

Improve Performance of Your Octopus V/I Curve Tracer Using a Single Voltage Transformer

Perform in-circuit trouble shooting with this improved tester that provides selectable higher scanning voltages for testing.

Many hams enjoy experimenting with electronics and troubleshooting circuits. However, it is frustrating when we have no access to schematics or component identification, or when we need to remove the suspicious components from the board to check them individually. We might even finish by damaging the component or the board itself, or we might even get false readings with the multimeter, depending on the component. Fortunately, a simple and efficient way to overcome these problems has been around for decades. It consists in an electronic device connected to an oscilloscope. It has a number of designations, such as V/I (voltage/current) curve tracer, analog signature analyzer, component tester, oscilloscope test adapter, or simply “Octopus”. I constructed a basic Octopus after reading an article published by David Ludlow, W7QHX, in *QST*.¹ My device nicely accomplished the job with its single output of 1 V limited to 1 mA. As noted by David, the voltage and current are low enough for safe testing of almost any semiconductor circuit board assembly.

Recently I needed to check some unidentified Zener diodes and also a suspicious integrated circuit (IC) from my junk box, and required more optional voltages to trace possibly higher Zener voltages and IC junctions. After surveying the available literature, I found Octopus circuits using transformers with multi-tap voltages in the secondary. Because these transformers are hard to find, and re-winding

the secondary was out of question for me, I designed a simpler solution keeping my previous single-voltage secondary transformer by using multiple voltage dividers and current limiters. My Octopus had its range improved at an insignificant cost, and I got my junk box organized!

Octopus Basics

A curve tracer is a test equipment added to an oscilloscope — either digital or analog — that provides a graphical display of the V/I characteristic of an electronic component. It can be used to quickly check resistors, capacitors, inductors, semiconductors — both diodes and transistors — and, under some circumstances, integrated circuits.

The oscilloscope must have X-Y mode capability, which allows one channel to drive the horizontal amplifier (the X-channel), while the other (Y-channel) drives the vertical amplifier. The X-channel measures voltage, while the Y-channel measures current. This V/I testing permits an on-screen plot of I versus V. The device has a precise limited current applied to appropriate points on the device under test using common multimeter red and black leads. The measured voltage drop, current flow, and phase shift are plotted as the current versus voltage on the oscilloscope. The observed signatures, called Lissajous patterns, of known-good components or printed-circuit boards are compared with those of a suspect one. Unusual or unexpected signatures

indicate a potential problem. There are four fundamental components signatures: resistive, capacitive, inductive and semi-conductive. Recognizing and interpreting these four basic signatures is crucial to successful Octopus utilization.

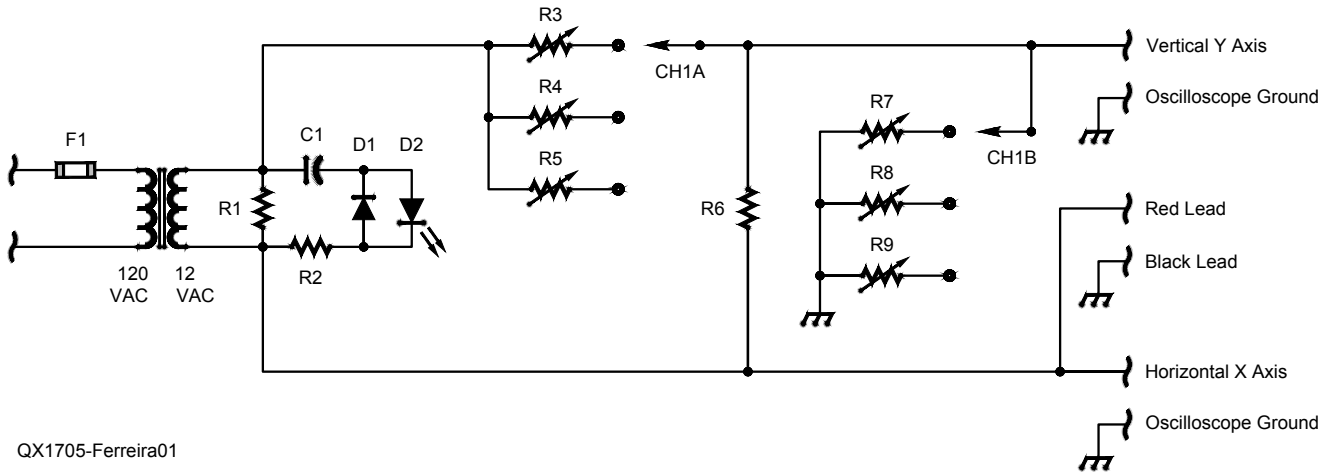
In-circuit tests are generally possible in many cases. However, complex Lissajous figures from resistors, capacitors and inductors connected to semiconductors can also be produced. In this case, we disconnect one terminal of the device under test (DUT) from the circuit. Once we are familiarized with Octopus operation, we can create a file of the measured Lissajous patterns of both normal isolated and in-circuit components for future comparisons.

