QUACKTECH QUARTERLY

The Technical Art Magazine

ISSUE 1

FREE DIGITAL EDITION

WHY QUACKTECH QUARTERLY?

Revealing the Art Inside Technology

BUILD OTTO: A PDP-8 REPLICA

A Classic Minicomputer Recreated in FPGA

- **COLLINS KWM-2**
  The Revolt of Tone Oscillators
- **TEKTRONIX 2431L**
  After "only" 40 years RIFA capacitors keep exploding

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QUACKTECH QUARTERLY

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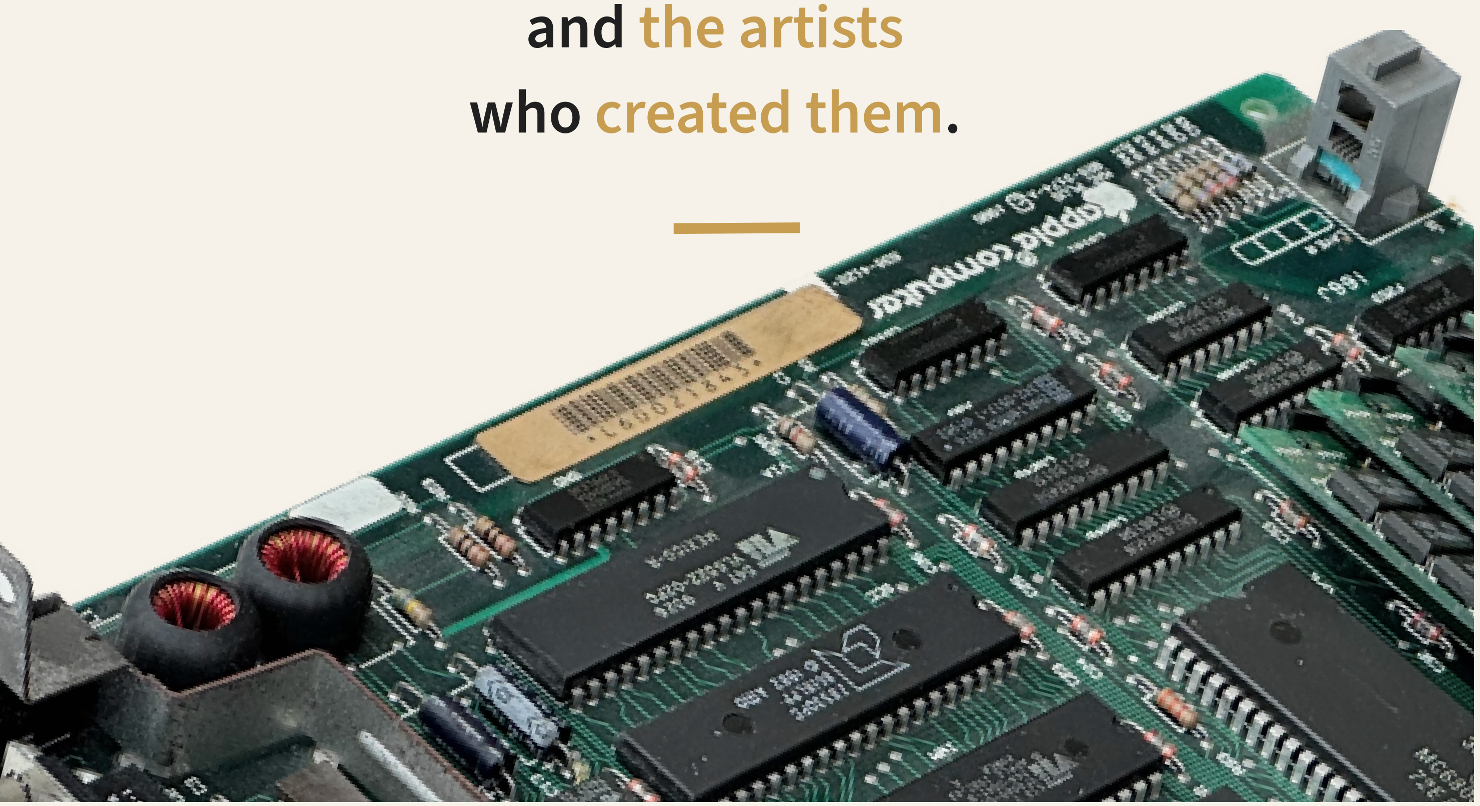
A free digital magazine
about masterpieces of technology
and the artists
who created them.



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info@k100.biz

This first issue is experimental and intended to present the editorial concept of Quacktech Quarterly

WHY QUACKTECH QUARTERLY

REVEALING THE ART INSIDE TECHNOLOGY

Technology is often described as cold, detached, almost the opposite of art. Nobody hesitates to recognize a painting, a sculpture or a building as a work of art. Today we also recognize the value of industrial archaeology: factories, bridges, power stations, workshops, machines and structures that once belonged only to production, and are now also seen as part of our cultural heritage.

So why should we not recognize art in technology itself? The answer is simple: because technical art is harder to read.

A complex instrument, a computer, a radio, a tube tester, an oscilloscope or a piece of industrial equipment may be the result of a creative process not so different from that of a painter, a sculptor or an architect. It may contain passion, intuition, elegance, frustration, sleepless nights, brilliant compromises, and the intelligence of people who had to transform ideas into working objects.

The difference is not in the act of creation. The difference is in the observer.

A painting can be approached immediately, even by someone who knows nothing about pigments, canvas or perspective. A technical object often asks for more. To see its beauty, one must understand its purpose, its constraints, its materials, its circuits, its mechanical solutions, its failures and its victories. Only then does it reveal itself.

This is the idea behind Quacktech Editions — Technical Art Books — and behind Quacktech Quarterly: to document, explain and preserve this extraordinary heritage of instruments, machines, circuits, solutions, documents and ideas.

WHAT WE ARE LOOKING FOR

- Restoration stories
- Technical experiments
- Classic instruments and computers
- Components with a story
- Engineering lessons
- Projects that make technology visible

IN THIS ISSUE

Quacktech Quarterly is a free digital magazine published four times a year by Quacktech Editions.

We welcome articles, notes, photographs, schematics, projects and suggestions

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BUILD OTTO:
A PDP-8 REPLICA

A classic minicomputer recreated in FPGA.

By Giovanni Becattini

History, restoration and FPGA design

The PDP-8 was one of the most influential minicomputers of the 1960s and 1970s. Small, relatively affordable, and remarkably elegant in its architecture, it helped move computing out of dedicated machine rooms and into laboratories, universities, factories, instruments, and control systems.

Well, perhaps before going any further we should first explain what a PDP-8 is. From this alone, after all, two things become immediately clear: how old you are and what you have done in life.

If you are past a certain age and have worked in computing, electronics, automation, or scientific instrumentation, you probably know perfectly well what a PDP-8 is. Apart from the usual discussions that arise whenever the word first is used, the PDP-8 from Digital Equipment Corporation can reasonably be considered one of the machines that defined the minicomputer era. It appeared

AT A GLANCE

- The PDP-8 helped bring computing into laboratories, instruments and control systems.
- The article recalls its front panel, core memory and the restoration of a real PDP-8/m.
- That restoration led to OTTO, a small educational computer inspired by the PDP-8 and recreated in FPGA.
- A complete free ebook describes the construction in greater detail.

My PDP-8/m remained on a shelf for more than forty years, in the various offices I had during my professional life, patiently waiting for the moment when it could be brought back to its former glory. Repairing it was anything but easy: many TTL integrated circuits had to be replaced. Fortunately, the most critical part, the core memory, had withstood the passage of time.

several years before the microprocessor and helped change the course of technology.

Dinosaurs

Before the PDP-8, computers were real dinosaurs: large, expensive, and power-hungry. They were rarely small enough to fit into a living room.

But cost and size were not their only defining features. They were distant machines, almost solemn ones. Practically nobody would have thought of putting one at home, and this was often true even for industrial companies, laboratories, and research centers.

They usually lived in the “machine room,” dominated by the hum of fans, where only a chosen few were admitted. Users accessed them indirectly, handing in tapes or punched cards and receiving, after some time, printed listings on the typical continuous-form paper with perforated edges.

Digital Equipment Corporation

It was in this setting that Digital Equipment Corporation began, almost silently, a revolution destined to change the world.

Digital Equipment Corporation, universally known as DEC and later simply as Digital, was founded in 1957 by Ken Olsen and Harlan Anderson. Both came from MIT Lincoln Laboratory, where they had worked on some of the most advanced digital machines of the time, including the TX-0 and TX-2 computers and some aspects of the gigantic AN/FSQ-7 system of the SAGE air-defense project.

One of the first strokes of genius, although partly imposed by the investors, was the company name itself. The founders would have preferred to call it Digital Computer Corporation, but they were advised against it. At the time, the word computer still evoked something enormous, expensive, and remote: a machine for a computing center, with specialized staff, air conditioning, raised floors, formal procedures, and investments beyond the reach of most organizations.

Computers were not yet perceived as tools to be placed near the people who needed to use them.

The name Digital Equipment Corporation was more cautious and more flexible. It suggested instruments, control systems, laboratory equipment, and digital logic blocks, without directly challenging IBM and the other giants of computing.

DEC’s first products followed the same approach. The company settled in an old woolen mill in Maynard, Massachusetts, a place that would remain closely tied to its history, and began not by selling complete computers, but transistorized logic modules: plug-in boards, each capable of performing a small digital function, intended for laboratories, control systems, test benches, and special-purpose equipment.

This point is important, because it places DEC in a world different from that of the large mainframe manufacturers. From the beginning, the company lived close to engineers, laboratories, instruments, experiments, and real machines. It did not sell computing as a centralized and abstract service: it sold digital logic that a technician could understand, connect, combine, and use.

Only later did DEC begin to sell complete computers. Even then, however, it carefully avoided the forbidden word.

Programmed Data Processors

DEC’s first computer, introduced in 1960, was the PDP-1. The acronym PDP is historically associated with the expression *Programmed Data Processor*, although it is often naturally interpreted as *Programmable Data Processor*. In either case, the essential point is clear: DEC carefully avoided calling those machines “computers.”

This was not only a technical choice, but also a commercial and psychological one. Calling them computers would have meant immediately comparing them with million-dollar mainframes and with all the cultural and organizational apparatus surrounding them. Calling them data processors instead suggested something different: a programmable electronic instrument, powerful but accessible, suited to scientific work, real-time control, laboratories, and direct interaction with the physical world.

The PDP-1 cost about $120,000 at the time: not a small amount, of course, but far less than the large computers of the time. It was inexpensive enough to change the type of customer that could be imagined. A university laboratory, a research group, or a technically ambitious company could finally think of owning such a machine.

