinge! This panel cannot be opened simply by removing its screws; the CRT must first be removed.

Power Supply

It Had to Handle 585 W

Probably a Project in the Project

On the right, we see the DSA 602A from underneath. Unlike many other Tektronix oscilloscopes, its bottom is remarkably clean, with virtually no functional components accessible from this side.

The only exception is the imposing power supply, tasked with feeding this monster with up to 585 W.

At first glance, it reminded me of the power supplies used in the 11300 and 11400 Series. There is something familiar about its construction—perhaps the unmistakable touch of the same designer.

Yet, as the photographs reveal, it is an entirely different design.



11403 Power Supply

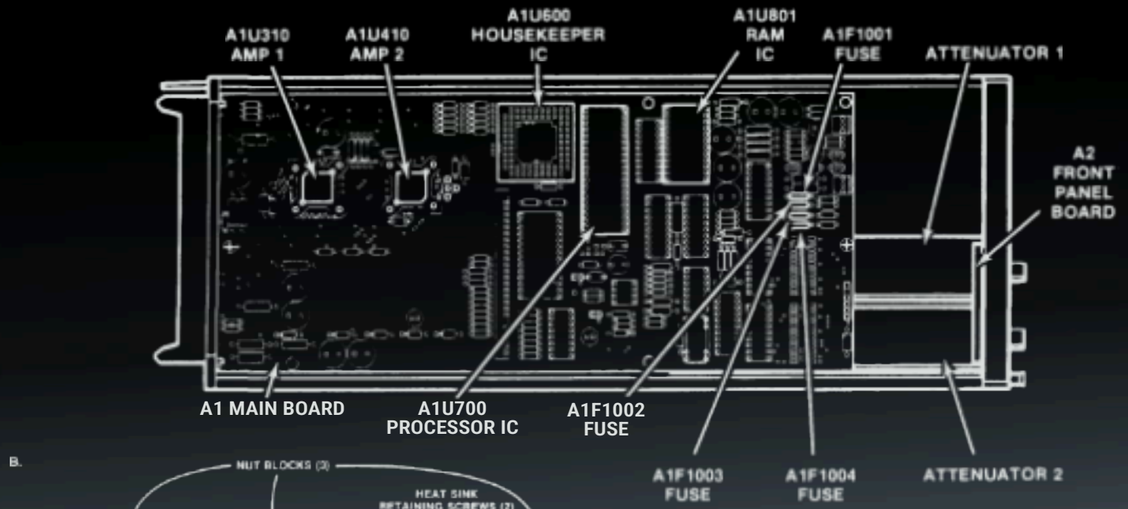
A Family Resemblance



The routine names are useful when looking up a failure in the service manual.

- **RELAY DRVR** checks the attenuator relay drivers.
- **PROBECODES** checks that the probe identification code is stable.
- **CKSM PLUG** checks the signal-path calibration checksum, where included in the firmware's self-test sequence.
- **CKSM PROBE** checks the probe calibration checksum.
- **ADC TEST** checks the plug-in's analog-to-digital converter.
- **FUSE TEST** checks the probe power fuses.
- **ACVS TEST** checks the analog control voltage system.

Further checks examine the calibration constants for **CH 1** and **CH 2**.



Left/above: 11A32 Main parts location.

Right: Lift the lid of one input attenuator and you find a beautiful piece of hybrid construction. Through the clear cases of the five magnetically latching relays, you can see the coils. A brief pulse switches each relay, and it holds its position without continuous coil current. Two of the relays switch the divider networks to give 1×, 10×, or 100× attenuation. At the far end, the black Tektronix 165-2073-00 buffer drives the blue 50 Ω coaxial cable that carries the signal to the channel amplifier.

Dynamic Current Measurement

From Voltage Drop to Current Waveform

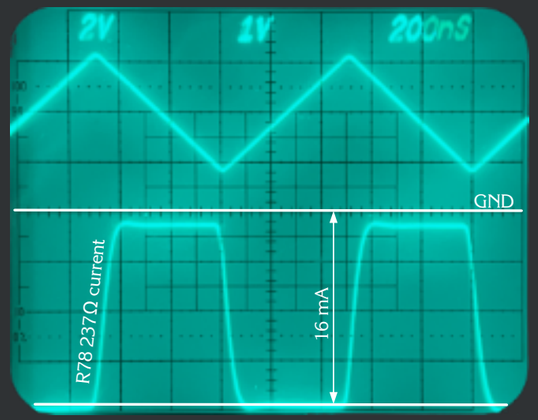
Sometimes the waveform you want to see is a current. If there's already a resistor in series with the branch you're investigating, you may be able to use it as a current sensor. Measure the voltage across it and divide by its resistance. Across a 10 Ω resistor, for instance, 100 mV corresponds to 10 mA. Follow the voltage on the screen and you're following the current through the resistor.