Please keep in mind, the components, as well as the board itself must not be connected to the ac mains line or to a battery. No signal inputs are recommended. Remove all unnecessary cables from the equipment under test and disconnect any other line or electrical source.

A in-depth discussion of V/I testing and signature analysis is beyond the scope of this article, but very good overviews are available.^{2,3} Descriptions of oscilloscope X-Y modes may be found in ARRL publications.^{4,5}

Assembly and Settings

This Octopus V/I curve tracer supports three output voltages: 1 V ac, 5 V ac, and 10 V ac, each at about 1 mA. Figure 1 shows the circuit schematic diagram. Figure 2 shows



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Figure 1 — Schematic diagram of the improved Octopus.

C1 — 470 nF, 400 V, ceramic capacitor
CH1 — Rotary switch, 2 poles, 3 positions
D1 — 1N4004 silicon diode or similar
D2 — Red LED
F1 — 1 A fuse and support
R1 — 1 k Ω ¼ W film resistor
R2 — 1 M Ω ¼ W film resistor

R3, R8, R9 — 10 k Ω variable resistor (trim pots)
R4, R5 — 2.2 k Ω variable resistors (trim pots)
R6 — 220 Ω ¼ W film resistor
R7 — 100 Ω variable resistor (trim pot)
R10 — 1 Ω ¼ W film resistor, or an approximate value

R11 — 50 Ω ¼ W film resistor, or an approximate value
T1 — 120 V ac primary, 12 V ac secondary, 500 mA transformer
 Various mechanical components, cables, and housing according to builder's preference.

a suggested PC board layout parts placement for the trimmer resistors, and Figure 3 shows a suggested component placement on the PC board that connects to the transformer and the ac mains. Neither of the PCB layouts nor the placement of components is especially critical. The components are commonly available and other component values may be substituted depending on your needs.

You will also need a multimeter with millivolts ac capability (or use the oscilloscope), a 20-30 W soldering iron, a drill for making the PC board holes, and various hand tools.

I started by assembling a rigid support for the 120 V ac input in a plastic box. I made a small circuit board, Figure 3, which was fixed to the bottom of the plastic housing using small screws and plastic separators. The board contains the connections to the LED red pilot, D2, and the wires of the transformer.

The switch CH1 must have at least 2 poles, A and B, and 3 positions (1 V, 5 V, 10 V) for a total of 6 taps connected to each of the 6 trimmer resistors. With your multimeter, identify and note which taps connect with the switch poles CH1A and CH1B in each one of the three positions. For practical purposes, I call CH1A the pole connected to voltage dividers (pole A) and CH1B, the pole connected to current limiters (pole B). Don't solder any wire to CH1 just yet.

Setting the voltage ranges

Solder the components on both PC boards and, then solder the 12 V ac wires into the Octopus board input. Don't connect any more wires at this time. Now, set the intended