New Applications

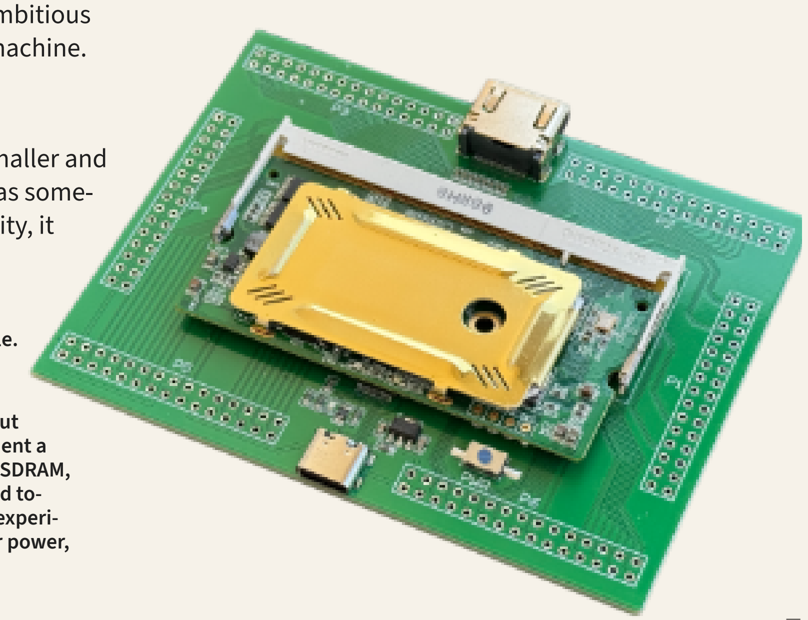
We should not think of the PDP-8 simply as a smaller and less expensive computer. Its real importance was something else: because of its size, price, and flexibility, it could become **the brain of machines** and equipment that until then could never have contained a computer.

I have described many electronic devices, but few of them can be called *machines* in the most literal sense of the word. Of course we continue to use this word also for oscilloscopes, receivers, transmitters, signal generators, counters, and power supplies. But, strictly speaking, a machine is something that acts upon the physical world: it moves, regulates, transports, prints, cuts, measures, selects, controls, repeats, or transforms.

For much of industrial history, the behavior of these machines was imprisoned in their construction. Gears, cams, shafts, relays, solenoids, contacts, selectors and, later, hard-wired electronic logic could achieve extraordinary results. Many of those systems were ingenious, reliable, and sometimes almost magical in the complexity of the functions they could perform without any software at all.

But they remained bound to their physical structure; their behavior was established once and for all by mechanical shapes, electrical connections, relay sequences, logic gates, and the intelligence of their designers. If a different behavior was desired, in most cases the machine itself had to be modified.

This remained true even when control passed from mechanics to electricity and then to electronics. It was certainly an enormous technological advance: machines became faster, more compact, quieter, more reliable, and less subject to wear. Relays could replace cams; electronic logic could replace relays; sensors could replace mechanical contacts. But from a conceptual point of view, the behavior of the machine was still fixed by the hardware.



The OTTO project is based on the Colorlight i5 v7.0 module. Originally designed to drive LED panels, it has become popular as a low-cost FPGA development platform.

At its heart is a Lattice ECP5 LFE5U-25F, a device with about 24,000 logic elements: far more than is needed to implement a computer similar to the PDP-8. The module also includes SDRAM, SPI flash memory, clock circuitry, and Ethernet PHYs. Used together with a small base board, it becomes a convenient experimental platform, providing the necessary connections for power, programming, and I/O.

With programmable systems, however, **a logical leap** occurred.

In a stored-program computer, the behavior of the machine **could be described by instructions**. It could be corrected, extended, or transformed by changing the program. Naturally the machine did not "think" in the human sense of the word, but it could follow a sequence of instructions, make elementary decisions, react to external conditions, acquire data, and control devices according to a modifiable logic.

The essential point is this: electronics could make a fixed behavior faster and more reliable; programmability made the behavior itself modifiable.

When **microprocessors** appeared in the mid-1970s, this idea became almost obvious. Suddenly it was possible to place a programmable processor inside instruments, controllers, terminals, video games, office machines, industrial equipment, and an enormous number of other devices. Software could replace cams, relays, sequencers, diode matrices, dedicated logic, and entire portions of special-purpose hardware.

But the story **does not begin** with microprocessors. Before them, machines such as the **PDP-8** had already shown that a computer could leave the machine room and become part of a real system: an instrument, a test bench, an industrial process, a laboratory, a machine capable of interacting directly with the physical world.

A Magnificent Toy

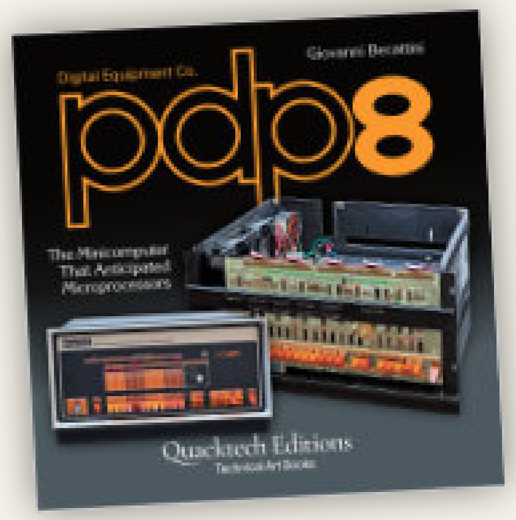
Unlike modern computers, closed, sealed, and with their mysteries carefully guarded inside, a PDP-8 is a magnificent toy. Its front panel allows direct interaction with the internal circuitry: you can enter machine instructions into its modest memory, examine the contents of each location, modify data and programs, start execution and, in many cases, proceed step by step.

All this guarantees hours of amusement. And if you think that, by today's practical standards, all of this is magnificently useless, you will understand why amusement and satisfaction are truly guaranteed.

Documentation

Another pleasant aspect of the PDP-8 is that its documentation is now almost **entirely available** on the Internet. You can find technical manuals, schematics, maintenance manuals, operator's guides, and even the wonderful pocket guides that explain the instruction set with great clarity.

The PDP-8 was a real computer, but a remarkably lean one. In the later versions of the family, such as the PDP-8/e and the PDP-8/m, this simplicity translated into a



The book "PDP-8, the Minicomputer That Anticipated Microprocessors", available from www.quacktech.it

hardware implementation based on a surprisingly small number of 74-series TTL integrated circuits. Precisely for this reason, it is still possible today to understand how it really works, following the signals on the schematics and, with a little patience, even on the boards.

Memory

One of the most fascinating features of the PDP-8 is its use of ferrite-core memory, or **core memory**, something that today can almost only be seen in museums, unless one is lucky enough to own a machine from that era.

Core memory did not use transistors, capacitors, or integrated circuits to store bits. It consisted of a matrix of tiny ferrite rings crossed by very thin wires. Each core could be magnetized in one direction or the other, thus representing either a zero or a one. To read or write a memory word, the machine circulated appropriate currents through the wires passing through the selected cores.

Reading was destructive: to know the state of a core, it was forced into a known state and the possible pulse generated on the sense wire was observed. If the data had to remain in memory, the computer therefore had to rewrite it immediately after reading it. This is a complication that may seem strange today, but at the time it was entirely normal.

On the other hand, core memory had one precious quality: it was non-volatile. When the computer was switched off, the contents of memory were not lost. It could therefore happen that a PDP-8 was switched back on and the program or data present at the moment of shutdown were still in memory. For those accustomed to modern RAM, which forgets everything as soon as power is removed, this is a small technological miracle.

My PDP-8/m

I have owned a PDP-8 since the late 1970s, thanks to a fortunate series of circumstances.

The machine at the center of this story is a PDP-8/m, not very different from the better-known PDP-8/e. Originally it was part of a larger system, confirming one of the typical uses of the PDP-8: not so much a computer to be used on its own, but an intelligent controller hidden inside a more complex machine.

In the early 1970s, my father directed a public health institute. To reduce the cost of blood tests, he decided to purchase an automatic analyzer produced by **Vickers Medical**, a large British company. Inside that sophisticated piece of equipment, a PDP-8 served as the system controller.

When the machine was installed, naturally I did not miss the chance to look inside it. I worked for free, but in exchange I could play with the PDP-8 whenever the analyzer was not in use. I still remember a very helpful English technician, who taught me many things about that machine and helped kindle a passion that has stayed with me ever since.

The Vickers analyzer was a remarkable machine, but for non-technical reasons its purchase proved to be an unfortunate choice. For reasons probably more administrative, political, or economic than technical, the machine, although perfectly functional, was never really put into service. After a few years it was dismantled.

And the PDP?

I asked whether I could keep the computer, probably a PDP-8/L, together with its teleprinter. At first the administration agreed, and I took those wonderful toys home, hardly believing my luck. A few hours later, however, they changed their minds. Someone came to retrieve them and, to my great sorrow, I was told that they had to be "officially" destroyed.

Then, perhaps seeing my despair, someone took pity on me and said something like: *"Listen, kid, in that other box there is another computer. It was probably a spare unit. There are no documents and officially it does not exist. If you want, you can keep it."*

That Was My PDP-8/m.

Since then it has followed me everywhere, remaining in all the offices I have had during my professional life.

At the beginning of this story, in April 2026, the PDP-8/m was not completely dead, but it was certainly far from alive. That was where its new adventure began—an adventure that also led to the creation of the book *PDP-8: The Minicomputer That Anticipated Microprocessors*, available from www.quacktech.it.

The Birth of OTTO

Several years ago, the familiar little devil on my shoulder put into my head the idea of learning a **hardware description language**.

The classic introductory **FPGA examples**, however, did not excite me very much. Making an LED blink is certainly useful, at least to begin with, but after a while it does not lead very far. I was looking for a project difficult enough to force me to really learn something, but still small enough to remain within my reach.

So I asked myself: *why not try to build a PDP-8 clone?*

That was the beginning of the **OTTO project**: my attempt to reproduce, inside an FPGA, a computer inspired by the PDP-8.

Why OTTO?

"Otto" is a German personal name, but in Italian it is also the number eight. For a project inspired by the PDP-8, therefore, the name was almost inevitable.

There was, however, another reason. Otto was the name of my partner when I founded my company in 1998. True, he was a dog, but that did not prevent him from being the boss.

In what was then my company, many software tools and several internal projects received names derived from Otto, and some still keep them today, almost thirty years later. So, when I needed to give a name to my personal PDP-8, OTTO was the most natural choice.

It meant eight, it was mine, and it was slightly crazy.

What Is Inside OTTO

OTTO is not a software emulator of the PDP-8. It is not a program running on a normal modern computer while pretending to be an old machine. It is something different: a hardware description of the processor, memory, and some essential peripherals, implemented inside an FPGA.

An FPGA, or **Field Programmable Gate Array**, is a programmable integrated circuit that can be configured to implement almost any digital circuit within its available resources. Instead of writing a program that is executed by an already existing processor, you describe the circuit you want to obtain: registers, counters, multiplexers, memories, control signals, logic gates, and connections between the various parts.

In the case of OTTO, inside the FPGA we therefore find a machine inspired by the PDP-8: a 12-bit accumulator, a program counter, memory, control logic, the main instructions, and a simple serial interface that plays the role of the old teleprinter.

