The Golden Age of HP Through Some of Its Masterpieces

Hewlett-Packard Voltmeters and Oscilloscopes

History, Engineering, and Restoration

400H, 410C, 3403C, 180, 181, 54502A, 54540A

Giovanni Becattini

References

The following references are used in this book:

- [TEO] Tektronix Epic Oscilloscopes – Elektor Books
- [7KS] Tektronix 7000 Series – Elektor Books
- [TREG] Tektronix Oscilloscopes Restoration Guide – Elektor Books
- [HP1] Hewlett-Packard and its Voltmeters and Oscilloscopes – Quacktech
- [HP2] Hewlett-Packard Signal Sources – Quacktech
- [HP3] Hewlett-Packard Counters and Spectrum Analyzers – Quacktech
- [HP4] Hewlett-Packard Calculators, Computers and HP-IB – Quacktech
- [VRE] Vintage Radio Equipment – Elektor Book
- [MAC] Apple Macintosh – History, Engineering, and Restoration – Elektor Books
- [QT602] The Good Giant – Tektronix DSA 602A Oscilloscope – Quacktech
- [QT11KP] The Last Plug-ins – Tektronix 11000-Series Plug-ins – Quacktech
- [SCLI] Strumentazione Vintage – Edizioni C&C
- [QTCOL] Collins Classics – KWM-2, 30L-1 and 51S-1: History, Engineering, and Restoration – Quacktech Editions
- [QT324] Two Giants and a Shorty – Tektronix 323/324 - Quacktech
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- [QTHPSS] Hewlett-Packard Signal Sources – Quacktech
- [DAB] Digital but Analog – Quacktech
- [TG7] When Machines Learned to Write - Quacktech

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Preface

For generations of engineers, Hewlett-Packard—simply "HP"—set the benchmark for electronic instrumentation. Its instruments were not merely tools, but expressions of precision, reliability, and a distinctive engineering culture. (When it came to oscilloscopes, many of us—including myself—often leaned toward Tektronix, but that is another story.)

Founded in 1939 by Bill Hewlett and David Packard, HP grew from a modest garage in Palo Alto into one of the most respected electronics companies in the world. Along the way, it shaped how measurements were performed, interpreted, and trusted, leaving an enduring mark on engineering practice.

This volume is part of the Technical Art Books collection and of the series HP: The Golden Age—An Era Told Through Electronic Masterpieces. Rather than striving for encyclopedic coverage, the series explores HP's most remarkable period through a carefully chosen selection of instruments, calculators, and computers—objects that embody both technical excellence and design clarity.

This book is conceived as a historical and technical journey, blending images, analysis, personal experience, and practical restoration. Its aim is not only to document remarkable instruments, but also to preserve the spirit of an era in which electronic measurement achieved a rare balance of rigor, elegance, and human ingenuity.

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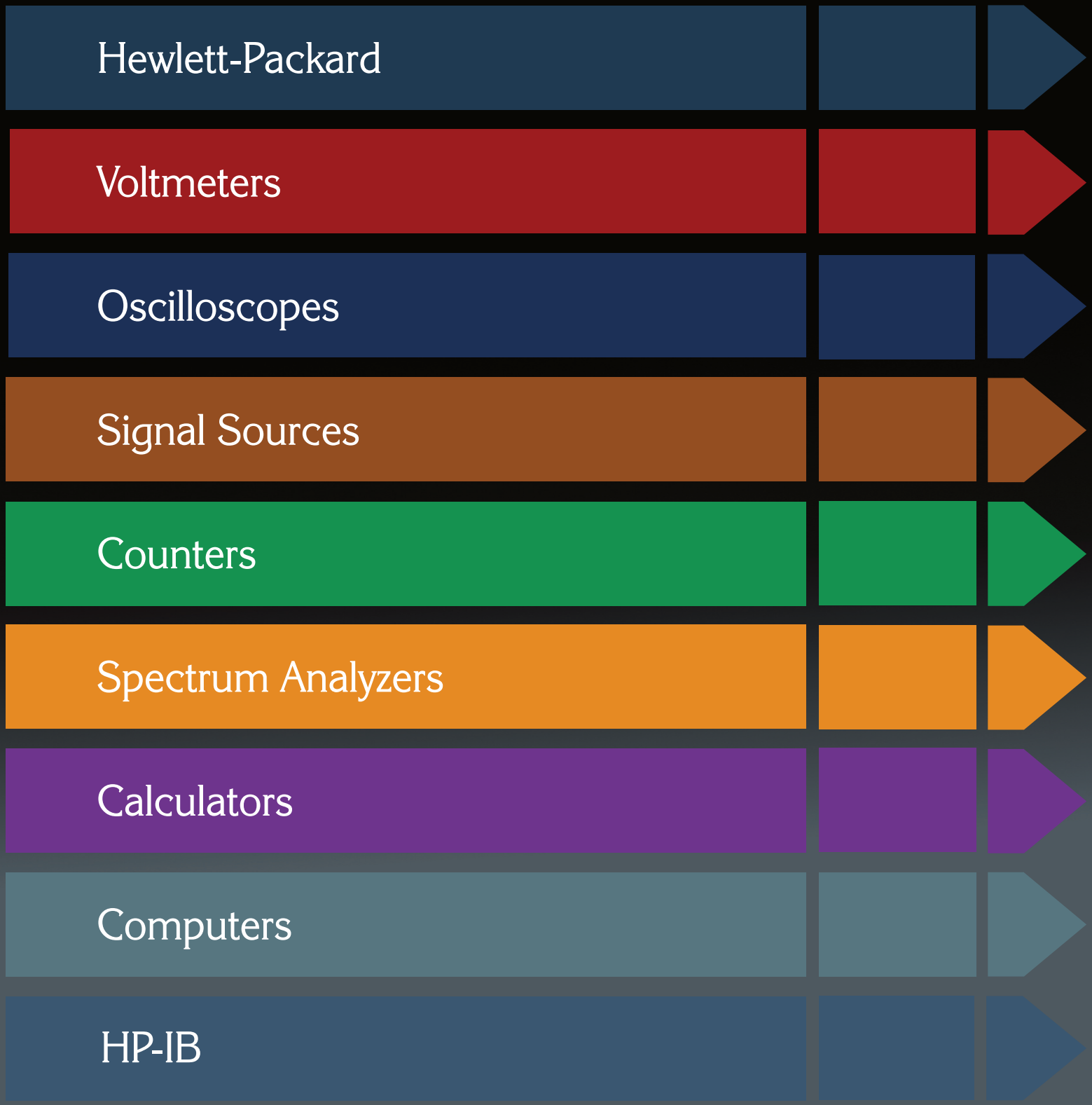
To my wife
and my family


Voltmeters and Oscilloscopes
Signal Sources
Counters and Spectrum Analyzers
Calculators, Computers, and HPIB


Hewlett-Packard
Voltmeters
Oscilloscopes
Signal Sources
Counters
Spectrum Analyzers
Calculators
Computers
HP-IB


HEWLETT-PACKARD

Section

Hewlett Packard

One of the greatest technology companies in the history


3000
Hanover Street
Main Lobby
Executive Briefing Center

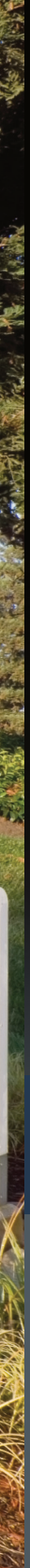


Photo: By LPS.1 - Own work, CC0, https://commons.wikimedia.org/w/index.php?curid=29344244

Section:

Hewlett Packard

Subsection:

The Company

Everybody's dream: from a garage to the stars

A Journey from Garage to Global Giant

Beginnings (1939)

In 1939, two Stanford University graduates, William (Bill) Hewlett and David (Dave) Packard, founded Hewlett-Packard in a small garage at 367 Addison Avenue in Palo Alto, California, a site now recognized as the birthplace of Silicon Valley. With an initial investment of $538 (about 12,120 in 2025), they set out to develop innovative electronic products.