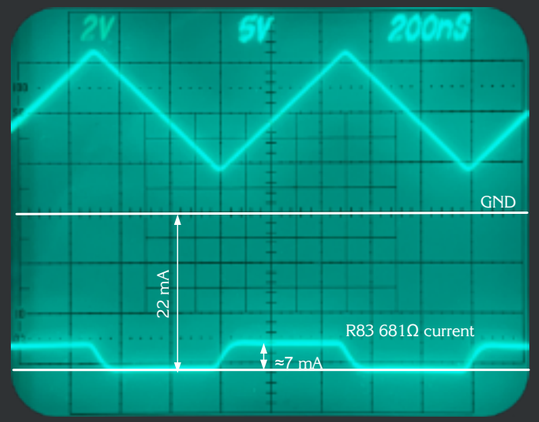
This is where a differential plug-in comes in handy. Both ends of the resistor may be moving relative to ground, while the voltage between them is quite small. The amplifier measures that difference directly. With DC coupling, you can see the steady current as well as its variations.

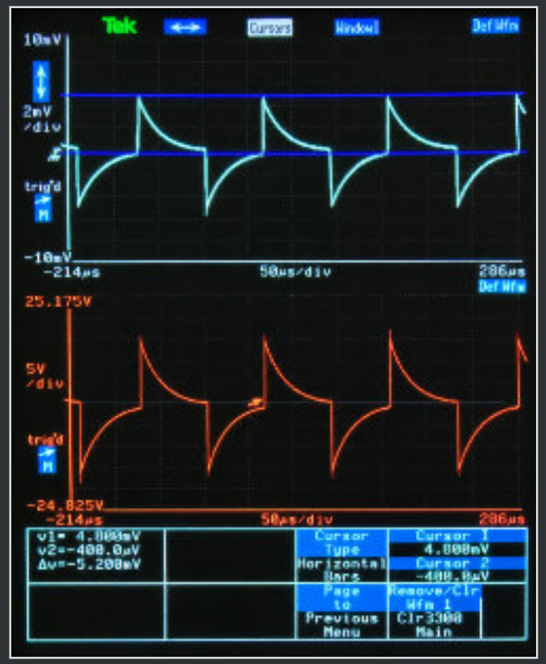
In the two 7A22 photographs below, I measured the voltage across R78 and R83 and converted the readings to milliamperes. With a 11400 or DSA, the oscilloscope can do the division for you and display the result alongside the measured voltage. The 7854 could do the same arithmetic on a stored waveform. Here, the calculated trace updates as the oscilloscope acquires new data.

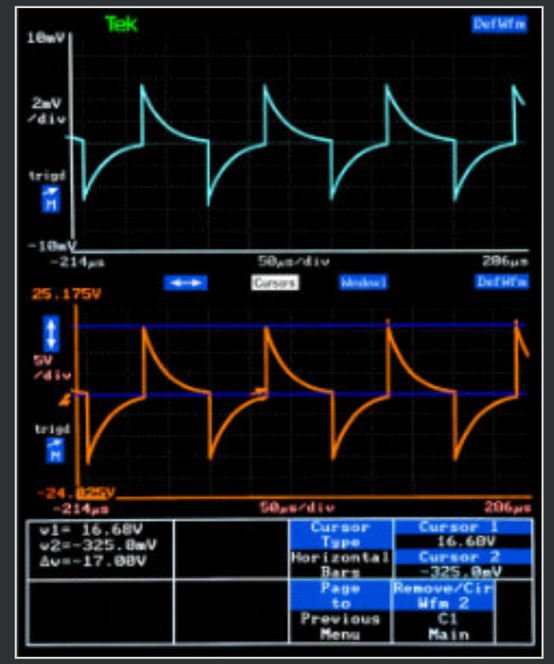
For the example on the right, I measured the voltage across a 3.3 kΩ resistor on channel C1 and defined a second waveform as C1 / 3300. Once the voltage and current traces are on screen together, you can put the cursors on either one.

Below. Two measurements with the 7A22 at 200 ns/div. The lower traces show the voltage across R78 (237 Ω) and R83 (681 Ω). The annotations give the corresponding currents.

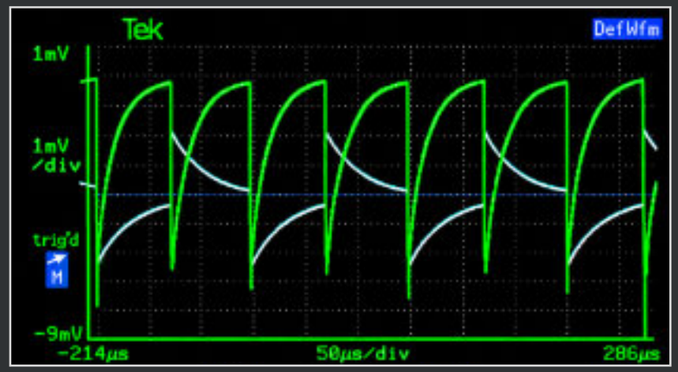








Above. The orange trace is the measured voltage, and the cyan trace is the calculated current. With the cursors on the orange trace, the separation is 17.00 V, equivalent to 5.15 mA through 3.3 kΩ. With the cursors on the cyan trace, the separation is about 5.20 mA. The oscilloscope still labels the calculated trace in volts. Read mV as mA on that trace.



