PRACTICALLY SPEAKING ... Joe Carr K4IPV

building the "poor man's spectrum analyzer"

In September 1986 an exciting article on spectrum analyzers appeared in *ham radio* ("Low-Cost Spectrum Analyzer With Kilobuck Features," page 82). Having been in both communications servicing and engineering school, I'd used spectrum analyzers, but never owned one. (Most professionals can't afford them.) I once considered purchasing a plug-in spectrum analyzer to fit our existing biomedical electronics laboratory oscilloscope mainframe, but it cost over $12,000! Then came W4UCH and his article on the very affordable WA2PZO/Science Workshop "Poor Man's Spectrum Analyzer."* I decided to build my own spectrum analyzer.

The WA2PZO concept is based on the fact that modern TV tuners, especially the "cable-ready" variety, are varactor-tuned. The familiar switched inductor tuner is replaced by a voltage-tuned varactor oscillator. Two types are available: one, which was used in the W4UCH article, has separate low-VHF, high-VHF, and UHF bands. A switch is used to select band coverage. The second is a wide-range "cable-ready" tuner that tunes from low VHF through UHF television bands in one 0-35 volt (some are 0-30 volt) range. Obviously, if you can modulate the tuning voltage with a sawtooth waveform (see "Practically Speaking," January, 1987, page 89), then you have a swept tuner. Demodulate its amplified i-f output and display it on a 'scope, and you have a spectrum analyzer. Sheer genius! I bought both forms of tuner from Science Workshop; **fig. 1** shows the cable-ready, wide-range model.*

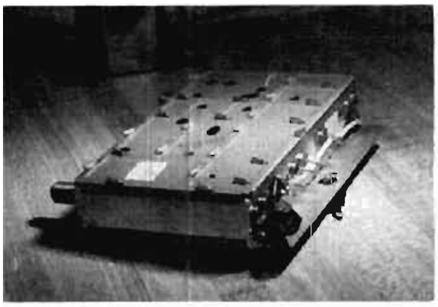

fig. 1. Wide range, L-VHF/H-VHF/UHF, voltage-tuned "cable ready" TV tuner used by the author.

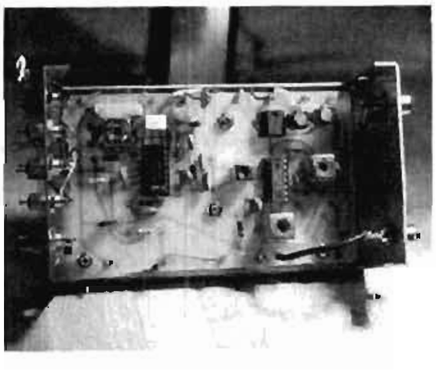

fig. 2. WA2PZO/Science Workshop I-f board built into shielded box.

*WA2PZO, *Science Workshop*, P.O. Box 393, Bethpage, New York 11714

The i-f board used in the W4UCH article and sold by Science Workshop is shown in **fig. 2**. The term "i-f" used here actually means a fixed frequency, single-conversion superheterodyne fm receiver tuned to 45.75 MHz (the tuner's i-f output frequency), and down-converted to the standard 10.7 MHz used for fm receiver i-f amplifiers. Because the i-f strip is actually a single-conversion receiver, the overall spectrum analyzer is a dual-conversion superhet. In fact, it can be used as a VHF receiver if the sweep is turned off (see *Sweep On/Off* in **fig. 3**).

The literature that came with the i-f board suggested that it be well shielded, and that feedthrough capacitors be used on all leads except the i-f input. The shielded enclosure is a standard chassis box with foldover flanges. Beware of many "shielded boxes" now on the market. The flanged type shown in **fig. 2** is minimally acceptable for shielded projects. The type of box that doesn't have overlapping flanges isn't acceptable at all. Some LMB boxes use little dimples on each edge for support, so they won't provide adequate shielding for most rf projects. While they're fine for audio and DC projects, they leave a great deal to be desired at rf.

Being an "older guy" in radio, I still called the feedthrough capacitors by that name and had a difficult time finding them locally; it seems that they're now called "EMI filters." Luckily, a local number for Newark Electronics was listed in the Yellow Pages, so I was able to buy them directly from the source called for in the article.

In retrospect, "next time" I might try using a single connector for all leads other than the i-f, and 0.002-μF disk ceramic capacitors on each lead at the connector. A good chassis-mounted connector costs about $5 (or less), and high quality disk capacitors cost only about 80 cents each and even less per unit in bargain packs. The EMI filters called for in the article are about $4 each; about 12 are required.

adding a sweep circuit

A significant problem with the W4UCH article for many readers is the lack of a sawtooth circuit. W4UCH used the sawtooth output of his Heath OL-1 oscilloscope to sweep the tuner. That approach works if your oscilloscope provides this waveform. But modern oscilloscopes rarely have the sawtooth available on the front or rear panels. Also, many don't have a horizontal input. Look at your own oscilloscope's front panel. Some two-channel oscilloscopes have an "X-Y" mode on the vertical selector. If yours does, then one of the vertical channels can be re-configured as a horizontal channel at the flick of a switch.