Of course I did not try to reproduce every electrical detail of the original PDP-8. That would have been useless and, in some cases, not easy. OTTO contains no ferrite cores, no DEC boards, no Omnibus, and no 74-series TTL circuits. The memory, for example, is implemented using the internal resources of the FPGA. From the physical point of view, therefore, it is a completely modern machine.

From the logical point of view, however, the game becomes interesting. The instructions are those of the PDP-8, the registers have the same size, programs can be entered from the front panel, and the general behavior remains close enough to that of the original machine to allow very realistic educational experiments. It also passes the original instruction-set tests.

This is, at least for me, the true charm of the project. OTTO does not want to replace a real PDP-8, and it does not claim to be a perfect clone. Rather, it wants to make a small computer architecture visible and understandable: old enough to be simple, but complete enough to remain surprising.

The Front Panel

The most important part of OTTO, at least from the point of view of the user experience, is the front panel.

A modern computer, even when extremely powerful, tends to hide everything. It turns on, displays a graphical interface, loads an enormous operating system, and presents us with a ready-made world inside which the real hardware has almost disappeared.

In the PDP-8, by contrast, the hardware is right there in front of us. The switches and lamps are not decorations: they are the most direct way to enter the machine.

That is why I wanted OTTO t**o have a front panel** as well. It is not merely an aesthetic or nostalgic choice. It is an essential part of the educational project.

Through the switches you can set an address, deposit a value in memory, examine the contents of a location, start the program, stop it, and observe its evolution. With just a few commands you concretely understand that memory is made of numerical words, that an instruction is nothing more than a number, that the program advances from one location to the next, and that even an apparently trivial result, such as printing a character, requires a precise sequence of operations.

In my prototype I also added a small **seven-segment display**, used to show information such as the contents of the program counter or the accumulator. It is not identical to the original DEC panel, of course, but it performs its task well: it lets you see the machine while it is working.

At this point, practical uselessness becomes a virtue. Nobody builds OTTO to replace a modern computer; it is even slower than the original. You build it to look inside a computer, to understand how an instruction comes to life, how data moves, how a sequence of bits can turn into behavior. It is a small, inexpensive, and slightly crazy object, but precisely for this reason it manages to restore something that has almost completely disappeared from modern computers: direct contact with the machine.

Practical Example

We have talked a lot, but we have not yet seen anything concrete. So here is a small practical example: a program that sends a character through the serial port. Immediately afterward we will also see how to load it into memory and run it from the front panel.

First, however, we must remember one fundamental thing: for the PDP-8, every instruction is simply a number.

The PDP-8 is a 12-bit machine. Each memory word therefore contains 12 bits, which can represent data, an address, or a machine instruction. Today it is natural for us to write a program using mnemonics such as `CLA`, `TAD`, `JMP`, or `HLT`, but the processor does not see those names. It sees only numbers.

For example, the instruction:

CLA CLL

which clears the accumulator and the Link, corresponds to the octal number `7300`.

The PDP-8 traditionally uses octal notation, that is, base 8. The possible digits are therefore only 0, 1, 2, 3, 4, 5, 6, and 7.

The choice is not accidental. One octal digit represents exactly three bits; a 12-bit word can therefore be conveniently written with four octal digits. For example, `7300` represents a complete 12-bit word. Memory addresses are also normally written in octal: in a basic 4K-word machine, locations range from `0000` to `7777`.

Our small program will be loaded starting at location `0200`, a very common address in PDP-8 examples.

We want to transmit the character `A`. In ASCII code, the letter `A` has the decimal value 65, that is, `101` in octal. The program may be the one shown on the facing page.

ADDRESS	CODE	INSTRUCTION	MEANING
0200	7300	CLA CLL	CLEARS THE ACCUMULATOR AND THE LINK
0201	1206	TAD CHAR	LOADS INTO AC THE CHARACTER TO BE TRANSMITTED
0202	6046	TLS	SENDS CHAR TO TELEPRINTER/SERIAL INTERFACE
0203	6041	TSF	CHECKS WHETHER TRANSMISSION HAS BEEN COMPLETED
0204	5203	JMP 0203	IF IT HAS NOT BEEN COMPLETED, WAITS
0205	7402	HLT	STOPS THE PROGRAM
0206	0101	CHAR	ASCII CODE OF THE LETTER A

Example program described in the text

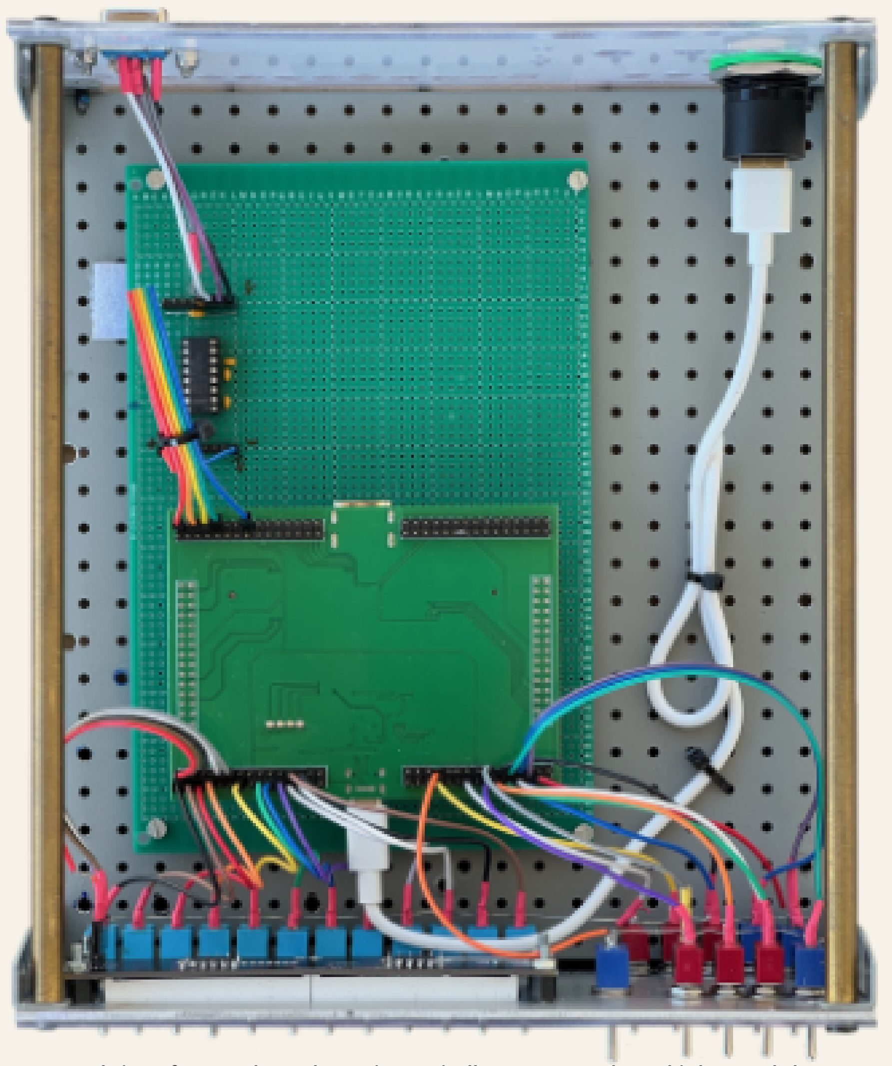
The program begins by clearing the accumulator, the machine's main register. It then executes the instruction `TAD CHAR`, which adds to the accumulator the contents of the location symbolically called `CHAR`. Since the accumulator had just been cleared, the result is simply the value of the character to be transmitted.

At location `0206` we have in fact written the number `0101`, that is, the ASCII code of the letter `A`.

The instruction `TLS`, short for *Teleprinter Load Sequence*, transfers the contents of the accumulator to the transmit register of the teleprinter, or more generally of the PDP-8-compatible serial interface, and starts sending the character.

At this point the program must wait until transmission is complete. It does this with a small waiting loop: `TSF` checks the teleprinter flag. If transmission is complete, it skips the next instruction. If, instead, transmission is still in progress, it skips nothing, and therefore `JMP 0203` is executed, bringing the program back to check the flag again.

When the character has finally been transmitted, `TSF` skips the `JMP` and the program reaches `HLT`, stopping execution.



Internal view of OTTO. The enclosure is practically empty; I used one this large only because I already had it. Everyone can build it in whatever form they prefer.

Loading It Into Memory

The interesting thing is that this program can be entered directly from the front panel, without an assembler, without an operating system, and without any other help. You simply load into memory, one after another, the octal numbers shown in the table.

The operating sequence is typically this:

- set `0200` on the front-panel switches;
- press `ADDR LOAD` to load the initial address;
- set `7300` on the switches;
- press `DEP` to deposit the first value in memory;
- continue with `1206`, `6046`, `6041`, `5203`, `7402`, and `0101`, pressing `DEP` each time;
- set `0200` on the switches again;
- press `ADDR LOAD` again;
- press `CONT` to start the program.

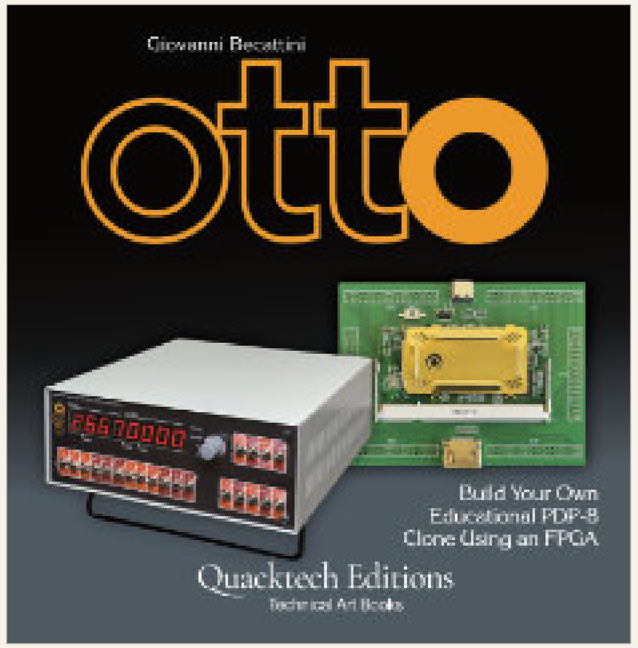
Detail of the core memory in the “real” PDP-8. Each core is less than one millimeter across.

If everything is connected correctly, the letter `A` will appear on the serial line.

It is a very modest result, of course. But it is also a small miracle: we have written seven octal words directly into memory, and a machine more than half a century old, or its FPGA clone, has executed those words as real instructions.

Building OTTO

The greatest difficulty in reproducing OTTO is not so much the electronics as the mechanical part: the front panel requires a fair number of toggle switches, push-buttons, connections, and a little care to obtain a pleasant appearance.



The free eBook you can download from www.quacktech.it

A Free eBook

For those who would like to explore building OTTO in greater depth, I have prepared a dedicated free ebook of about 100 pages, containing schematics, drawings, explanations, and much more information.

It can be downloaded free of charge, together with all OTTO source files, from www.quacktech.it.