Their first breakthrough was the **HP 200A Audio Oscillator**, an instrument used to test sound equipment. This product's success was highlighted by a substantial order from Walt Disney Studios, which purchased several units to fine-tune the audio for its revolutionary 1940 film Fantasia. This early achievement underscored HP's focus on high-quality products and strong customer relationships, a principle that would define the company for decades.

The Expansion (1940s)

The onset of World War II provided HP with significant opportunities as the company supplied essential electronic testing equipment to the U.S. military. This period solidified HP's reputation for producing reliable, high-performance instruments.

Post-war, HP capitalized on the burgeoning demand for electronic devices. The company's product portfolio expanded to include **voltmeters**, **frequency counters**, and **signal generators**. By the late 1940s, HP had relocated from the humble garage to a larger facility on Page Mill Road, which became its corporate headquarters.

One of the early foundations of HP's enduring success was its emphasis on research and development (R&D). Hewlett and Packard believed that continual innovation was key to long-term growth. This philosophy would soon manifest in a steady stream of industry-leading products.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Marc Mislanghe and the HP Memory Project

Marc Mislanghe (October 10, 1946 - July 23, 2014) was a French electronic engineer. Many engineers have childhood interests that fascinate them and has drawn them to something with great force as they grow. Some are drawn to football, others to music or politics. Marc was drawn to electronics. It was in his blood already as a kid and determined the course of his entire life, as electronics probably did for many who will read these pages.

1958 His Own Oscilloscope!

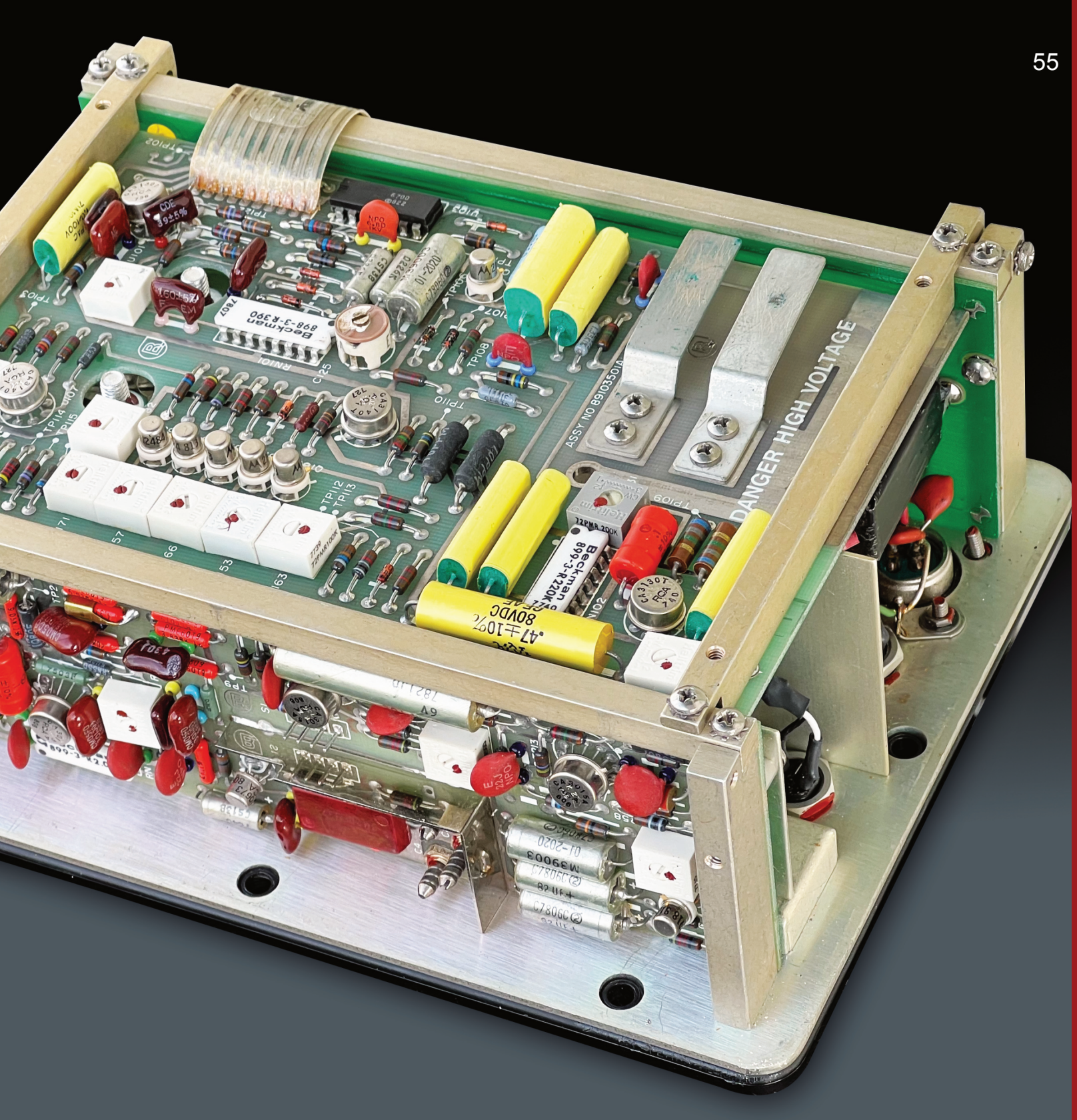
Marc was involved with instruments before he was twelve, when, in 1958, he built his own oscilloscope, using available surplus WWII electronics. It required a DG7-32 CRT tube, which needed to be bought new, with funds that took him a year to accumulate.

1963 Ham License

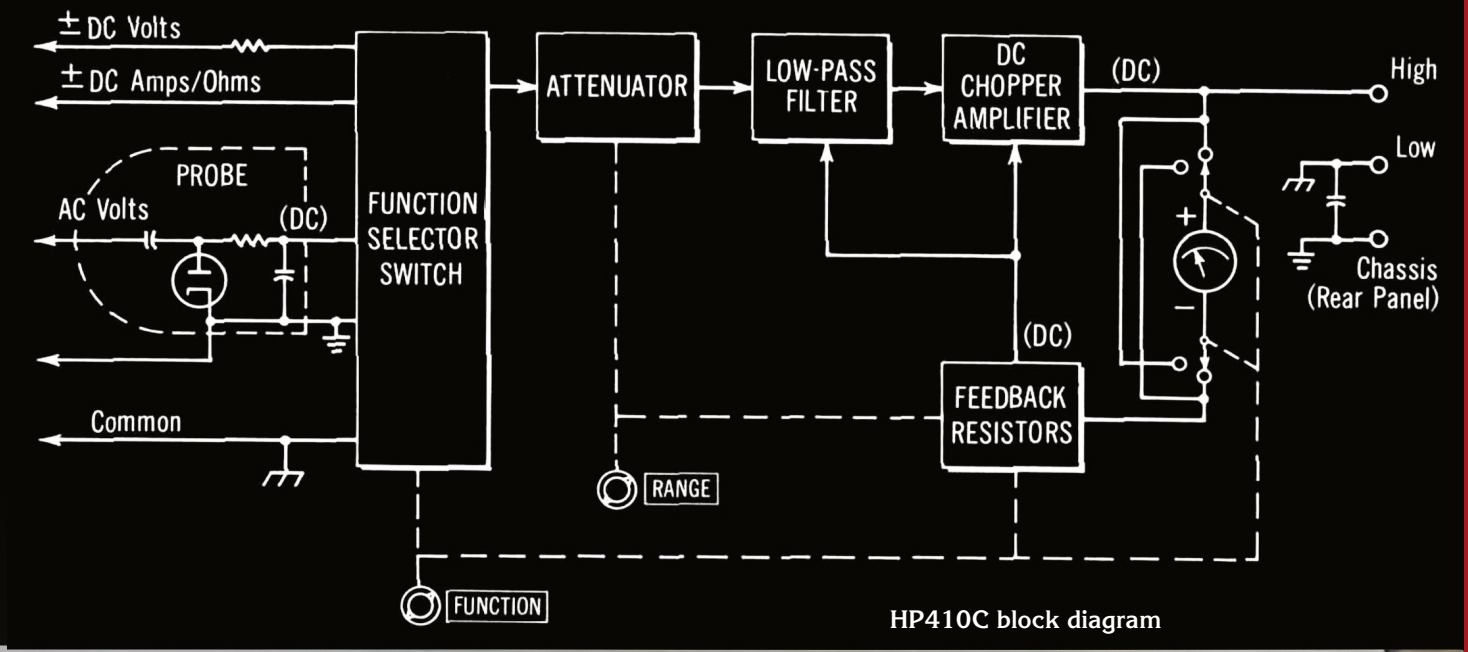
The availability of WWII surplus equipment was a joy for Marc, who in 1963 obtained a Ham Radio license including Morse code proficiency with the call sign F5MM.