If you don't have a horizontal input, or X-Y capability, you can still build the "Poor Man's Spectrum Analyzer" if you have either an "EXTERNAL TRIGGER" input (most 'scopes do) or a "TRIGGER GATE" output. The former allows an external signal, such as the falling edge of an external sawtooth, to trigger the sweep. The latter outputs a narrow pulse every time the oscilloscope triggers. By allowing the 'scope to self-trigger, you get a string of pulses that can be used to trigger certain types of sawtooth generators.

Science Workshop makes a board available (**fig. 3**) that can be used for generating and controlling an external sawtooth. Although it suffices at this point, I'm not totally happy with the design. As I see it, there are two problems (see **fig. 4**): first, the sawtooth isn't very linear (see **fig. 4A**), and its fall time is too long. Second, the sawtooth clips at various settings of the center frequency and sweep rate controls. Perhaps in the future I'll find time to re-design these circuits, but for now the sawtooth board is satisfactory.

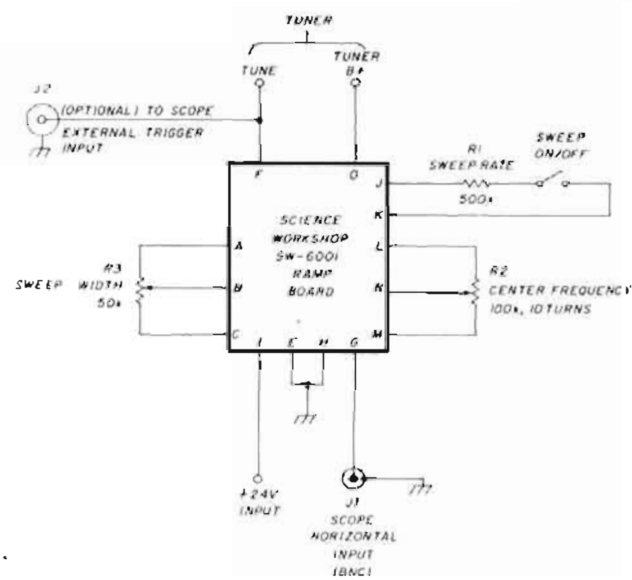

fig. 3. Sweep board SW-6001 connections (available from Science Workshop).

dc power supply

The Poor Man's Spectrum Analyzer requires a two-voltage, single-polarity dc power supply: +12 VDC and +24 VDC. The schematic diagram of a power supply that meets these requirements is shown in **fig. 5**.

I used a pair of small 12.6-VAC transformers (T1 and T2), with the primaries connected in parallel and the secondaries connected in series, to obtain the required voltage. I used available components — a pair of brand-new *Radio Shack* pc-mount transformers. You can use instead either a 25.6-VAC transformer or a dual-secondary transformer stocked by Digi-Key.* Dick

*Digi-Key Corporation, P.O. Box 677, Thief River Falls, Minnesota 56701.

fig. 4. Waveforms from SW-6001: (A) Mid-range sawtooth. (B) and (C) are sawtooths taken at extremes of CENTER FREQUENCY and SWEEP RATE controls.

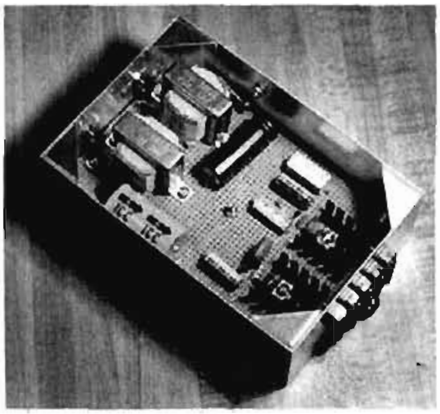

fig. 5A. DC power supply: top view of perf-mounted assembly.