Quick Start

To give an idea of the required level of difficulty, without immediately going into the details of Verilog, synthesis tools, place-and-route, timing constraints, and the other small esoteric rituals of FPGA development, a very simple path can be followed.

To replicate OTTO, it is in fact not necessary to install the entire development environment. You do not need Yosys, nextpnr, ecppack, or the other tools required to rebuild the project from source. All you need is a correctly wired Colorlight i5 board, the configuration file I have made available in the free downloadable kit, and the `ecpdap` program, used to transfer the bitstream to the FPGA.

In practice, you must build the hardware, connecting the front panel, the display, and the serial interface according to the connection scheme defined in the `colorlight_i5.lpf` file. Then you copy the ready-made file, for example `PDP_colorlight_top.bit`, into a convenient folder on your computer and connect the board to the PC via USB.

Before programming the board, it is advisable to check that `ecpdap` recognizes the CMSIS-DAP interface and the FPGA:

`ecpdap probes`

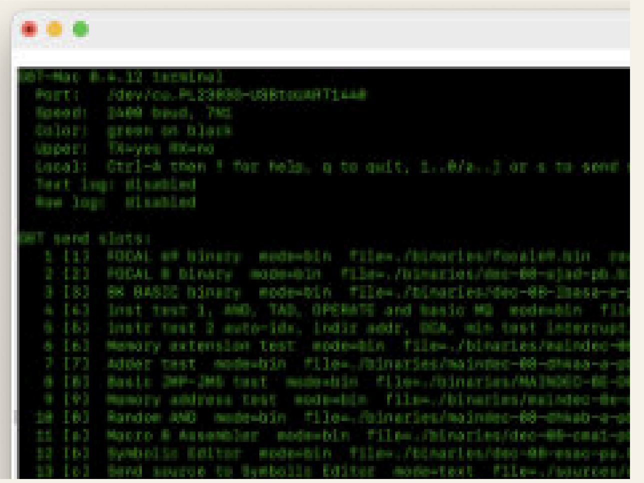
`ecpdap scan`

For a first test, OTTO can be loaded temporarily into the FPGA SRAM:

`ecpdap program PDP_colorlight_top.bit -f5M`

In this way the configuration works immediately, but it is lost when power is removed from the board.

The technique used to make the front panel is described in detail in the eBook.



Together with OTTO, I also created a companion Teletype emulator. It includes several classic DEC software packages, such as FOCAL, BASIC, and assemblers, so that they can be loaded into OTTO and tested. It runs at the astonishing speed of 2400 baud. Originally, my PDP-8 was limited to 110 baud, but a small modification allowed it to scale these dizzying heights.

To make OTTO permanent, so that it starts automatically when powered on, the bitstream must instead be written to the SPI flash memory:

`ecpdap flash write PDP_colorlight_top.bit`

On some boards the flash may be protected. If writing fails, it can first be unlocked with:

`ecpdap flash -f5M unprotect`

and then the write command can be repeated.

At this point, just switch the board off and on again. If the wiring is correct, OTTO starts by itself, without needing the FPGA development environment and without having to recompile anything.

FOCAL

A brief sermon is due on the amount of memory, which after many years is once again becoming a scarce and valuable resource because of the growing demand created by artificial intelligence systems.

But in the late 1960s, when integration technology still did not allow adequate memory chips to be

OTTO compared with the “real” PDP-8, built in Europe, as proudly stated by the inscription on the front panel. Note the key-operated power switch: a real security key. Evidently, not everyone was allowed to turn on a real computer.

produced, memory was something incredibly rare. When, in 1973, I tried to build my first computer, I did everything I could to get hold of a core memory, without success.

Today the 4K words of the basic PDP-8 version make you smile; a single icon on your screen consumes much more.

But at the time one had to make do with what was available, and for the PDP-8 DEC offered carefully “shaved down” programs, with tricks we can no longer even imagine today, in order to exploit the platform as well as possible.

Among them was FOCAL, a programming language similar in some respects to BASIC, which could run within the famous 4K-word limit. In the downloadable kit you will find two different files: one with the binary loader already in memory, ready to receive other programs through the serial port, and one with FOCAL ready to run. You only have to switch the machine on, set `0200` on the switches, and press `ADDR LOAD` and `CONT`. On your terminal emulator the magical `*` will appear, indicating that OTTO is waiting for your commands.

Conclusion

At this point one might ask: why do it?

Why build, today, an almost-clone of the PDP-8, when even the cheapest microcontroller has immensely superior performance?

The PDP-8 belongs to a generation of machines in which computer architecture was still small enough to be understood by a single person. It was not simple in an absolute sense, but it was still readable. One could follow an instruction, understand where data went, observe the contents of the registers, read the circuit diagram and, with patience, reconstruct the behavior of the machine.

OTTO tries to preserve precisely this aspect. It is not a commercial product, it is not a useful computer in the modern sense of the word, and it does not claim to be a perfect replica.

It is simply a way to bring back to life, with modern tools and at very low cost, a small part of the spirit of the PDP-8.

In the end, the charm of these machines does not depend only on nostalgia. It depends on the fact that they remind us of a fundamental truth of computing: a computer is not magic. It is a logical machine, made of registers, memory, signals, instructions, and time. When it can be observed closely enough, even a simple program that prints a letter becomes a small lesson in architecture.

And if in the end all this is practically useless, so much the better. Some of the most beautiful things that can be built in a laboratory are not born because they are useful, but because they help us understand, remember and, above all, have fun. And it is hard to imagine anything with a better fun-per-euro ratio...

ON THE NEXT ISSUE
TEKTRONIX 191

The Tektronix Type 191 Constant Amplitude Signal Generator is a sine wave source introduced in 1966. It produces a sine output from 350 kHz to 100 MHz in seven bands.

COLOPHON

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info@k100.biz

COLLINS KWM-2
THE REVOLT OF THE TONE OSC

When a Good Tube Refuses to Oscillate

By Giovanni Becattini

Story of a repair more laborious than expected

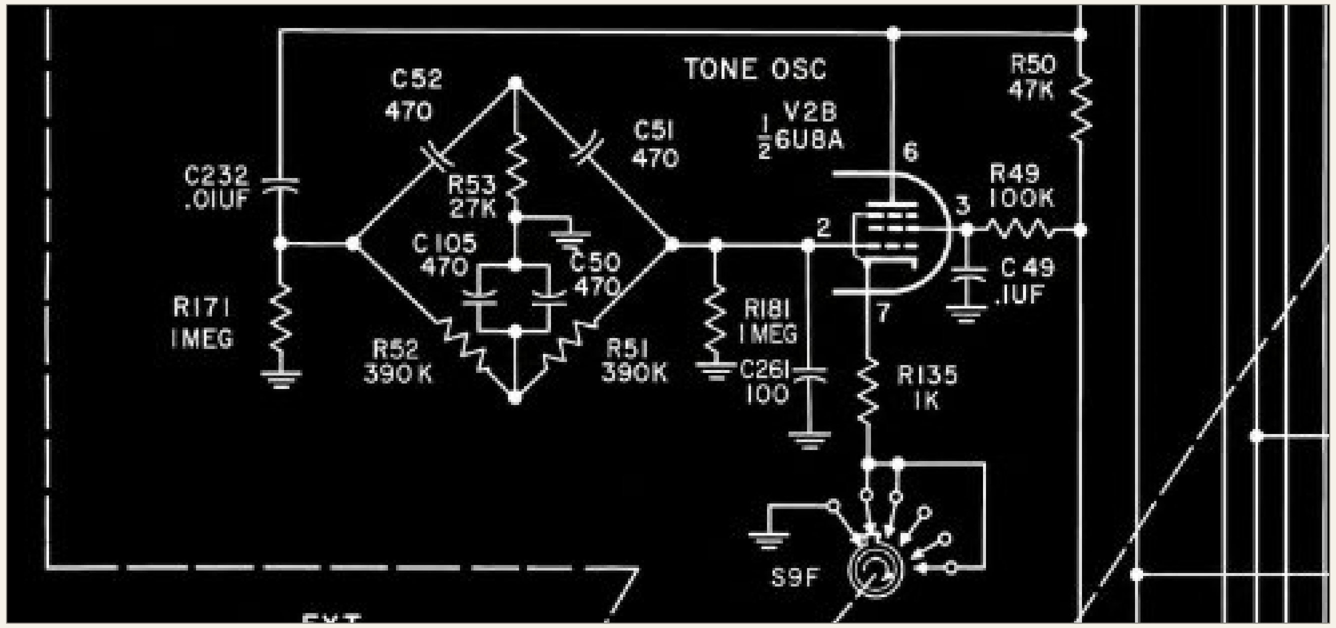
A problem that initially looked trivial eventually absorbed much more time than expected. After my Collins KWM-2 had been switched on for a while, it apparently stopped transmitting. Moving the EMISSION switch to TUNE or LOCK produced no grid-current indication on the meter.

In cases like this, the power supply is always the first suspect. It naturally complained about discrimination as soon as I discovered that it was completely innocent.

The KWM-2 was actually switching to transmit correctly. The real problem was the approximately 1.7-kHz tone oscillator, V2B, which is used to excite the transmitter chain in TUNE, LOCK and CW. When the oscillator stopped, there was no drive and therefore no RF output.

AT A GLANCE

- The KWM-2 tone oscillator can become marginal as the set warms up, even when all DC voltages remain normal.
- A 6U8A may still test “good” on a tube tester yet fail to sustain oscillation reliably in the actual circuit.
- 6EA8 tubes are not all equivalent in this application: some do not oscillate, while others work perfectly.
- Collins Service Bulletin No. 10 adds a 47 Ω screen-grid resistor to suppress VHF parasitic oscillations in V2B.



Excerpt from the KWM-2 tone-oscillator circuit around V2B.

My first thought was reassuringly simple: some old resistor had probably become temperature-sensitive. A few measurements, one replacement, and the problem would be gone.

It did not work out that way.

The Usual Suspects

The first component I checked was, of course, the tube itself. V2 is a 6U8A: its triode section, V2A, operates as the VFO cathode follower, while the pentode section, V2B, is the tone oscillator.

At that time I had no tube tester available, so I simply substituted another 6U8 from the KWM-2. The result did not materially change.

I then checked the DC voltages. In TUNE I measured approximately:

- plate: 130 V
- cathode: 4.2 V
- screen grid: 157 V

All were perfectly plausible and, more importantly, essentially unchanged whether the oscillator was working normally or had become weak after warming up.

The resistor hunt therefore began. One after another, the resistors around V2B were checked and eventually replaced, including the screen-grid supply resistor. Nothing produced a decisive improvement. This was not particularly enjoyable work: Collins managed to fit an impressive number of components into a very small space.

Meanwhile I had ordered what was supposed to be a new 6U8A. What arrived was a NOS tube carrying the double marking 6EA8/6U8A.

It performed considerably worse than the original tube. At first I assumed it was simply defective, and the very helpful seller offered to send another one.

That replacement is still somewhere in the postal system.