This drawing is an idealized image of Marc, but... he could be, like, probably could be many of us who have had electronics in their blood since childhood. Possibly me too, or you reading these notes....


VOLTMETER

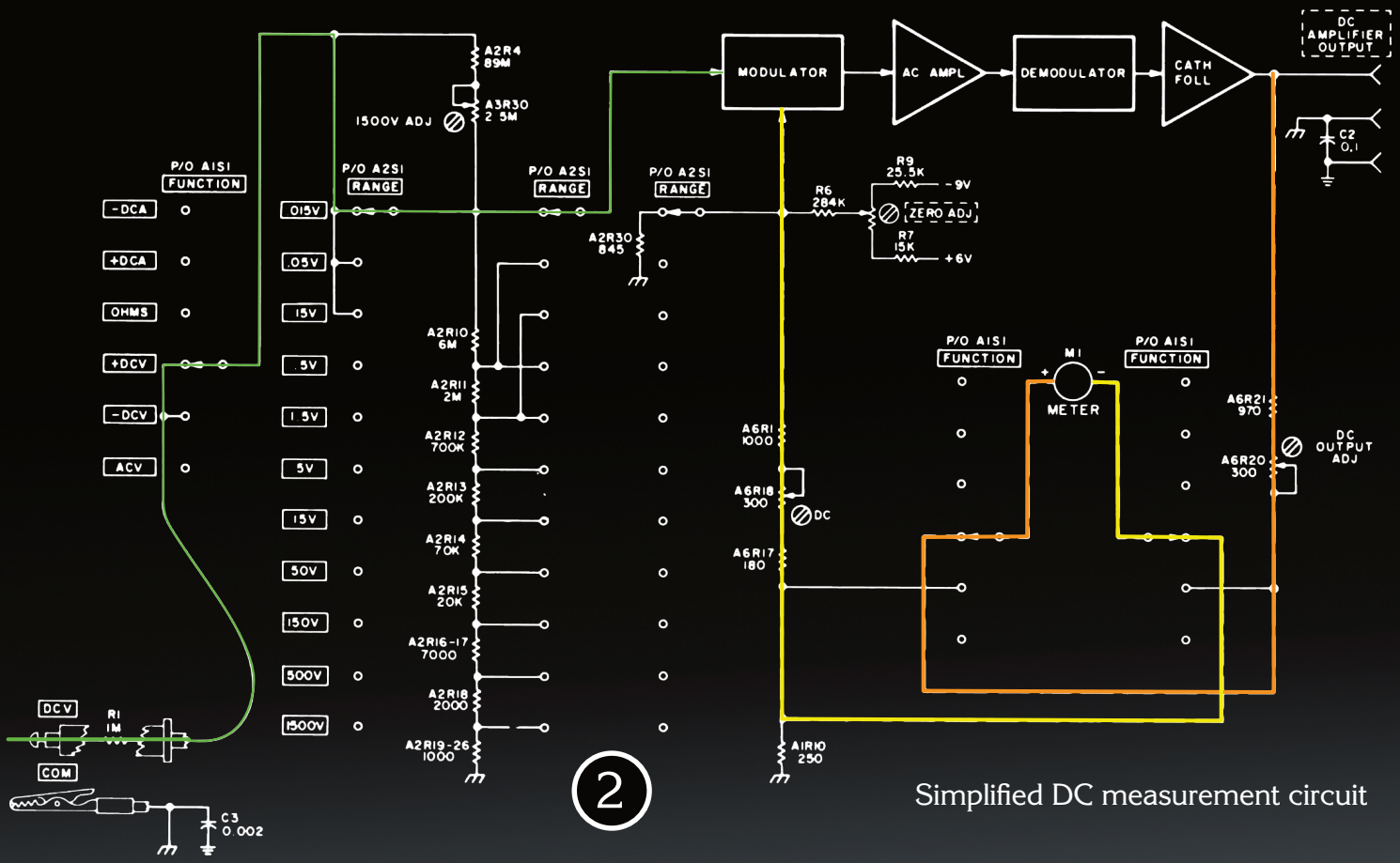

DANGER HIGH VOLTAGE
ASSY NO 891035OIA
Beckman
898-3-R390
Beckman
898-3-R220K
.47±10%
80VDC

HP400H Front View



HP410C block diagram

❶ Basic chopper amplifier block diagram.



Simplified DC measurement circuit

connects to output terminals at the rear of the instrument, supplying a voltage proportional to meter deflection (1.5 V full scale). Negative feedback reduces the output impedance to less than 3 ohms so that up to 1 mA can be taken from this output without affecting accuracy. The instrument also may be used as a narrow-band amplifier (or attenuator) with voltage gains from 100 down to 10^{-3}. Frequency of the amplifier is 0.5 Hz at the -3 dB point.

DC Measurement Circuit

As with all multimeters, the basic measurement is DC voltage; the others are a derivative of it in some way. As you can see above, the input circuit is very simple and easy to understand. Practically a simple voltage divider.

The diagrams on the right are taken from the military version of the manual (TM 11-6625-1614-15) and are more complete than the others, including DC levels and time values.