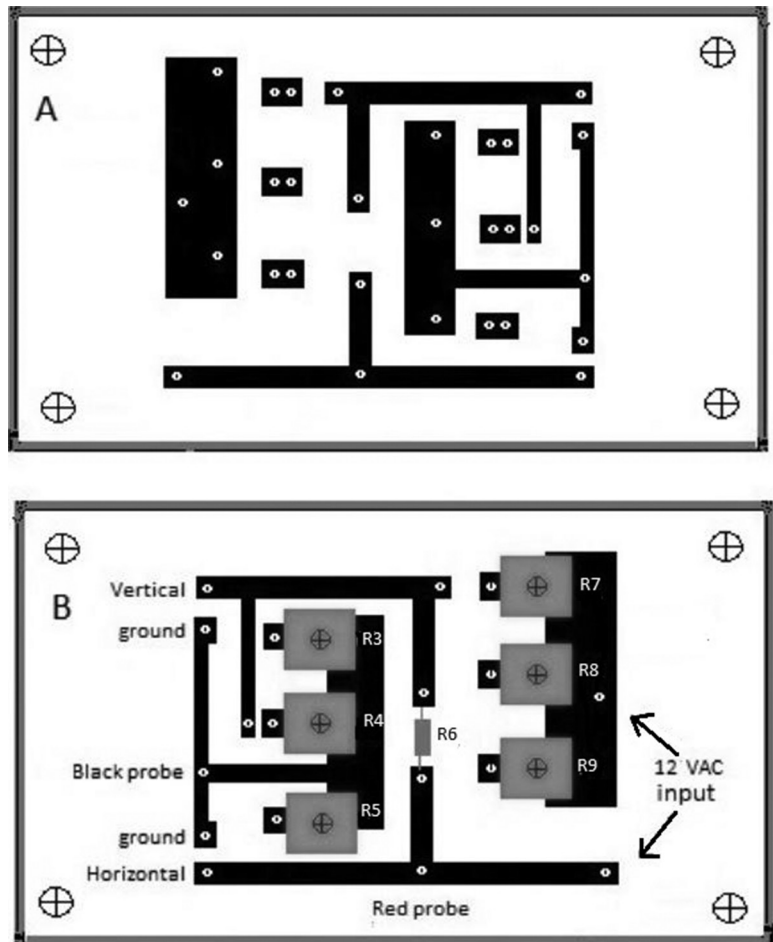


Figure 2 — Main PC board suggested layout.

output voltages following these steps.

(1) – Check to make sure that you have 12 V ac at the Octopus input. If so, solder a temporary jumper between CH1A and R3.

(2) – Set the variable resistor R3 for 1 V ac between the red and black lead outputs on the PC board. Then disconnect the temporary jumper from R3.

(3) – Connect the jumper from CH1A to R4. Set R4 for 5 V ac. Then disconnect the temporary jumper from R4.

(4) – Connect the jumper from CH1A to R5. Set R5 for 10 V ac. Then disconnect the jumper from R5 and keep it to CH1A.

Setting the current limits

Temporarily, make a sub-circuit shown in the dashed outline in Figure 4. On the PC board solder R10 to the red lead connection point and solder R11 in the black lead connection point. R11 will serve as a 50 Ω load for ac current readings. Set your multimeter to the millivolts ac scale, or use your oscilloscope for the measurement. Make sure the instrument is in parallel with R10. Since R10 is 1 Ω, then a voltage of 1 mV you read across R10 corresponds to a current of 1 mA.

(5) – Connect a jumper from CH1A to R3, and another jumper from CH1B to R7. Set R7 for approximately 1 mA (1 mV meter reading). When done, disconnect the jumpers from R3 and R7.

(6) – Connect the jumpers from CH1A to R4 and CH2B to R8. Set R8 for approximately 1 mA calculated through R10 (1 mV meter reading). Then disconnect the jumpers from R4 and R8.

(7) – Connect the jumpers from CH1A to R5 and CH2B to R9. Set R9 for approximately 1 mA calculated through R10 (1 mV meter reading). When done, disconnect these jumpers and the sub-circuit shown in dashed line of Figure 4.

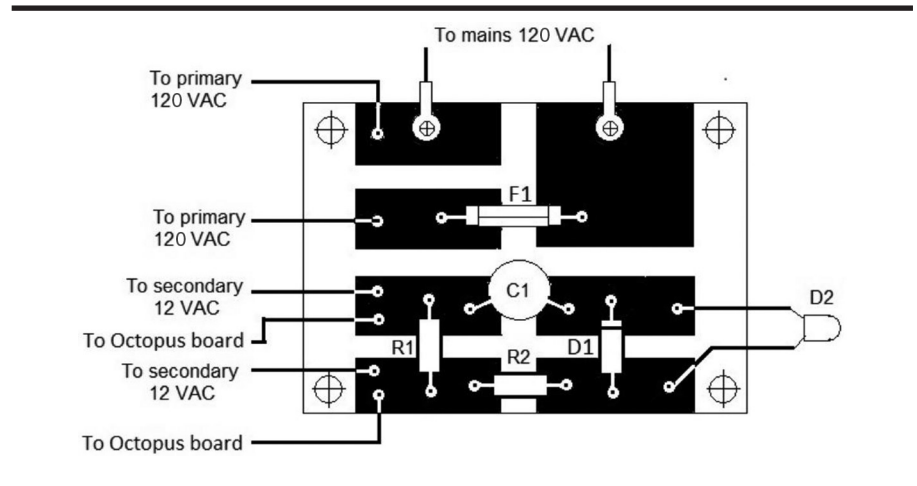
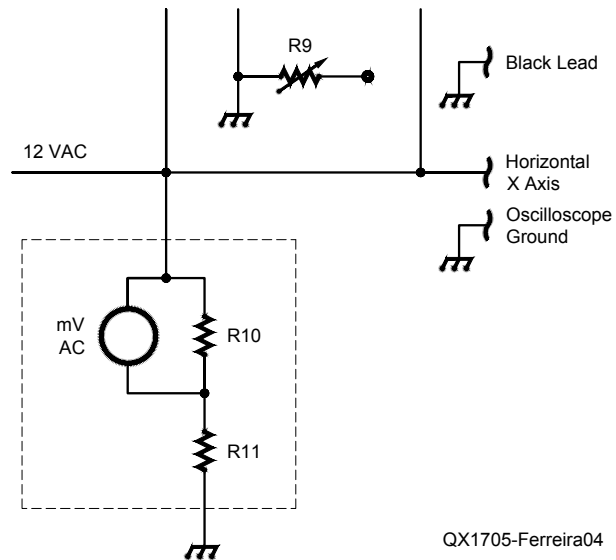