Cooling Things Down

The thermal nature of the problem was undeniable. Blowing a strong stream of air into the underside of the chassis restored the oscillator almost immediately.

I therefore started using freeze spray on individual components.

The results were not perfectly clear-cut, but C51 and C52, both 470-pF capacitors in the feedback network, appeared to have the greatest influence. Cooling either could improve the oscillation, although no single component produced the dramatic and repeatable effect I had hoped for.

C51 was particularly suspicious because it was mounted directly on a tube-socket terminal and was therefore exposed not only to the general temperature inside the cabinet but also to heat conducted through the socket itself.

Eventually C51 and C52 were replaced with new silver-mica capacitors. C261, a 100-pF capacitor, was also replaced after I discovered that one of its leads was not properly soldered, and R49, the 100-kΩ screen supply resistor, was renewed.

These changes did improve the margin of the oscillator. With the old 6U8A it no longer stopped completely. But the large temperature dependence remained.

At this point the apparently simple repair had become considerably less simple.

Five 6EA8s, Five Different Answers

I obtained another four 6EA8s from different manufacturers, giving me a small panel of five tubes.

Their behavior in exactly the same oscillator was astonishingly different:

- #1 Raytheon: no oscillation
- #2 General Electric: extremely weak oscillation, about 44 Vpp
- #3 Union, Korea: about 160 Vpp and apparently stable
- #4 RCA: about 220 Vpp, but with a strong whistle in the loudspeaker, unaffected by the volume control
- #5 RCA: about 220 Vpp and apparently stable, although initially tested for a shorter period

The tests were performed consecutively, without allowing the passive components to cool significantly between tubes. It was therefore difficult to blame the enormous differences on temperature alone.

I concentrated on two tubes: the original 6U8A, which I began calling “tube zero,” and the Union 6EA8, tube #3. The contrast was remarkable.

Starting from cold, the original 6U8A typically showed a rapid fall in oscillator amplitude. In one test it went from 152 Vpp to 108 Vpp after 12 minutes and 98 Vpp after 16 minutes. A one-minute blast from a fan immediately restored it to approximately 150 Vpp.

In a later test, after the passive components had been renewed, it fell from 134 Vpp to only 56 Vpp in 24 minutes.

The Union 6EA8 behaved quite differently. In a comparable run it started at 178 Vpp and, after twenty minutes, had settled at approximately 164 Vpp. Some thermal drift remained, but it was modest and perfectly acceptable.

An even more revealing experiment was made with the circuit already thoroughly warm. After operating the Union tube for half an hour at about 162 Vpp, I switched the KWM-2 off, immediately replaced it with the original 6U8A, and switched it on again.

The oscillator initially failed to start, then appeared at about 36 Vpp and finally settled near 84 Vpp.

The passive components could hardly have changed temperature during the few seconds required to change the tube. The tube itself was clearly a major part of the story.

But the Tube Tester Said It Was Good

By then I had restored and calibrated my TV-2/U tube tester, so the obvious next step was to test the tubes properly.

The results were again surprising:

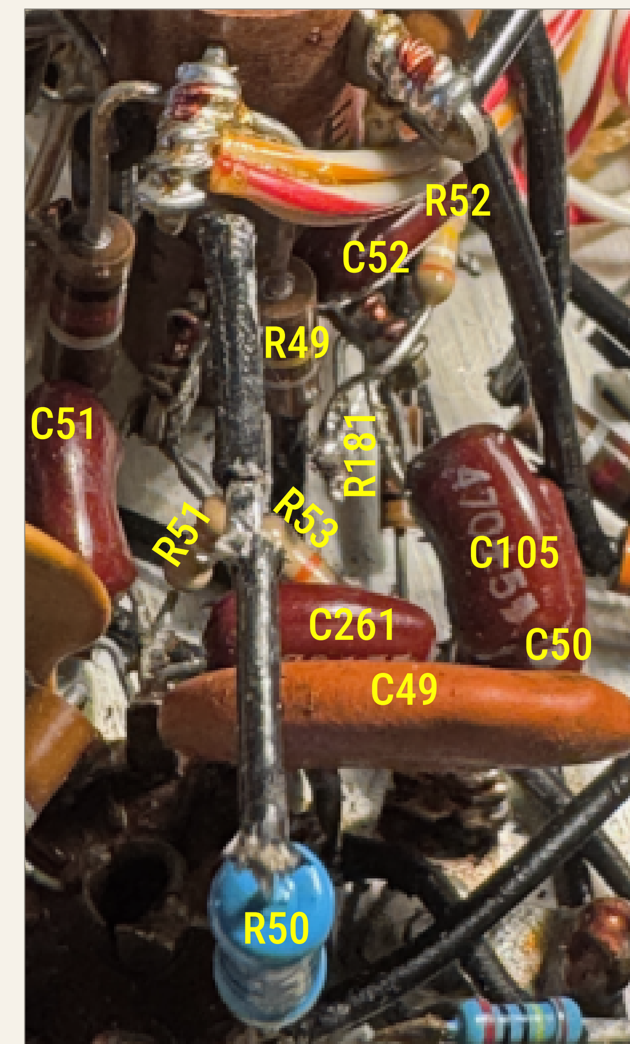
- original 6U8A: approximately 70%, with 60% specified as the minimum acceptable value;
- Union 6EA8: approximately 110%.

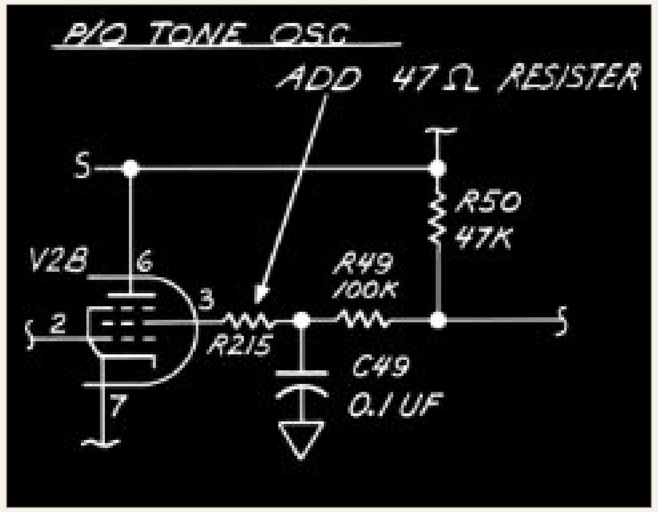
Neither tube showed positive evidence of gas or significant interelectrode leakage.

I even performed a particularly unfair test on the old 6U8A: I removed it from the KWM-2 while it was thoroughly hot and immediately transferred it to the TV-2. It still showed no obvious anomaly.

So the original 6U8A was not dead, shorted, gassy or dramatically low in transconductance. According to the tube tester, it was still serviceable.

Under-chassis detail of the KWM-2 tone-oscillator area, with the main components identified.





Collins Service Bulletin No. 10 added a 47 Ω resistor in series with the screen grid of V2B to suppress VHF parasitic oscillations.

According to the KWM-2 tone oscillator, it was not.

This is an excellent reminder that a tube tester and the actual circuit do not necessarily ask the same question.

Then I Found Bill Orr

Only at this point did I come across William I. Orr, W6SAI, and his article Updating the Collins KWM-2, published in ham radio in September 1979.

Orr noted that the 6U8/6U8A and 6AZ8 tubes used in the KWM-2 had acquired a reputation for relatively short life. The 6EA8 was commonly suggested as a longer-lived substitute.

There was, however, one important exception: the tone oscillator.

Orr specifically warned that some 6EA8s would not oscillate in this circuit at all, while others could produce a distorted waveform. His recommendation was therefore to retain a 6U8/6U8A in that particular position.

After spending days wondering why five apparently serviceable tubes behaved so differently, it was rather comforting to discover that someone had described essentially the same problem almost fifty years earlier.

My tests had accidentally reproduced Orr's warning: five 6EA8s, all apparently reasonable tubes, produced everything from no oscillation to more than 200 Vpp.

Repeated tests with both the TV-2/U and TV-7/U produced consistent results but gave no simple explanation for these enormous differences. Apparently the operating characteristics that determine whether V2B has sufficient loop gain are not completely represented by the usual tube-tester measurements.

Collins Had Found Another Problem

There was one more piece of the puzzle. Collins Service Bulletin No. 10, issued for the KWM-2/2A, addresses VHF parasitic oscillations in the V2B tone oscillator. The later Collins circuit adds R215, a 47-ohm resistor, directly in series with the screen grid as a parasitic suppressor.

My KWM-2 did not have this modification, so I added it.

A curious previous observation then became meaningful. With a small socket extender inserted under V2 to make measurements easier, the behavior of the tubes changed substantially: the old 6U8A would oscillate under conditions in which some 6EA8s would not. After R215 was fitted, this extender-dependent behavior disappeared.

Even more significantly, the RCA tube #4 no longer produced its strong unwanted whistle in the loudspeaker.

The parasitic oscillation was therefore another real phenomenon, although it was not the principal cause of the original thermal failure.

More Than One Culprit

Looking back, I do not think there was a single defective component waiting to be discovered.

The original 6U8A was clearly marginal in this particular application. It still passed the TV-2 test, but as it warmed up its ability to sustain oscillation in V2B deteriorated dramatically.

The passive components probably contributed as well. Replacing the capacitors and resistors improved the oscillator margin enough that the old 6U8A no longer stopped completely. C51 remains particularly suspicious because of its position directly on the tube socket and its exposure to heat.

Finally, the missing Collins parasitic-suppression modification introduced yet another variable, especially when socket extenders or different tube types altered the circuit's stray capacitances and inductances.

The final solution was therefore not the satisfying replacement of one obviously defective component.

I left the Union 6EA8 in V2. It performs very well, the VFO remains perfectly stable, and the tone oscillator settles at approximately 140–150 Vpp at the plate after warming up.

Not every 6EA8 will work there. Bill Orr told us that in 1979.

TESTERS FOR THE TUBES THAT CHANGED THE WORLD

Why testing a tube is only the beginning of the story

By Giovanni Becattini

Tube testers, visible electronics and the rediscovery of vacuum tubes

T the TV-2/U is one of the most impressive military tube testers ever built. Testing a tube looks like a simple matter, but the word “good” hides many different questions.

A tube tester can reveal much about a tube, but it can never replace the actual circuit.

This article introduces some of the ideas explored in the book Tubes.

I must admit it: for a long time I considered testing vacuum tubes more a tiresome necessity than an interesting activity.