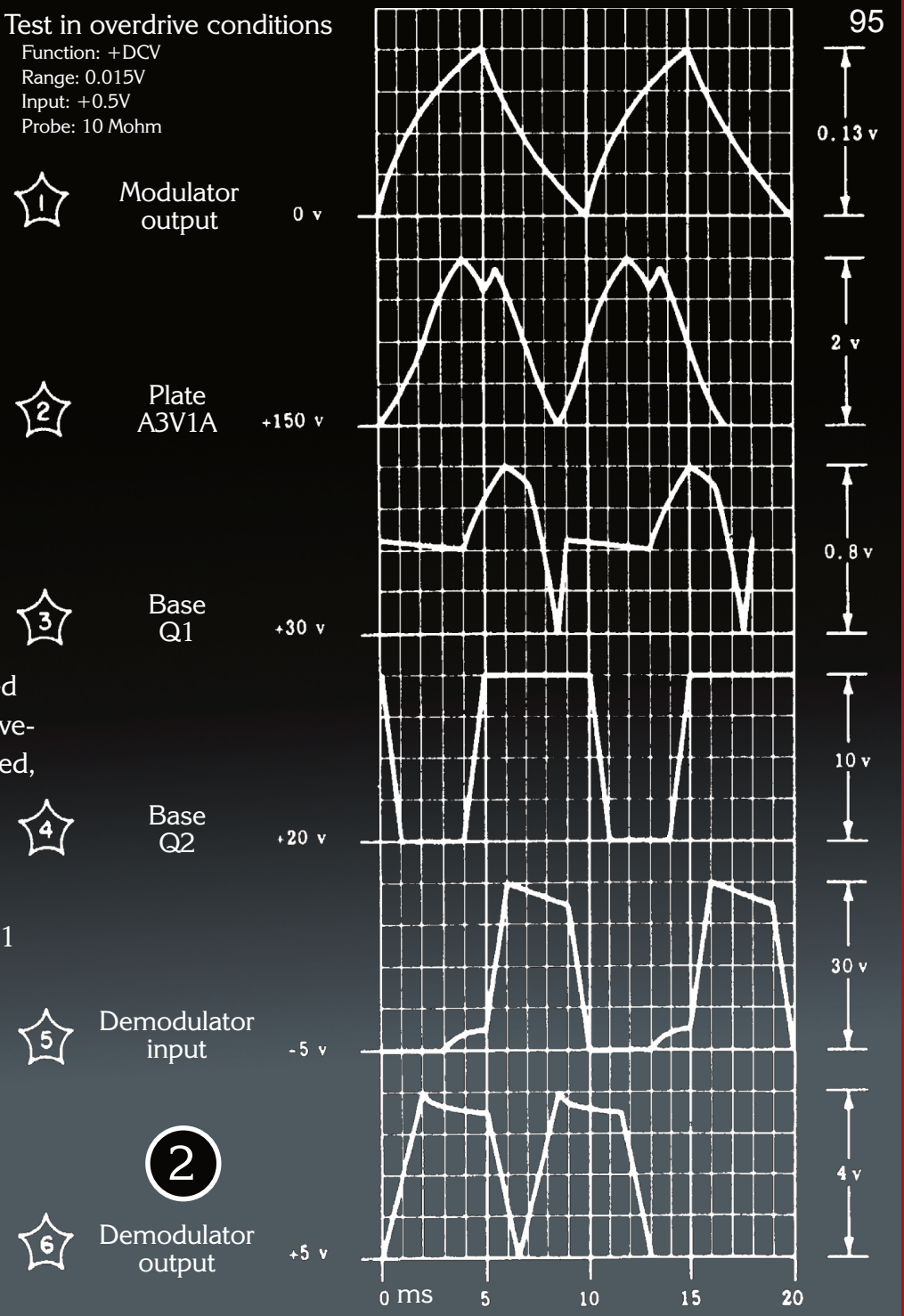
Don't forget to use at least a 10 Mohm oscilloscope probe or you risk not seeing anything in some cases.

Zero Instability

This overdrive test allowed me to find a problem in my second unit. The problem was zero instability. The test showed that the modulator output (waveform 1) was lower than expected, although the voltmeter was working quite well.

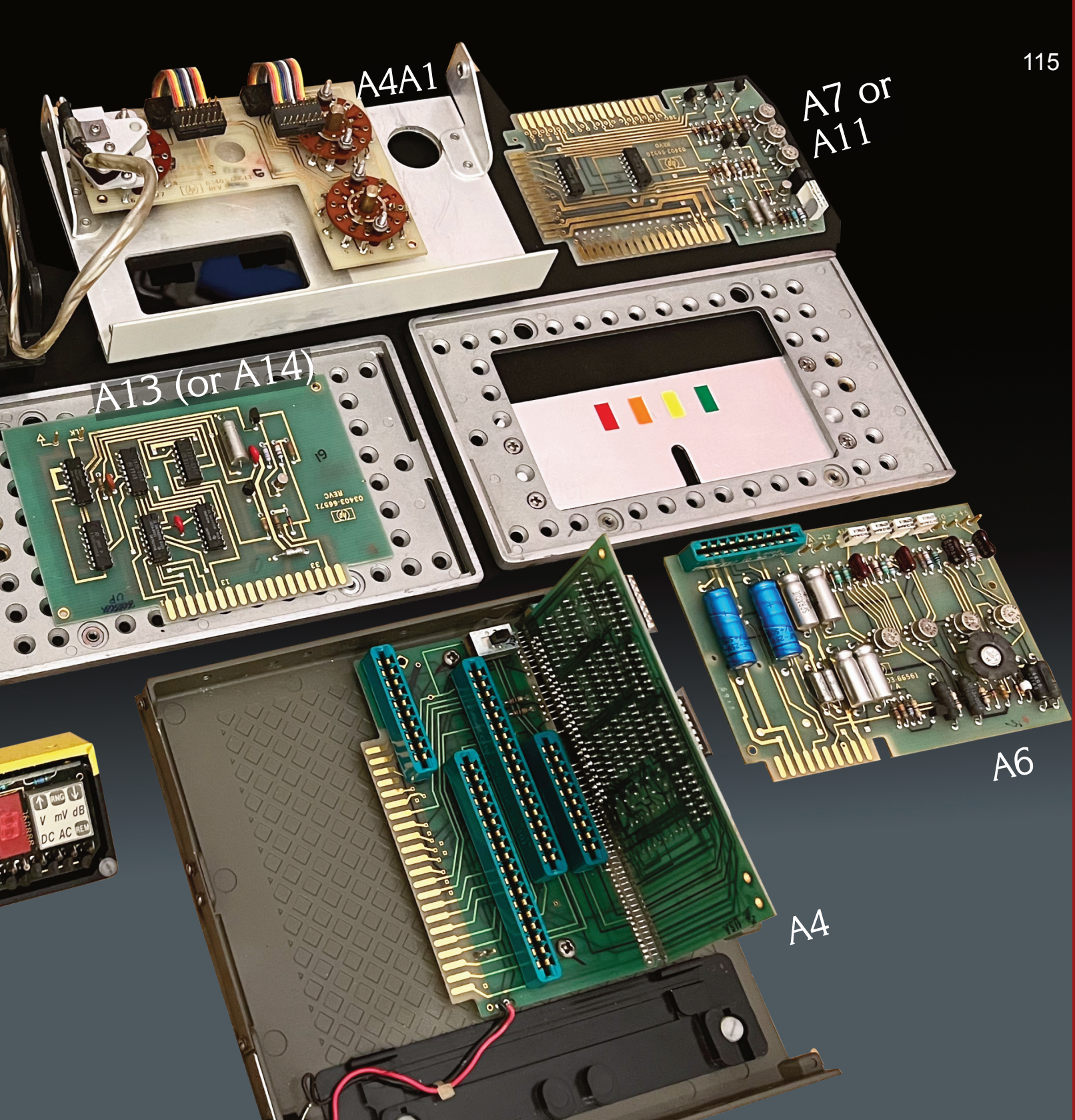
After a lot of work, my suspicions focused on the CR1 and CR2 diodes, which I assumed were there to protect the photoconductor. I tried to remove them, and without them the zero was absolutely stable. I tried replacing them with two 1N5819s, the only ones I had on hand, but the problem returned.