Figure 3 — Smaller PC board suggested layout.



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Figure 4 — Temporary sub circuit designed for setting the Octopus output ac current limits.



Figure 5 — Internal view of the assembled Octopus.

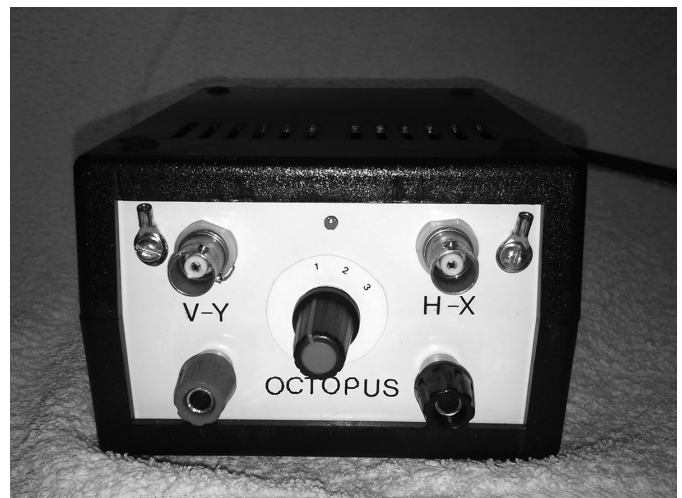


Figure 6 — Front view of the assembled Octopus.

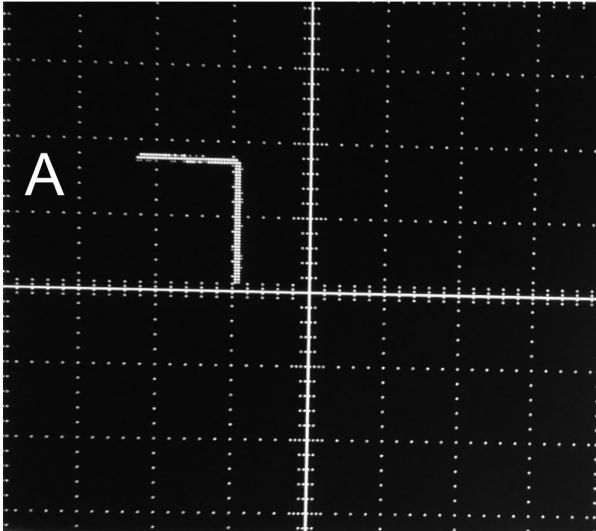


Figure 7A — I-V pattern for a 7V Zener diode with a 1 V sweep.

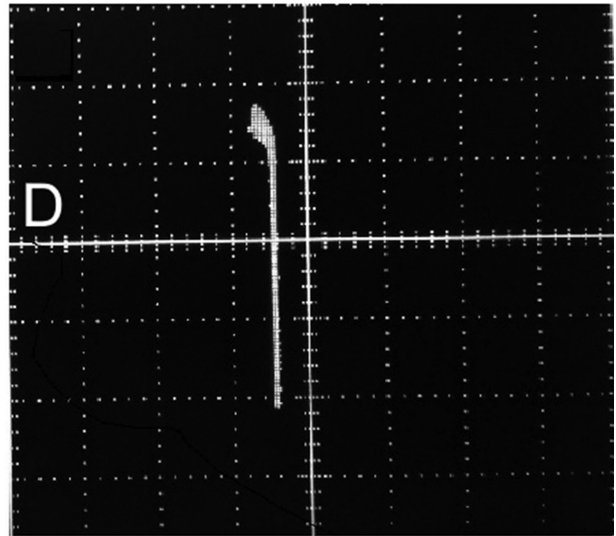


Figure 7D — I-V pattern for a healthy IC using a 1 V sweep.