Something changed when I received a beautiful TV-2/U. With its intimidating military appearance, its meters, switches, knobs, sockets, and almost excessive sense of

AT A GLANCE

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- Testing a tube looks like a simple matter, but the word “good” hides many different questions.
- A tube tester can reveal much about a tube, but it can never replace the actual circuit.
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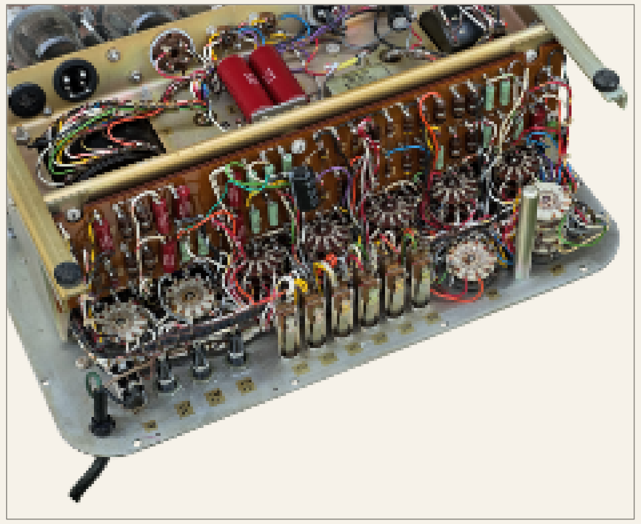


The TV-2 is well designed, and most components are easily accessible for inspection and servicing. The main exception is the central group of switches and potentiometers, which is considerably more difficult to reach. Convenient supports are built into the chassis, allowing the instrument to be placed safely on the workbench in several different positions while it is being serviced.

seriousness, the TV-2 touched my heart. It made me want to understand not only the tester itself, but also the tubes it was designed to test.

Of course, I already knew something about vacuum tubes. I had studied them, not very enthusiastically, at university. At the time they were considered “old stuff,” something belonging to a previous generation. Later, I met them again while repairing many pieces of classic electronic equipment: oscilloscopes, receivers, transmitters, audio amplifiers, signal generators, and other machines that still depended on glass, metal and heat to do their work.

But I had never really gone inside them. I had never looked closely enough at their history, their physics, their mechanical construction, and the very special way in which they turn invisible electric fields into useful behavior.

The TV-2 was the trigger. It made me want to understand everything I had always wanted to know and had never taken the time to study properly.

The adventure proved much more interesting than I expected. The technology of persuading electrons to perform the motions we wanted from them was called, quite naturally, electronics. Exactly as today.

The difference is that in modern semiconductor devices almost everything is hidden. In vacuum tubes, instead, the mechanism is still visible. You can see cathodes, grids, plates, supports, distances, materials, vacuum, heat, and electric fields translated into physical form. It is a technology so far removed from everyday practice that, for anyone willing to understand it, it can almost feel new again.

But let us proceed in order and return to our tube testers.

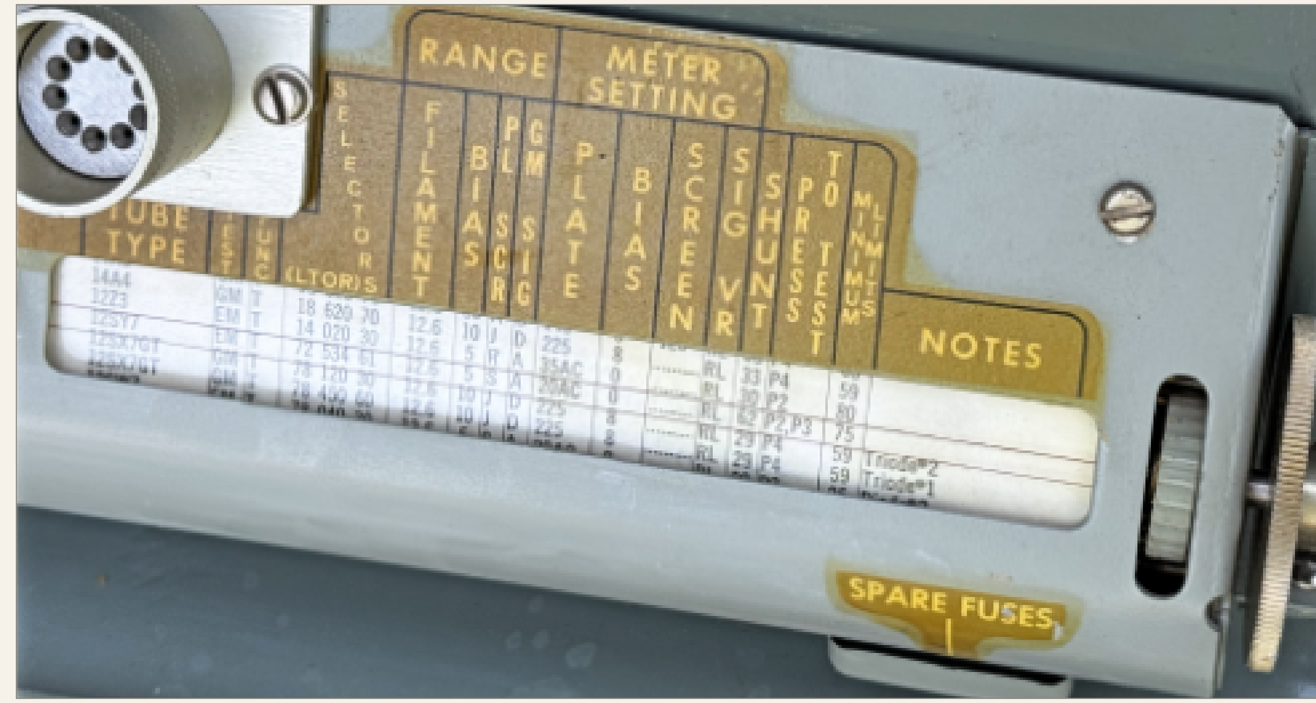
The TV-2 and the TV-7

Before the TV-2, I had already met tube testers twice.

The first was an old emission tester that had belonged to my father. Until I discovered mutual-conductance testers, I regarded it almost as the oracle of Delphi: its measurements were the truth.

TV-2/U IN BRIEF

- Type: portable dynamic mutual-conductance tube tester
- Tubes: receiving tubes and low-power transmitting tubes
- Supply: 103.5–126.5 V AC, 50–1,000 Hz
- Main test: transconductance, shown as percent quality
- Other tests: shorts, leakage, filament continuity, gas and emission
- Special tubes: rectifiers, voltage regulators, thyratrons, electron-ray indicators and ballast tubes
- Triodes: direct plate-current reading below 50 mA
- Maximum indication: up to 60,000 µmhos



Above: The Tube Test Data Roll Chart – The TV-2/U carries its tube-test data on a roll chart mounted inside the cover. The chart is divided into two sections, with tube types arranged in ascending numerical and alphabetical order. Repeated headings identify the tube type, the sequence in which the tester controls must be set, and the minimum acceptable percentage of rated transconductance to be read on the PERCENT QUALITY meter. For each listed tube, all required switch and control settings appear directly beneath these headings.

Later I also became familiar with the better-known TV-7/U, a much smaller and more portable military instrument. It is probably the tube tester most familiar to many collectors and radio amateurs, and it certainly deserves a story of its own.

But the TV-2/U is different. With its meters, switches, procedures, and almost theatrical seriousness, it does not merely give an answer. It makes the question visible.

We will return to the TV-7 in a future issue. For now, the TV-2 is the instrument that best explains why the question “Is this tube good?” is much less simple than it seems.

A vacuum tube can have a good filament and still be unusable. It can emit electrons and still have poor gain. It can look acceptable on a tester and fail in a real oscillator. It can suffer from gas, leakage, weak emission, low transconductance, thermal drift, microphonics, internal shorts, or simply from characteristics that are still within a generic specification but unsuitable for a particular circuit.

A tube tester therefore never asks every possible question. It asks a limited set of questions under controlled conditions, then reduces the answer to something a technician can use.

That was already a remarkable ambition.

A Closer Look at the TV-2

The TV-2/U is officially a portable dynamic mutual-conductance tube tester, designed for receiving tubes and low-power transmitting tubes. In practice, however, it is much more than a simple “good/bad” instrument.

Depending on the tube and on the selected test, it can check shorts, interelement leakage, filament continuity, gas, emission, transconductance, voltage-regulator tubes, gas rectifiers, thyratrons, electron-ray indicators, ballast tubes, and even small lamps. For some triodes, it can also measure plate current directly.

This explains much of its apparent complexity. A triode, a pentode, a rectifier and a thyratron are not different versions of the same problem. They are different devices, and the tester must ask each of them a different question.

In the mutual-conductance test, a small AC signal is applied to the control grid and the resulting change in plate current is measured. The result is shown on the PERCENT QUALITY meter as a percentage of the reference value specified for that tube.

This is already a more meaningful test than simple emission. Emission tells us whether the cathode can still supply electrons. Mutual conductance tells us something deeper: how effectively the grid can control that electron flow.

The TV-2 is fascinating because it makes this process visible. Before giving an answer, it asks the operator to establish meaningful operating conditions: filament voltage, bias, plate voltage, screen voltage, signal level, socket connections and electrode assignments.

It is still a tester, not the actual circuit in which the tube will be used. But precisely for that reason it teaches a useful lesson: before deciding whether a tube is "good", one must first know what question is being asked.

What Does "Good" Mean?

The most dangerous word in tube testing is "good." It looks innocent, but it hides too much.

A tube may be good for one circuit and marginal for another. It may work as an audio amplifier but fail as an RF oscillator. It may have adequate emission but poor transconductance. It may behave well when cold and drift as it warms up. It may pass a leakage test and still be noisy, microphonic, unstable, or simply wrong for a demanding position.

The question "Is this tube good?" should therefore always be followed by another question:

Good for what?

This is not a limitation of tube testers. It is a reminder that a tube is not an abstract component, but a physical device whose behavior depends on the circuit in which it is asked to work.

Once this is understood, tube testing becomes much more interesting. The meter reading is no longer a final verdict. It becomes evidence. It tells us something about emission, transconductance, leakage, gas, or some other measurable aspect of the tube. But that evidence must still be interpreted.

A tube tester and the actual circuit do not necessarily ask the same question.

That lesson becomes especially clear when a tube tests reasonably well, yet refuses to work properly in a demanding oscillator, RF stage, audio circuit, or regulator. At that point, the tester has not lied. It has simply answered a narrower question than the one the equipment is asking.

Tubes as Visible Electronics

Modern electronics is astonishing, but it is often invisible.

A microcontroller contains thousands, millions or billions of devices that we cannot see. Even when we understand the schematic, the physical structure remains hidden inside silicon. We interact with pins, packages, voltages, data sheets and development tools. The real action is microscopic.

A vacuum tube is different.

It is not simple, but it is visible. Its internal parts are large enough to be seen. Its function is directly related to its structure. A triode looks different from a pentode because it is different. A rectifier, a voltage regulator tube, a thyratron, an electron-ray indicator and a power output tube are not merely different symbols on a schematic; they are visibly different machines.

This visibility is one of the reasons tubes remain so compelling.

You can look at a tube and understand that electrons are emitted by the cathode, influenced by the grid and collected by the plate. You can understand why a screen grid changes the behavior of a tetrode or pentode. You can see why electrode spacing, support wires, mica spacers, getters, plate shapes and envelope size are not decorative details.

They are engineering.

This is also why tube testers are fascinating objects. They are machines built to interrogate other machines. They apply voltages, create operating points, measure currents, observe gain, reveal defects, and turn the invisible behavior of a tube into a pointer moving on a scale.

There is something wonderfully direct about that.