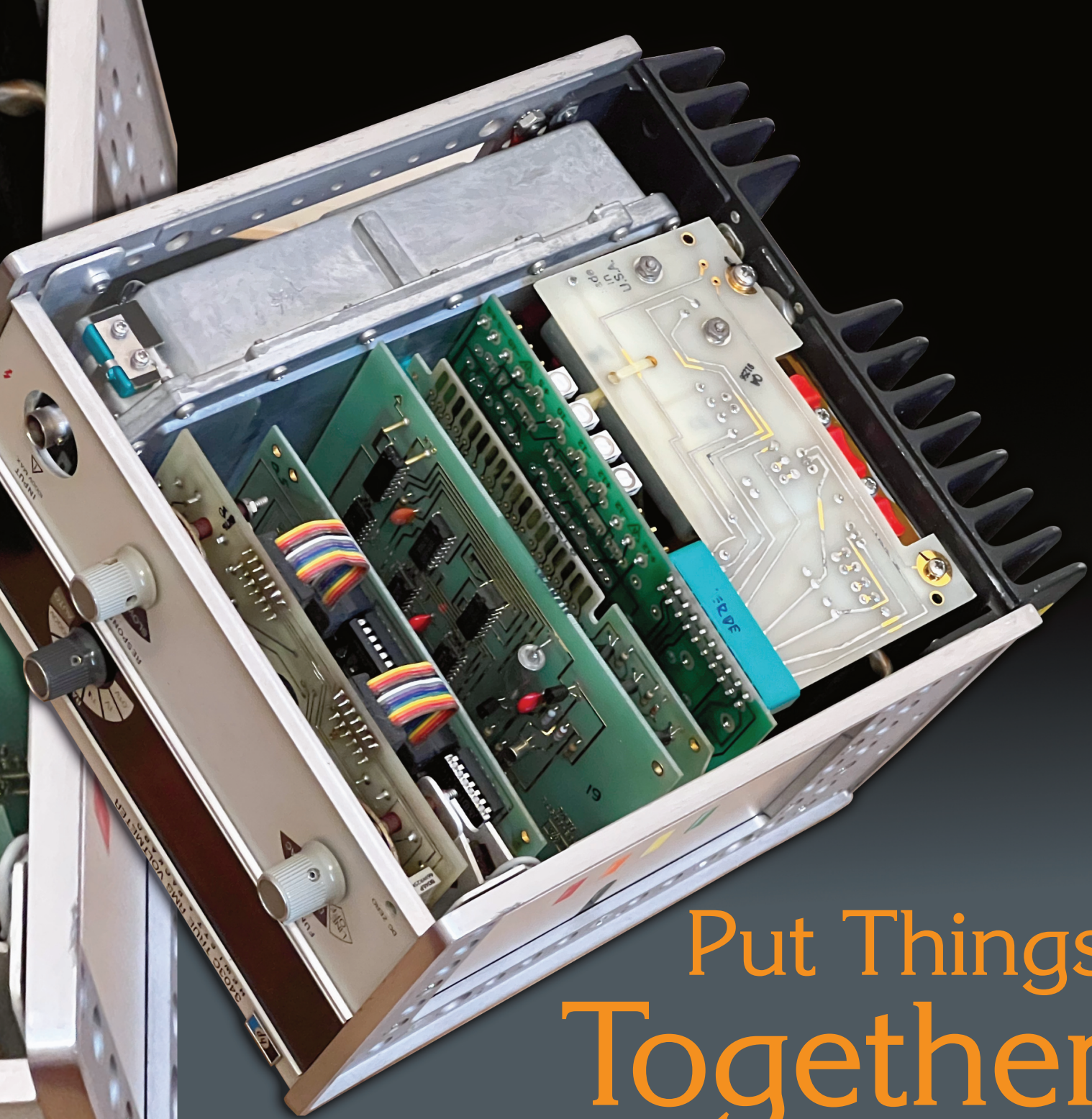
Test in overdrive conditions
Function: +DCV
Range: 0.015V
Input: +0.5V
Probe: 10 Mohm