Left. I added the green trace to show instantaneous power alongside the current waveform. I defined it as L1 × C1 / 3300. L1 measures the voltage across the device, and C1 measures the drop across the 3.3 kΩ current-sense resistor. The green scale reads 1 mV/div on the screen, which corresponds to 1 mW/div in this calculation.

This was one of the things I liked about the 11400 and, even more, the DSA. I could watch the calculated waveform change while the circuit was running.

016-0829-00 Blank Plug-in

- Full-depth plug-in frame
- Closes an unused bay
- A platform for custom circuitry

1986

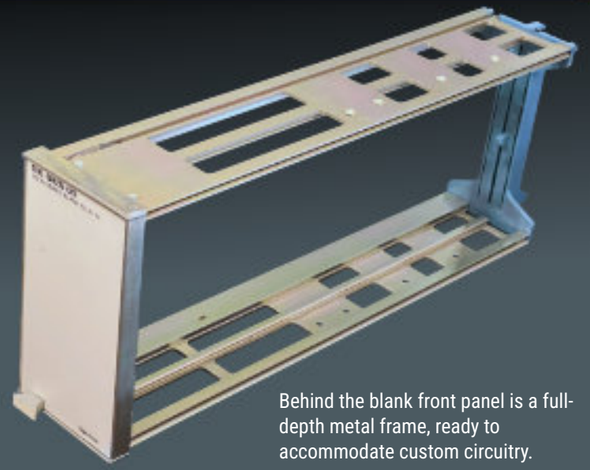


016-0829-00 Front Panel

Tektronix also offered the 016-0829-00 blank plug-in. Unlike the simpler 016-0155-00 compartment cover, it provided a full-depth frame that could fill an unused bay or serve as the starting point for custom circuitry.

Tektronix advised against operating 11000-Series oscilloscopes with open compartments, since these could disturb the intended airflow and reduce cooling efficiency. A blank plug-in or cover kept the unused bay closed.

Nevertheless, photographs in the Handshake newsletter sometimes show instruments operating with one or even two compartments open. Apparently, the photographers preferred to leave a little breathing room—though not necessarily where the cooling engineers intended!



Behind the blank front panel is a full-depth metal frame, ready to accommodate custom circuitry.

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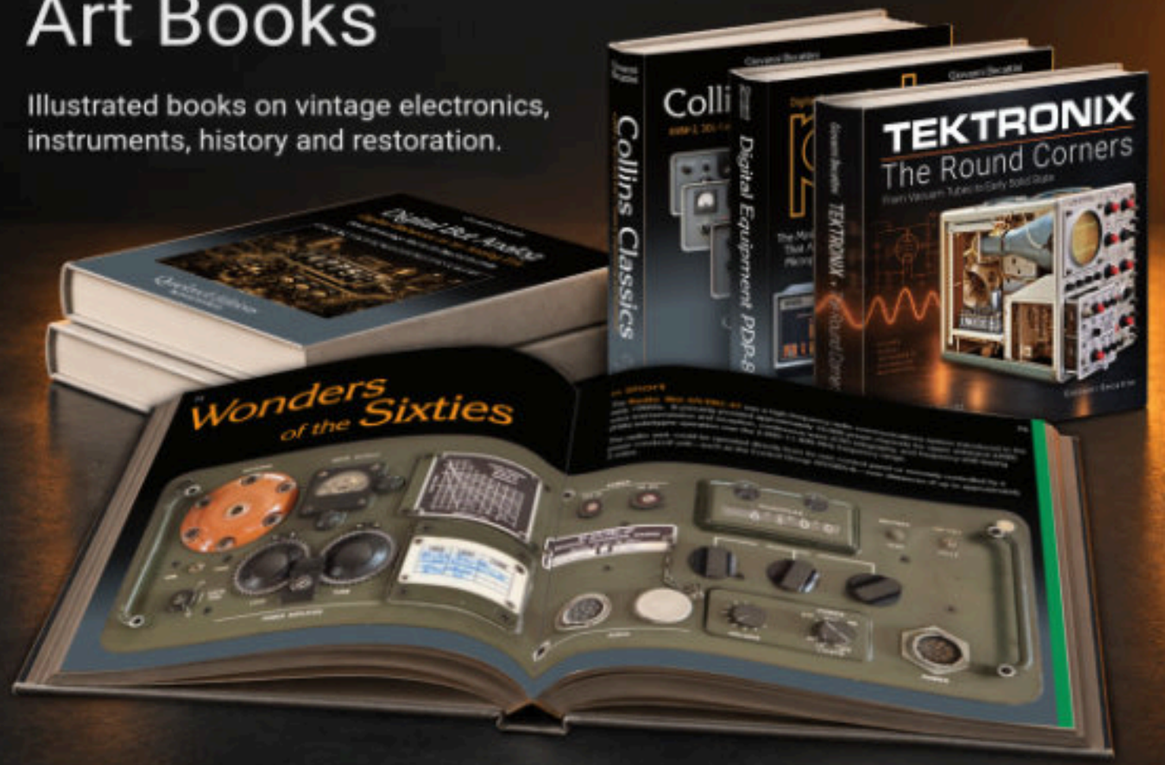

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