The Book Behind This Article

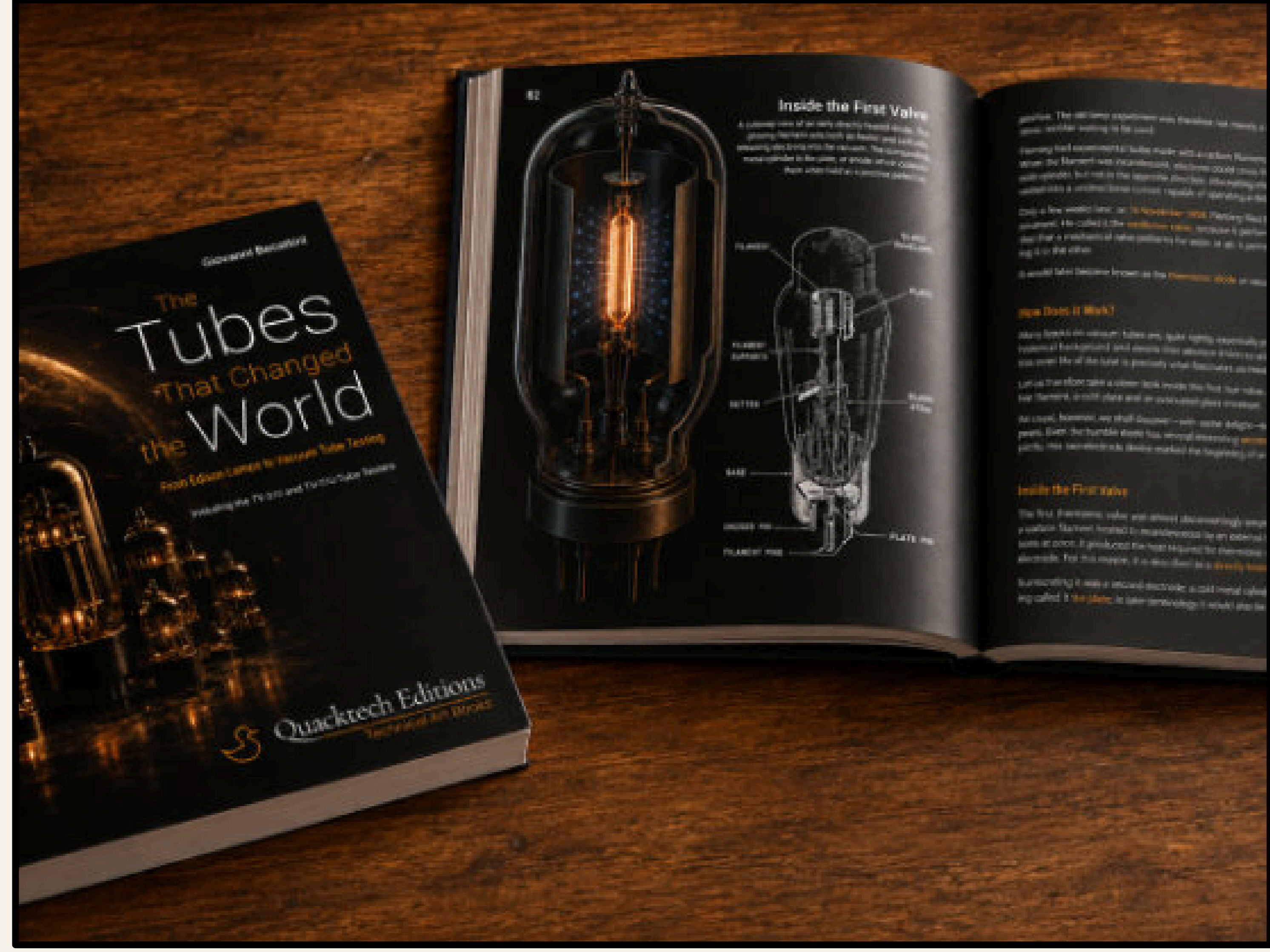
This short article began with a tube tester, but the real subject soon became much larger.

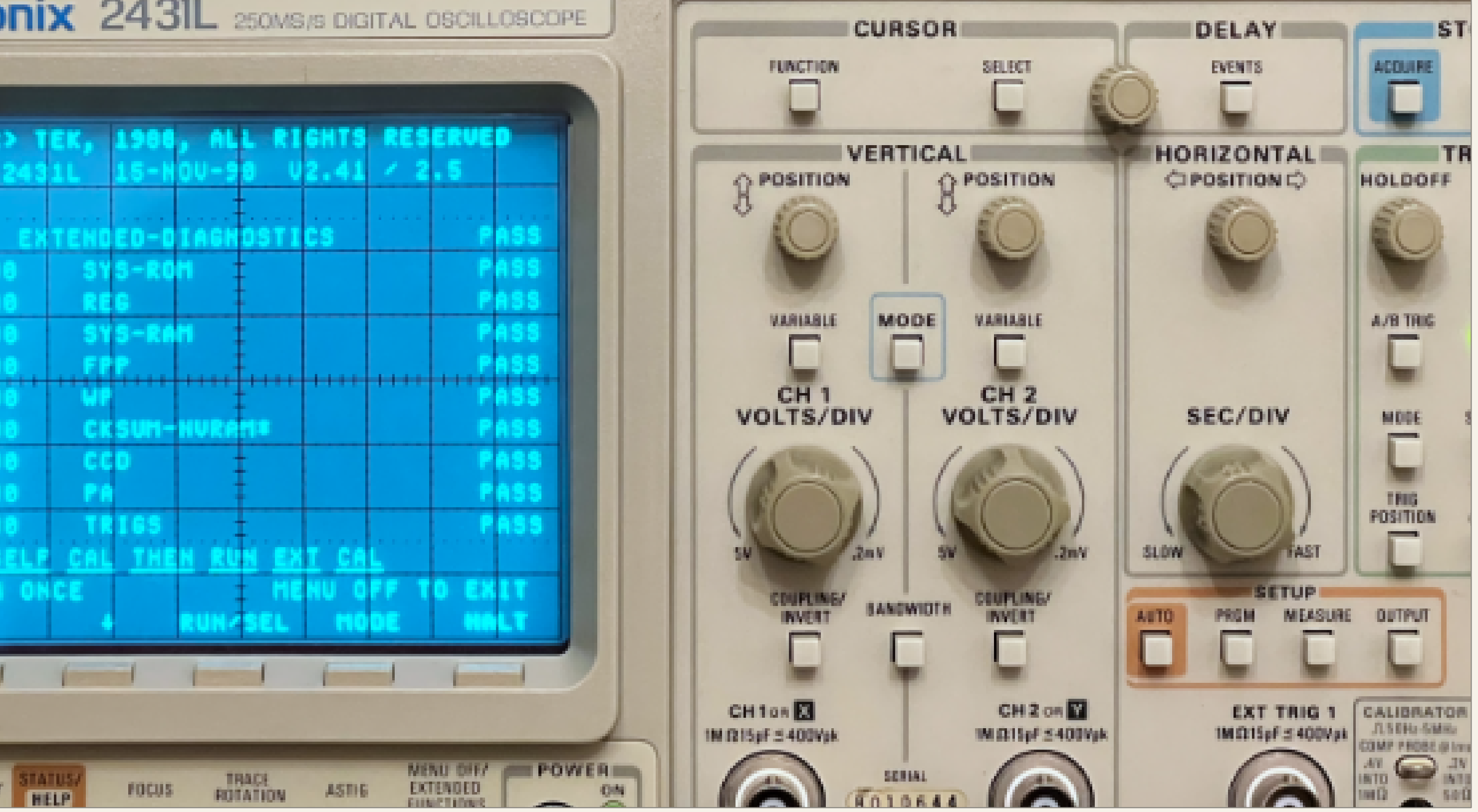
The TV-2/U made me want to understand tubes in a more complete way: their physics, their history, their applications, their strange beauty, and the instruments used to test them. The result was Tubes, a book devoted to vacuum tubes and to the many machines that made them useful.

The book is not intended as a nostalgic catalogue. Its purpose is to look at tubes as real engineering objects: devices made of materials, geometry, heat, vacuum and electric fields, capable of performing functions that shaped radio, television, radar, computing, instrumentation, audio and industrial electronics.

Tube testers are part of that story. They try to answer the practical question: "How good is this tube?" But the more interesting question is often deeper: how does this tube work?

That is the question that makes the subject worth exploring.





RIFA CAPACITORS
THEY KEEP EXPLODING

After all, is forty years really such a short life?

By Giovanni Becattini

The opportunity to talk about them comes from a Tektronix 2431L oscilloscope repair

The infamous RIFA capacitors keep exploding.

I try to keep my collection of vintage equipment in working condition, so from time to time I switch the various instruments on for a while. This gives electrolytic capacitors a chance to re-form and, where applicable, keeps internal rechargeable batteries from remaining completely discharged for long periods.

My **Tektronix 2431L** oscilloscope is a different case, however, because it is one of the instruments I still use regularly.

A few days ago, the poor thing suddenly produced a large cloud of bluish smoke. I switched it off immediately and opened it, although I already had a fairly good idea of what I was going to find: another RIFA capacitor had exploded.

AT A GLANCE

- RIFA capacitors are notorious metallized-paper capacitors widely used for EMI/RFI suppression.
- Today they may fail dramatically, often with a small explosion and a surprisingly large quantity of smoke.
- The case of a repair in the 1990 Tektronix 2431L oscilloscope.

TEKTRONIX 2431L

Left: The 1990 Tektronix 2431L is a curious example of product segmentation. Nominally, it was a low-cost version of the 2432A: 300 MHz bandwidth and 250 MSa/s sampling rate, but without delayed sweep, glitch capture, some rear-panel connectors, and with reduced autosetup and automatic-measurement capabilities.

The price difference was significant. In 1991, the top-of-the-line 2440 was listed at 12,390 USD, while the entry-level 2430A was 6,950 USD — down from 8,235 USD only a year earlier. The 2432A was listed at 10,335 USD, while the 2431L cost only 7,990 USD: 2,345 USD less, which was not bad at all.

The amusing part is that the 2431L appears to be essentially a 2432A. As far as I could determine, most of the differences are implemented in software. Yes, the rear panel lacks some BNC connectors, but the electronic circuitry is otherwise the same as in the 2432A.

To confirm my suspicion, I replaced the front panel with one from a 2430A, and the delayed time base magically appeared.

This does not make it a poor instrument. Quite the opposite: the 2431L is an excellent oscilloscope, and I still use and appreciate it very much.

RIFA capacitors are notorious metallized-paper capacitors that were widely used during the 1970s, 1980s and 1990s for EMI/RFI suppression. They were commonly connected directly to the AC mains as safety-rated X or Y capacitors and can be found in the power supplies of countless vintage computers, tape recorders, audio equipment and test instruments.

The classic RIFA capacitor is easily recognizable. It usually has a yellowish, whitish or transparent rectangular body, encapsulated in a hard epoxy resin.