3C TRUE RMS VOLTMETER
WLETT • PACKARD
mV
AC
RANGE
1V
10V
100V
1000V
AUTO
.1V
RESPONSE TIME
SLOW
FAST
INPUT
1000V MAX.
AC

1973

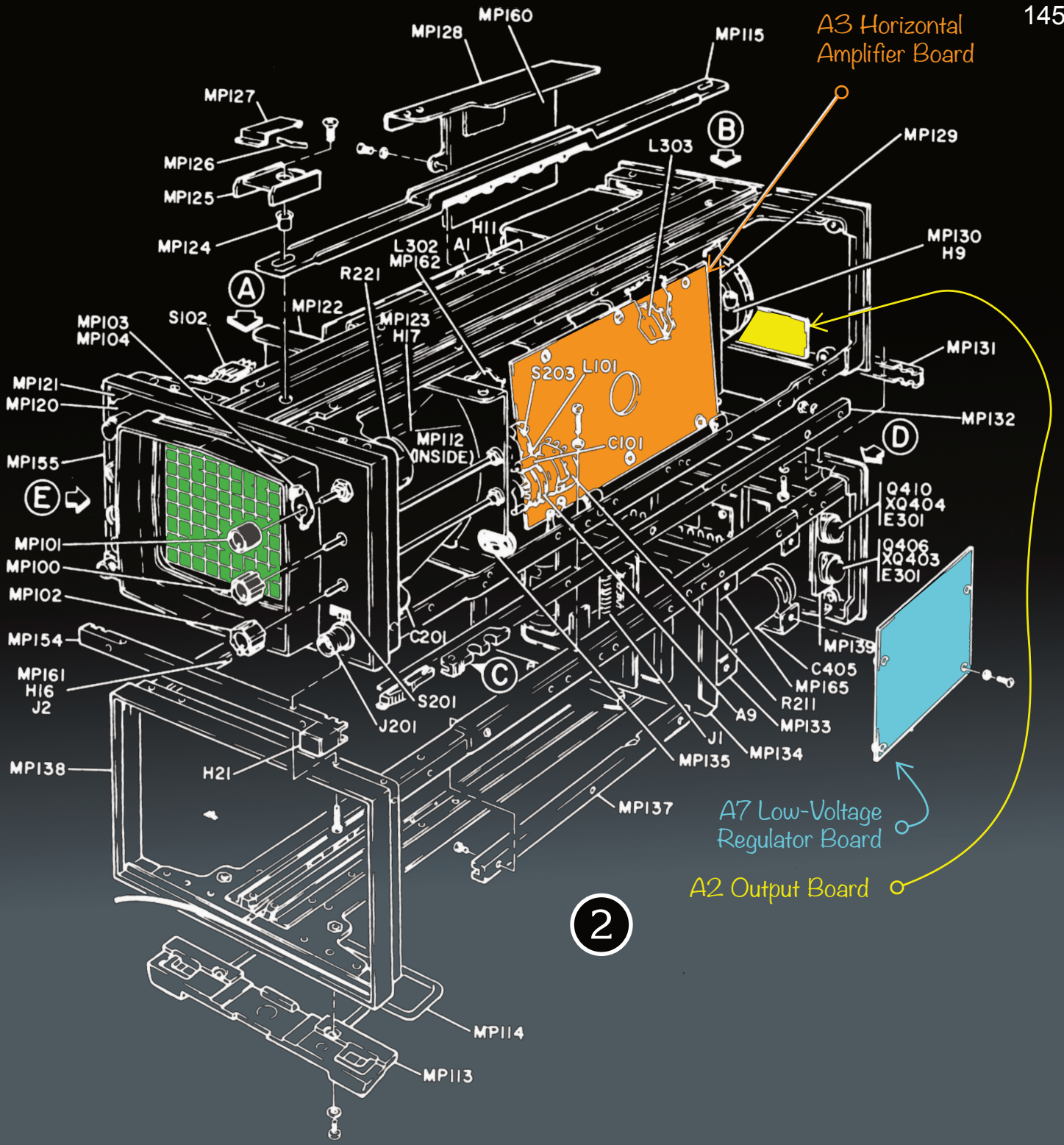

A4A1
A7 or
A11
A13 (or A14)
A6
A4

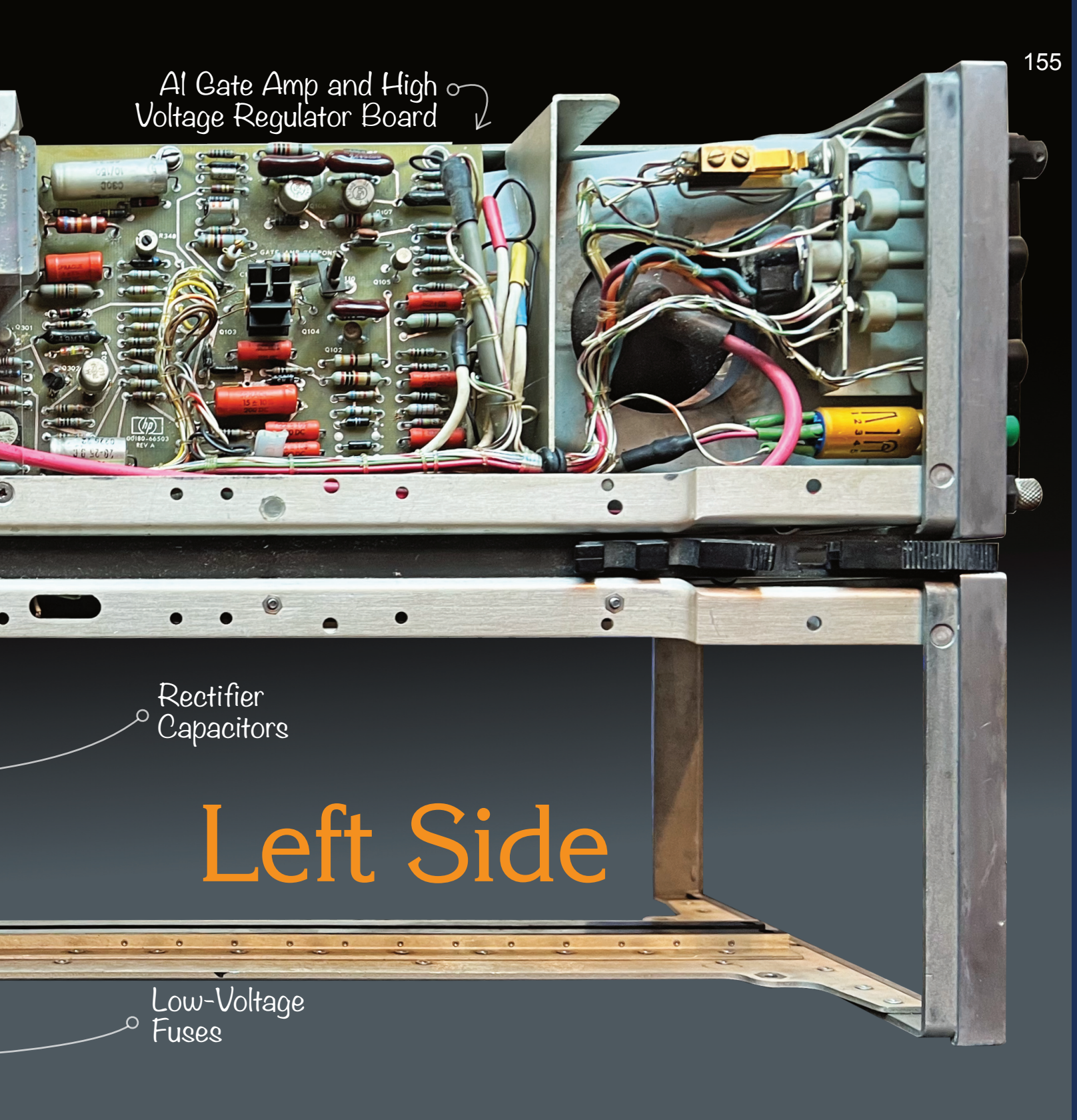


Put Things Together

1966

HP180A Oscilloscope


A3 Horizontal Amplifier Board
A7 Low-Voltage Regulator Board
A2 Output Board
MP160
MP128
MP115
MP127
MP126
MP125
MP124
MP129
MP130
H9
MP131
MP132
MP103
MP104
S102
MP122
MP123
H17
R221
L302
MP162
H11
A1
L303
S203
L101
C101
MP112
(INSIDE)
MP121
MP120
MP155
MP101
MP100
MP102
MP154
MP161
H16
J2
C201
S201
J201
MP138
H21
MP137
MP114
MP113
Q410
XQ404
E301
Q406
XQ403
E301
MP139
C405
MP165
R211
MP133
MP134
MP135
A9
J1
A
B
C
D
E
2


A1 Gate Amp and High Voltage Regulator Board
Rectifier Capacitors
Left Side
Low-Voltage Fuses

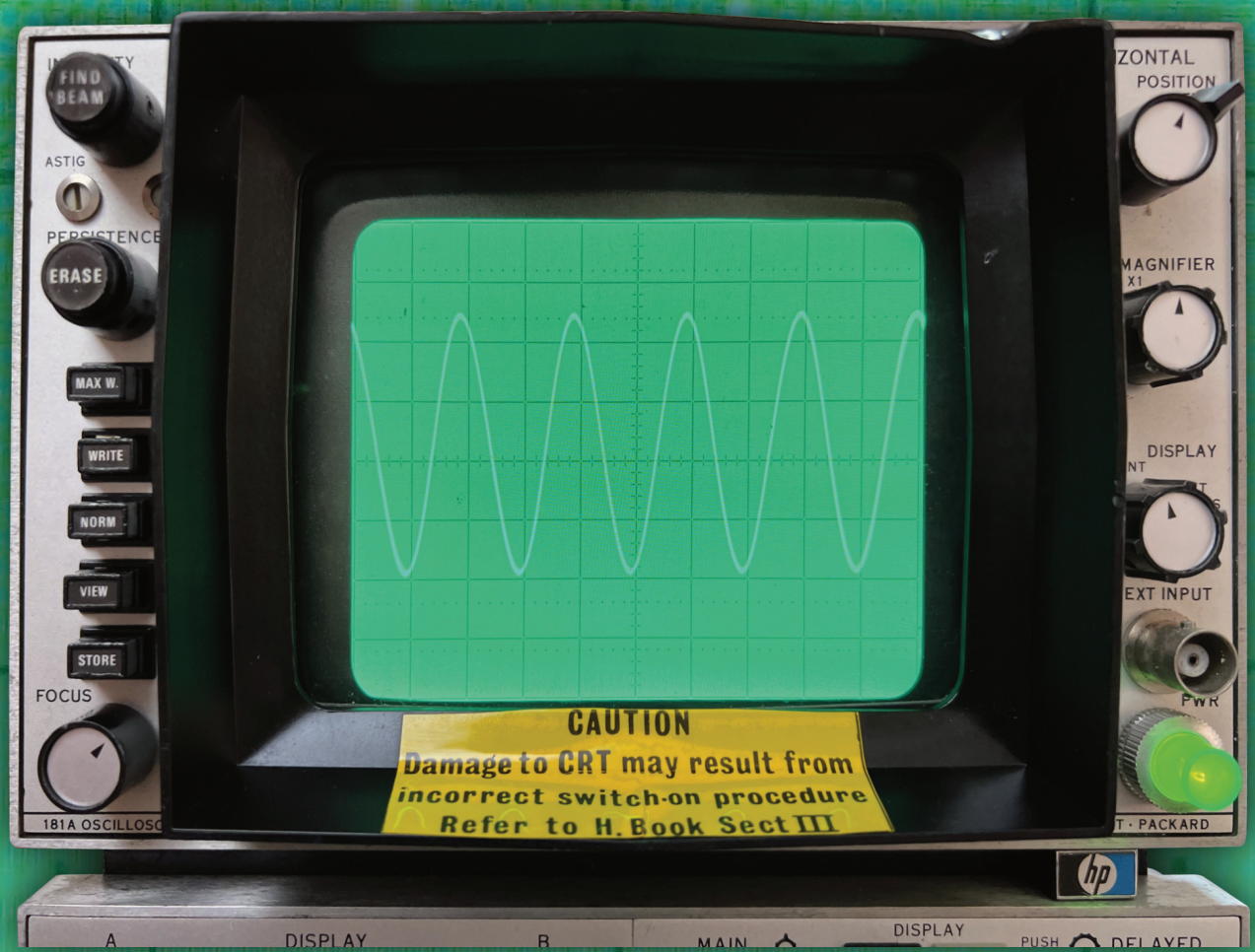
Section:

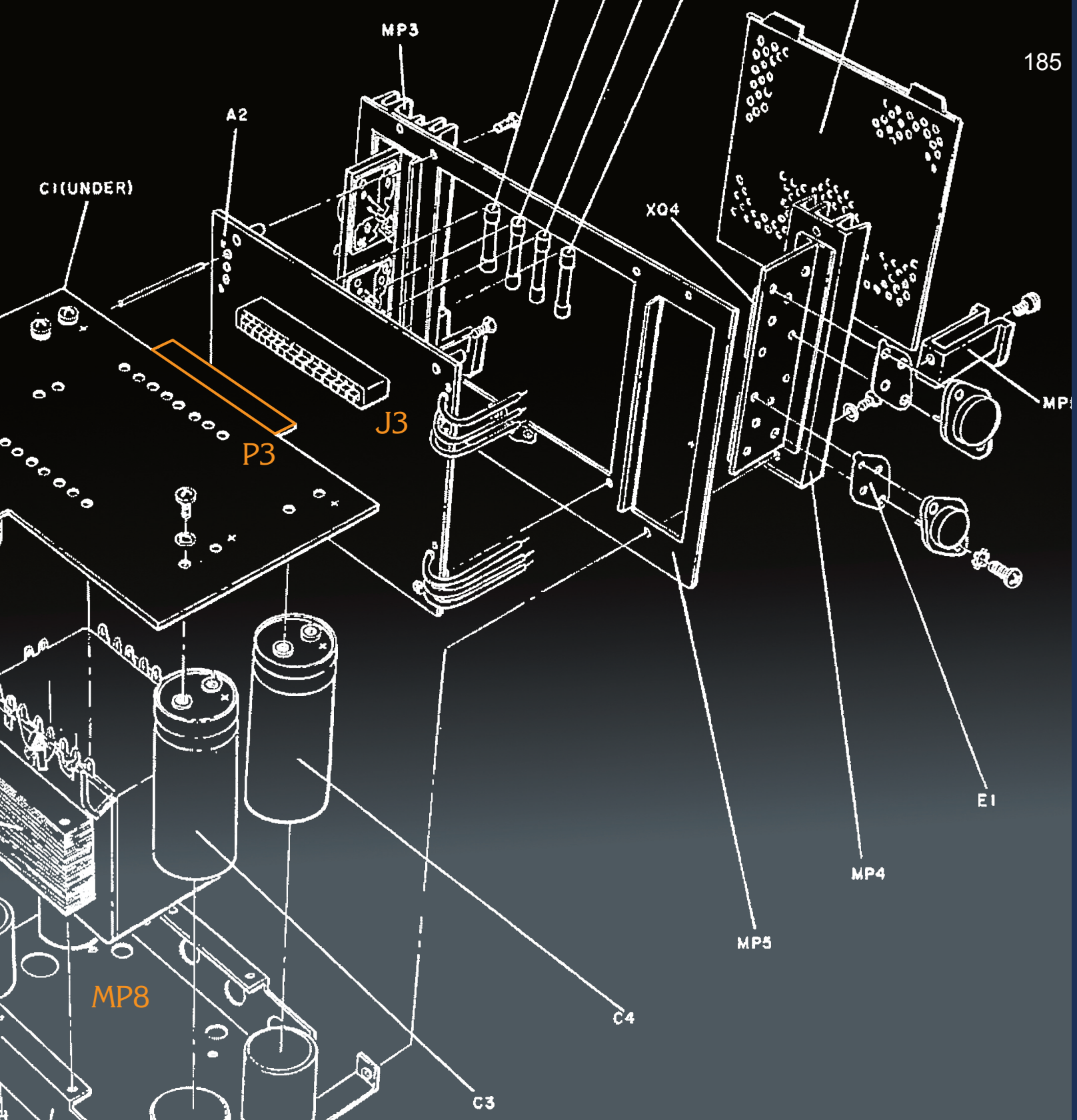
Oscilloscopes

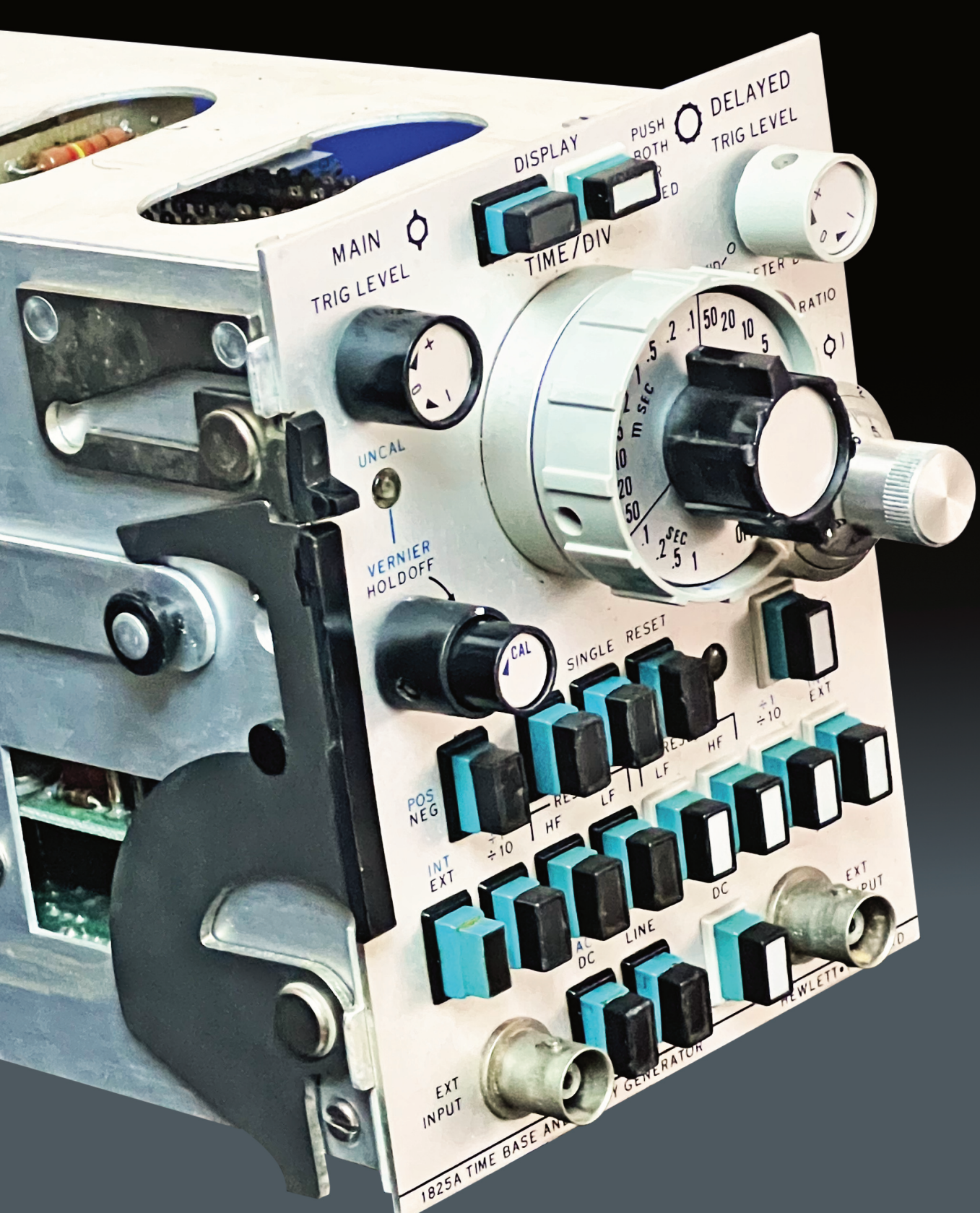
Subsection:

181A CRT Storage Mainframe

One of the first CRT storage oscilloscopes of the new transistor age. Simple yet powerful, it remains a very capable instrument even today.