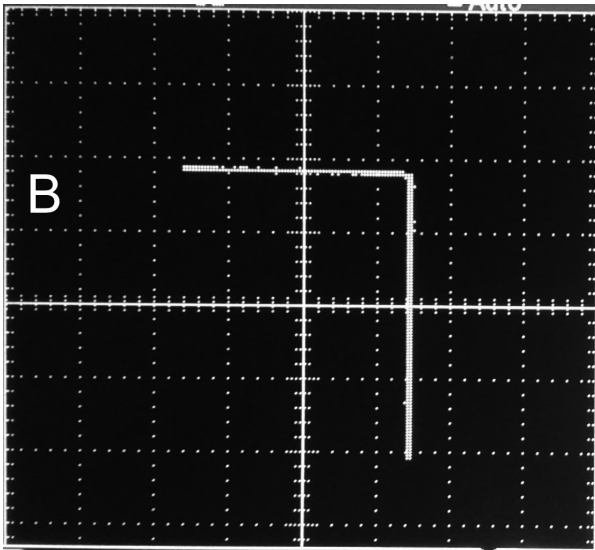


Figure 7B — I-V pattern for a 7V Zener diode with a 5 V sweep.

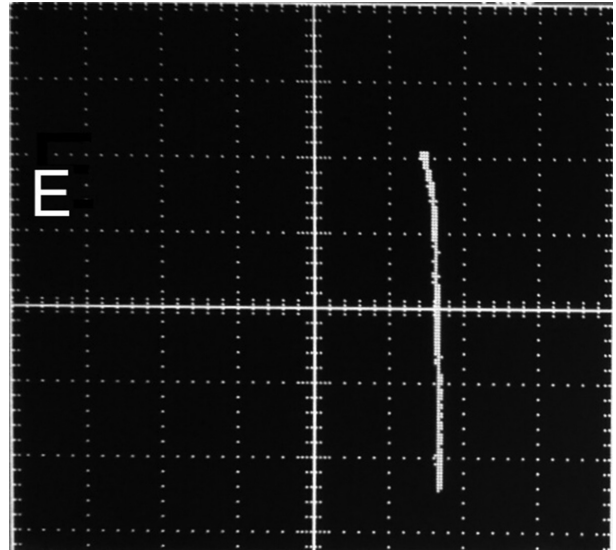


Figure 7E — I-V pattern for a damaged IC using a 1 V sweep.

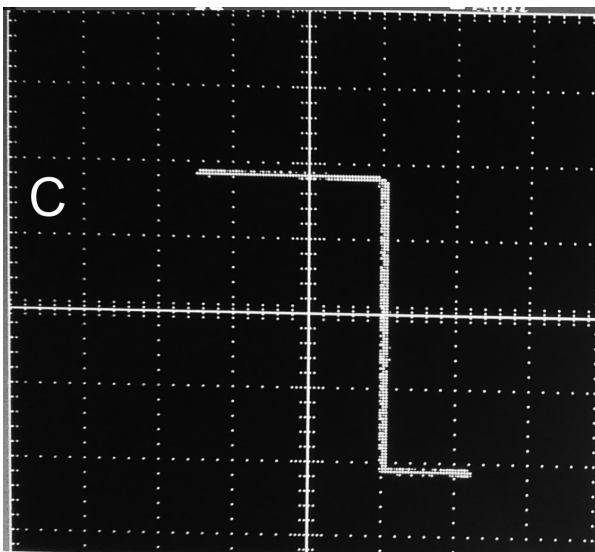


Figure 7C — I-V pattern for a 7V Zener diode with a 10 V sweep.