Unfortunately, with age this resin tends to develop a characteristic network of cracks. Moisture can then penetrate the package and reach the paper dielectric. Its insulation resistance progressively decreases, leakage current increases, and the capacitor heats up. Eventually it may fail dramatically, often with a small explosion and a surprisingly large quantity of dense, acrid and distinctly unpleasant smoke.

For this reason, old RIFA mains capacitors are generally better replaced before they fail.

The appropriate replacements are modern safety-approved capacitors, normally metallized polypropylene (MKP), of the correct X or Y class. For a capacitor connected between line and neutral, as in the example described here, an X2-rated capacitor is normally used.

Safety capacitor classes such as X1, X2, Y1 and Y2 are internationally standardized by the IEC, in particular by IEC 60384-14.

X capacitors are intended for connection across the mains, typically between line and neutral. Their main purpose is to suppress high-frequency interference generated by the equipment and prevent it from being conducted back into the power line. Conversely, they also help prevent mains-borne interference from entering the equipment.

The distinction between X and Y capacitors is important. Failure of an X capacitor does not normally create an electric-shock hazard because it is connected across the supply rather than between the mains and an accessible part of the equipment. Y capacitors, on the other hand, are used between the mains and protective earth or other touch-accessible circuitry and therefore have considerably more stringent failure requirements.

The X2 subclass is intended for applications subject to impulse voltages of up to 2.5 kV. These capacitors are specifically designed and certified for continuous connection to the AC mains and to withstand the transients expected in such service.

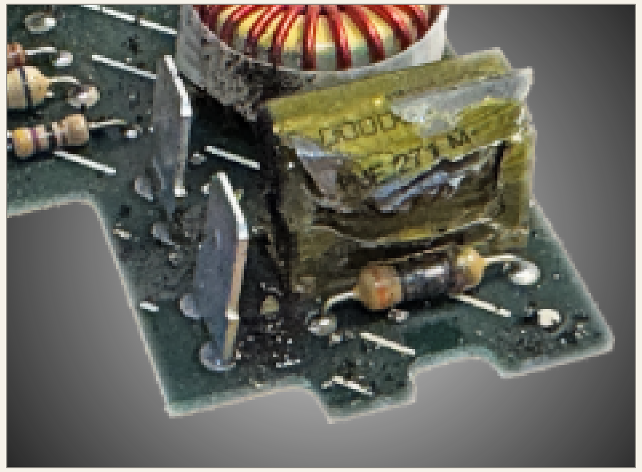


Photo: The exploded RIFA capacitor described in the text. Note that its failure also caused the 30 Ω resistor R882 to burn. This is a useful reminder of what the "safety" rating of an X2 capacitor actually means: it does not guarantee that its failure cannot damage other components. If the surrounding circuitry is not adequately protected, a failing capacitor may still create potentially hazardous conditions.

Modern X2 capacitors are generally made from self-healing metallized polypropylene film and are designed so that dielectric breakdown does not normally result in sustained arcing or fire.

Fortunately, X2 capacitors are inexpensive and readily available from electronic component suppliers — and even from Amazon, where RIFA capacitors are still sold. They have surely improved over the years, but can you blame me if I no longer trust them?

After all, is forty years really such a short life?

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WRITE TO US!

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Please send a short description of your proposed contribution before preparing a full article.

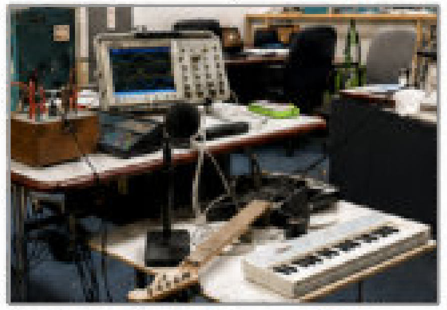
Whenever possible, send original high-resolution photographs, not compressed screenshots.

vintageTEK Museum

Preserving the Tektronix legacy

Preserving the instruments — and the people — that made Tektronix history.

The vintageTEK Museum is a nonprofit organization dedicated to preserving Tektronix instruments, technical documentation, and the remarkable stories of the engineers and innovators who shaped the world of electronic test and measurement.



A LIVING COLLECTION

Hundreds of instruments — from early vacuum-tube oscilloscopes to modern digital systems — are preserved and maintained for future generations.

HANDS-ON EXHIBITS

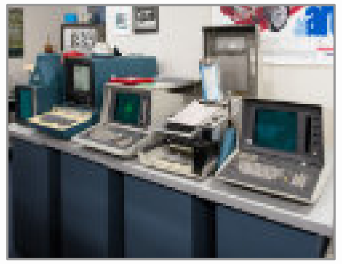
Volunteers keep the equipment working through demonstrations, restoration projects, education programs, and STEM outreach.

KNOWLEDGE & DOCUMENTATION

We preserve knowledge through our vast manual and microfiche archive, documentation, photos, stories and exhibits — ensuring the history of innovation is never lost.

MUSEUM FACTS

- **Location** Beaverton, Oregon, USA
- **Founded** 2010
- **Nonprofit** volunteer organization
- **Visit** – Saturdays and by appointment
- **Website** vintagetek.org



Founded in 2010, the museum opened in 2011 and moved in 2017 to Building 13 on the Tektronix campus in Beaverton, Oregon. We welcome visitors on Saturdays and by appointment.

VISIT · LEARN · SUPPORT

VISIT – Explore a unique collection of historic test instruments.

LEARN – Discover the innovations and people behind the instruments.

SUPPORT – Volunteer your time or skills to preserve the legacy.

> *"Our mission is to leverage the museum, website, and STEM outreach to encourage the next generation of engineers and scientists."*

vintageTEK museum

Learn more at **vintagetek.org**

THE ART OF THE POINTER

When current becomes motion

Above: the moving-coil mechanism. A few parts transform an invisible electrical quantity into visible motion.

Not every masterpiece of technical art has to be large, rare, expensive, or historically famous.

Sometimes it is enough to look at a simple analog meter.

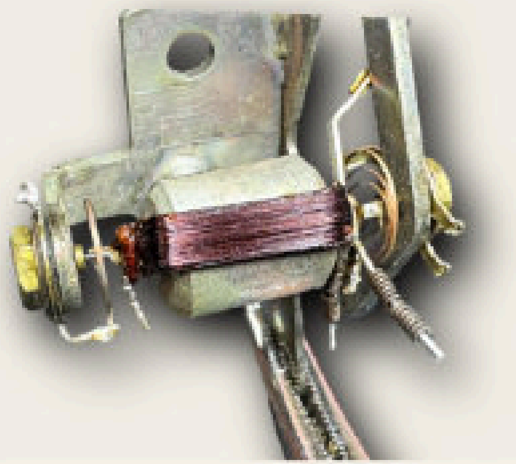
A scale, a pointer, a magnet, a coil, a spring, a few screws, and a carefully printed dial: almost nothing, compared with the complexity of a computer or an oscilloscope. And yet, in that small object, a complete idea becomes visible.

The electrical quantity is invisible. The instrument gives it form.

Old instruments remain fascinating because they do not merely display a number. They translate a physical phenomenon into motion, proportion, balance, and judgment. The pointer moves, settles, hesitates, overshoots, returns. The measurement becomes something the eye can follow.

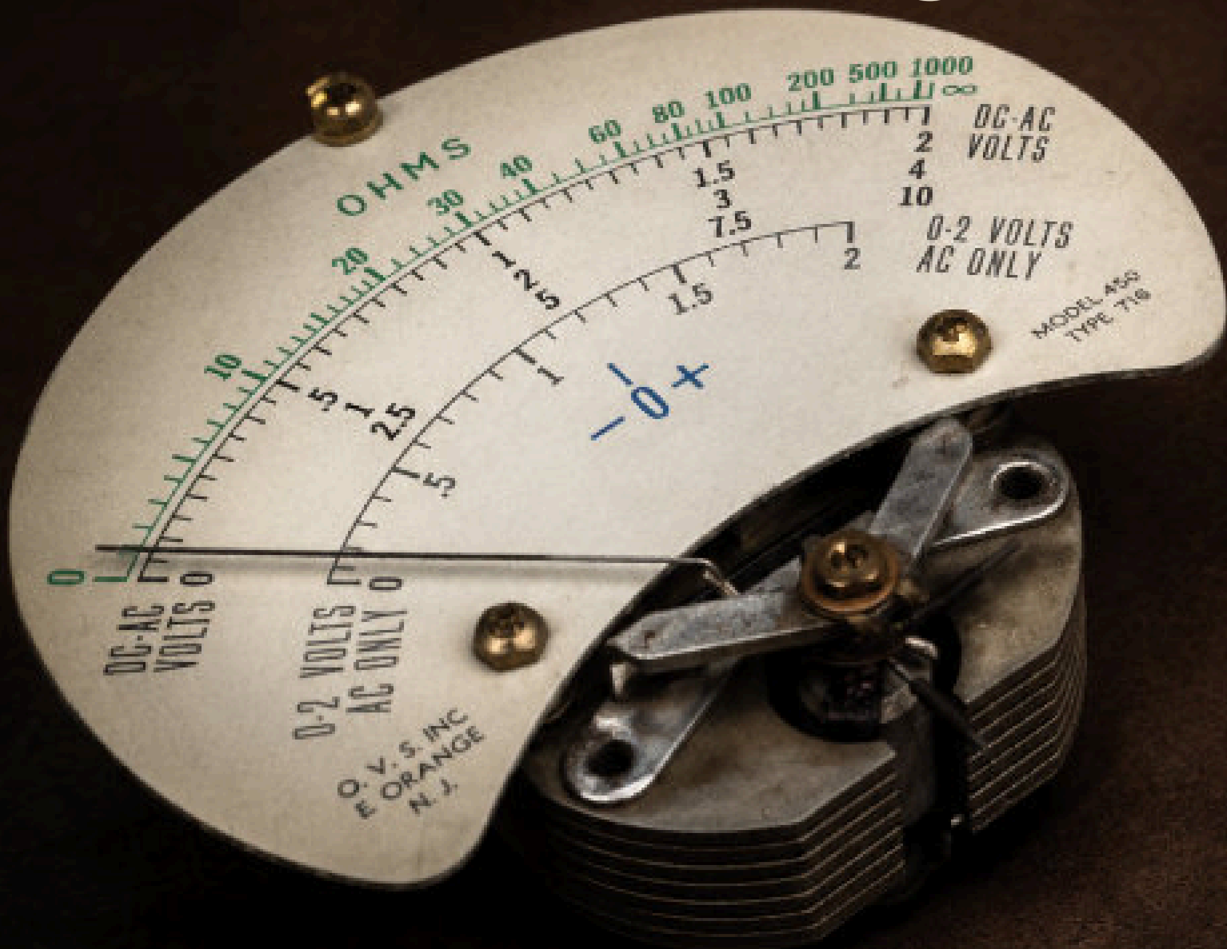
TECHNICAL ART CAN BE SMALL

- a readable scale
- a balanced pointer
- a mechanism that turns current into motion
- a useful object made beautiful by function



Technical art is also hidden in the ordinary instruments we have stopped noticing.

Revealing the *Art* Inside Technology



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