FIND BEAM
ASTIG
PERSISTENCE
ERASE
MAX W.
WRITE
NORM
VIEW
STORE
FOCUS
ZONTAL
POSITION
MAGNIFIER
X1
DISPLAY
EXT INPUT
PWR
CAUTION
Damage to CRT may result from
incorrect switch-on procedure
Refer to H. Book Sect III
DISPLAY
MAIN
DELAYED
PUSH


MP3
A2
C1(UNDER)
XO4
J3
P3
MP8
C4
C3
MP5
MP4
E1


DISPLAY
PUSH BOTH
DELAYED
TRIG LEVEL
MAIN
TRIG LEVEL
TIME/DIV
RATIO
UNCAL
VERNIER HOLDOFF
CAL
SINGLE RESET
POS
NEG
INT
EXT
LF
HF
÷10
÷1
EXT
AC
DC
LINE
EXT INPUT
EXT INPUT
HEWLETT
1825A TIME BASE

Section:

Oscilloscopes

Subsection:

1806A Dual Differential

Officially denominated “100 μV Dual Differential (500 kHz)”


POWER
CALIBRA
GND
SENS
AC
DC
EXT INPUT
CAUTION
EXCESSIVE INTENSITY MAY DAMAGE STORAGE SURFACE
HEWLETT · PACKARD
MAIN
TRIG LEVEL
DISPLAY
TIME/DIV
PUSH BOTH FOR MIXED
DELAYED
TRIG LEVEL
UNCAL
VERNIER HOLDOFF
INTENS
RATIO
DELAY (DIAL X)
CAL
OFF
SINGLE RESET
POS NEG
INT EXT
÷1 ÷10
HF LF
REJECT
÷10
AC DC
LINE
DC
EXT INPUT
1825A TIME BASE AND DELAY GENERATOR
HEWLETT-PACKARD

Section:

Oscilloscopes

Subsection:

54540 Quad 500 MHz

Almost a modern four-channel, full-featured DSO with 1 GSa/s sampling and FFT, still outperforming many modern low-cost oscilloscopes.

Window or Fake?

Main and Delayed Time Bases

> *On this subject, I must admit that in earlier editions I may have written some nonsense. This section is therefore an attempt to put some order into a topic that is often misunderstood.*

Many analog oscilloscopes—starting with the progenitor Tektronix 545—were equipped with two time bases. One could be delayed with respect to the other in order to analyze a specific portion of the input signal. As an example, consider the signal shown in Figure 1: the upper trace displays the complete input waveform, while the portion of interest is intensified and expanded in the lower trace on a 7854 oscilloscope using the main and delayed time bases. A digitized trace of the same signal is shown in Photo ❶, while Photo ❷ shows the same experiment performed on a 7633 CRT storage oscilloscope.

Main and Delayed Time Bases in DSOs

This naturally raises a question: are main and delayed time base functions available on most digital storage oscilloscopes? The answer is simple: digital storage oscilloscopes have only one time base.

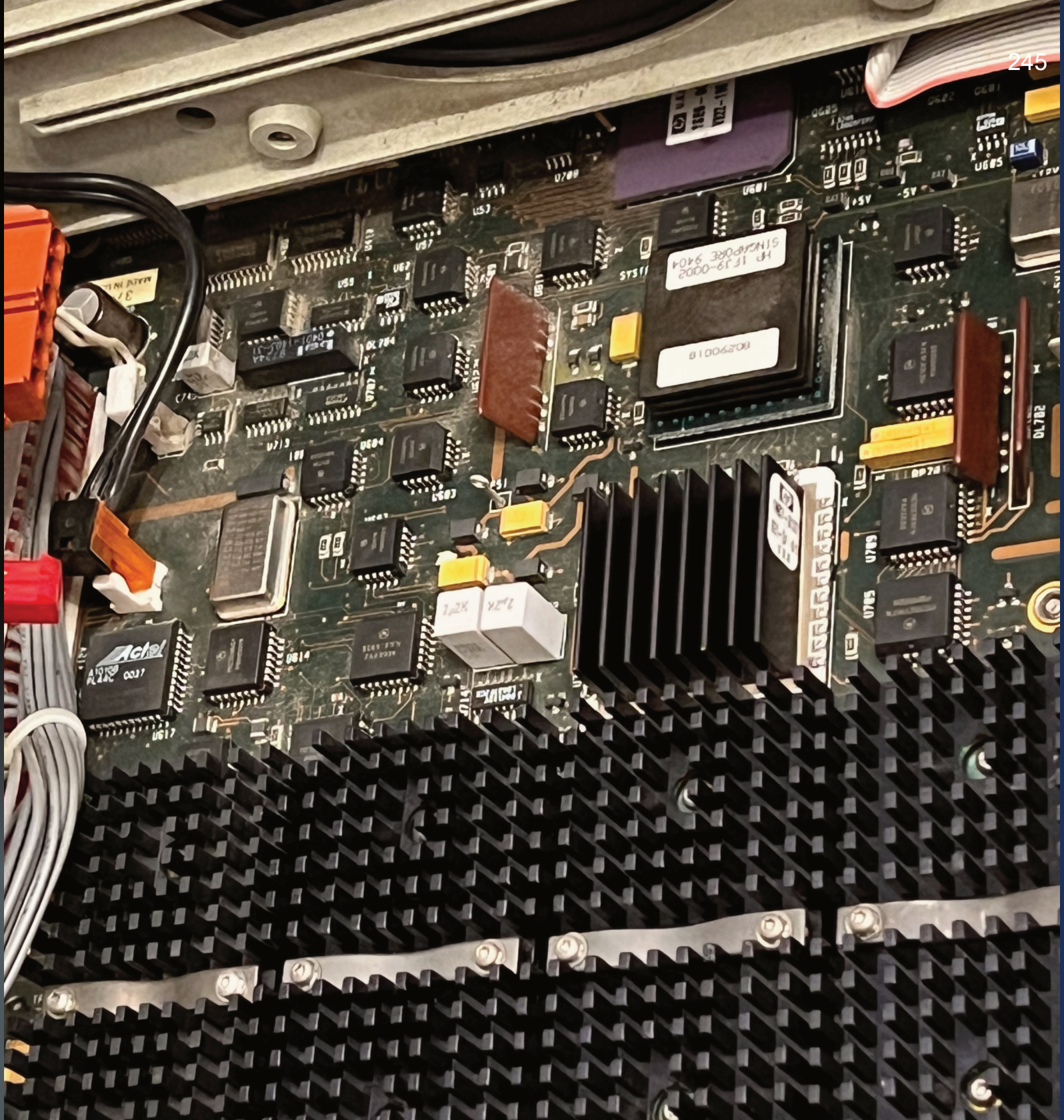
Tektronix's Position

According to Tektronix, only Tektronix oscilloscopes truly simulate the delayed time base operation found in analog instruments. In their DSOs, delayed time base accuracy is calculated in the same way as main time base accuracy, because in reality there is still only a single time base.

The Tektronix implementation simulates the delayed sweep by performing a second triggering operation after the delay, thereby eliminating much of the jitter error. It also provides an intensified-zone display that shows where the delayed sweep is positioned within the main sweep, closely mimicking the behavior of classic analog oscilloscopes.

Other Manufacturers

Again according to Tektronix, most other manufacturers adopt different approaches. Some use a horizontal position control that allows very long post-trigger delays; others rely on a zoom function, which requires a long record length and assumes that the region of interest is already contained within that record.


Actel

Marco, my son, is a genuine 3D design wizard. Through his project (toolsfix.eu), he develops clever and practical systems to keep tools and technical equipment perfectly organized.

Over time, he has also helped me by designing custom parts for some of my beloved boatanchors and vintage instruments — small components that are no longer available, yet essential to restore these machines to their proper dignity.

Several of these designs are now freely available for download from www.quacktech.it:

❷ Plastic front frame for the HP 54540A oscilloscope

❷ Replacement feet for the HP 180A oscilloscope and similar models

❸ Lever tips for various Tektronix instruments

❹ Upper and lower housings for the LeCroy 9000 Series oscilloscopes

A small example of how modern digital fabrication can serve the preservation of classic electronic art.