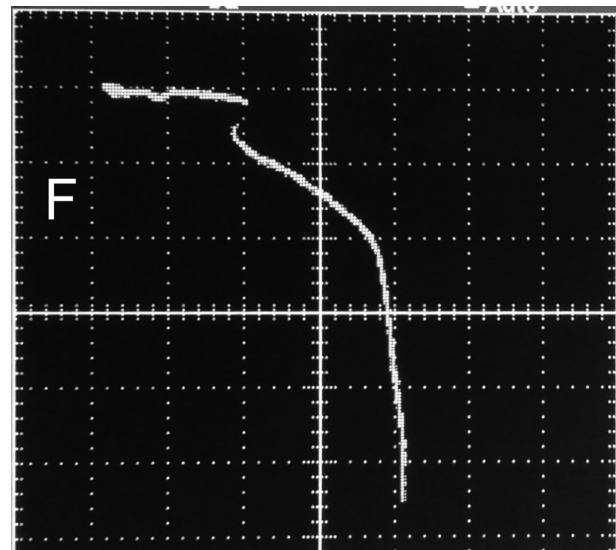


Figure 7F — I-V pattern for a damaged IC using a 5 V sweep reveals a distorted response.

Final Assembly

Once you have finished your PC board and set all the voltage and current limits, solder the connections from the CH1 poles to the respective sites on the PC board using different color wires. In position 1 (1 V selection), CH1A connects to R3 and CH1B, to R7. In position 2 (5 V selection), CH1A connects to R4 and CH1B to R8. In position 3 (10 V selection), CH1A connects to R5 and CH1B to R9. Install everything into the plastic housing, as seen in Figure 5.

Install the BNC connectors, and prepare two coaxial cables for connection to the oscilloscope. Figure 6 shows the front panel of the fully assembled Octopus.

Beyond 1 V

Set your oscilloscope to the *X-Y* mode and connect it to the Octopus. Set the Octopus to the 1 V position. Connect a 7 V Zener diode for testing. Try increasing the voltages from 1 to 5 and 10 V ac positions by rotating CH1 and observe how the *I-V* curves vary. Figure 7A shows the *I-V* response for the 7 V Zener diode with a 1 V sweep limited to 1 mA current. Figure 7B shows a sweep using 5 V ac limited to 1 mA, and Figure 7C shows a 10 V ac sweep with a 1 mA limit, which reveals the full performance of the diode. Clearly, the 7 V Zener diode cannot be properly evaluated using just the 1 V sweep.

A 1 V sweep of pin 5 referenced to ground

of a 555 IC is shown for a known good IC (Figure 7D) and a damaged IC (Figure 7E), but not much difference is evident. However, distortion is evident in Figure 7F on a 5 V sweep of the damaged IC

Now that you have your Octopus working, be sure to consider component voltage and current limitations before exposing components to different voltage values.

In Conclusion

The Octopus curve tracer is one of several ways available to test electronic components. The device described here is a simple alternative to get three different voltage ranges using a single secondary output transformer. Don't forget to disconnect the ac mains line or battery of the board under test, and don't overlook component voltage and current tolerances and limitations. With some practice, experience, and research you will be able to correctly interpret the measured Lissajous patterns.

Acknowledgment

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Paulo Renato F. Ferreira, PY3PR, is a radiation oncologist in Porto Alegre, RS, Brazil. He earned the MD and PhD degrees in Medicine. An ARRL member; he was first

licensed in 1979 at age 22 and now holds an Amateur A class license. Paulo has written technical contributions for QST, QSP (a Portuguese publication), Eletronica-Popular (a ceased Brazilian publication) and some web pages. His main radio interests are low-band DX, experimenting with homebrew antennas, analog electronics, CW rag-chewing and CW contests. He also enjoys bicycling and seashore fishing in Xangri-lá, RS, where he also has his Amateur Radio station.

Notes

¹D. Ludlow, W7QHX, "The Octopus", *QST* Jan 1975, pp 40-42.

²A. Lowne, "An analog signature analysis primer", www.electronicproducts.com/Test_and_Measurement/Benchtop_Rack_Mountable/An_analog_signature_analysis_primer.aspx.

³Huntron, Inc. "Fundamentals of Signature Analysis. An In-depth Overview of Power-off Testing Using Analog Signature Analysis", www.huntron.com/corporate/docs/ASA-paper-extract.pdf.

⁴*The ARRL Handbook Book*, 2017 Edition. ARRL item no. 0635 (hardcover) or 0628 (soft cover), available from your ARRL dealer, or from the ARRL Store, Telephone toll-free in the US 888-277-5289, or 860-594-0355, fax 860-594-0303; www.arrl.org/shop/; pubsales@arrl.org.

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