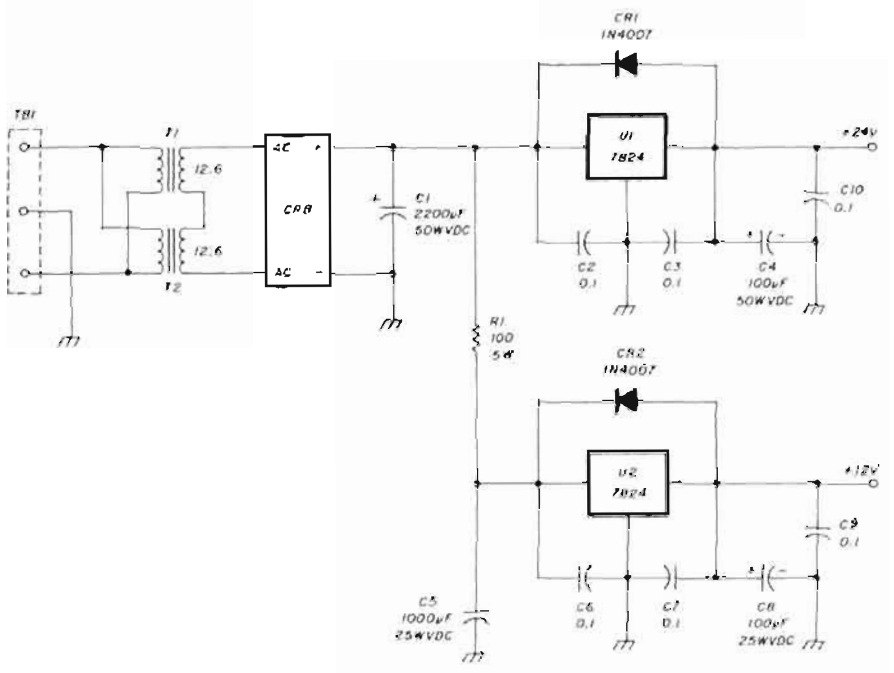

fig. 5B. DC power supply schematic.

Smith Electronics,** and other distributors. The current requirements for this project aren't critical, so almost any transformer with a rating of 300 mA or more is acceptable.

Two three-terminal IC regulators are used in this project. The 7824 (also usable: LM-340T-24) provides the needed +24 VDC, while a 7812 (or LM-340T-12) provides the +12 VDC. Both regulators are standard, but I found that the 7824 was a little hard to find locally. The NTR line of replacement semiconductors, stocked by many local distributors, carries a good replacement number.

There's nothing critical about the parts layout, and perf board can be used for construction. The diodes (CR1 and CR2) are used to prevent the charge in the output capacitors from damaging the voltage regulators at turn-off. Don't delete them, even though you may see many circuits using these regulators without charge dump diodes. The shielded construction and the 0.1-µF output capacitors are needed because one might be using this device in close proximity to a high-power transmitter. The capacitors must be mounted on the output terminal, or at least as close as physically possible.

performance

Figure 6 shows an oscilloscope photo of the spectrum analyzer display. The center frequency was adjusted to the low end of the fm broadcast band. The large center spike is the signal from my Measurements Model 80 signal generator set to approximately 85 MHz. The small spike to its right is WAMU-FM (88.5 MHz), my favorite public radio station; the other spikes are other fm band signals. The large signal barely visible on the left side is, I believe, Channel 5 TV in Washington, DC.

Those who don't have a horizontal input must use the sawtooth to trigger the sweep through the EXTERNAL TRIGGER input. I recommend using the negative trailing edge of the sawtooth waveform for this purpose (set TRIGGER SLOPE — or equivalent switch — to the negative position). Also, be sure to make the sweep time across the entire horizontal aspect of the 'scope graticule equal to the period of the sawtooth leading edge. Otherwise, the 'scope and sawtooth won't sweep in sync.

future projects

The spectrum analyzer project has given me a few ideas for changes or improvements. First, I plan to redesign the sawtooth generator (possibly generating the sawtooth digitally). Second, I plan to add an amplifier/attenuator based on Mini-Circuits fixed attenuators and a Signetics NE-5205 amplifier.[1] The range will be -60 to +19 dB. Third, there may be a converter for hf, and tuners to band-limit the spectrum analyzer at will to certain VHF Amateur bands. This modification will punch out certain local signals that tend to drive receivers into intermod problems at my QTH. Fourth, WA2PZO is working on a tracking oscillator circuit, and in fact has a tentative approach to its design. A tracking oscillator produces an output at the spectrum analyzer's center frequency. Besides its obvious use as a signal source, it's also useful for driving a frequency counter. Presently, tuning indication is by seat-of-the-pants calibration of the voltage control. I plan to buy the WA2PZO tracking oscillator kit if, and when, it becomes available.[3]

Varactor tuners are inherently non-linear in their voltage-vs-frequency

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fig. 6. FM broadcast band signals from my spectrum analyzer project. Central spike is a signal generator on 85 MHz (± 25-year-old dial calibration).

characteristic and the resulting curve looks parabolic in shape. Digitally generating the sawtooth signal is a worthwhile consideration. If you want to try it yourself, write to me and I'll send you a brief on the method. (Please enclose a No. 10 SASE.) A very brief discussion of the digital linearization method is given on pages 300-302 of my book, *How to Design and Build Electronic Instrumentation*.[2] Although my method is based on discrete logic circuits, it can easily be applied to digital computers should you want to provide computer control of your spectrum analyzer.

conclusion

WA2PZO deserves accolades (and our business) because of the Poor Man's Spectrum Analyzer project, which offers opportunity for experimentation in areas previously closed to Amateurs solely for reasons of cost. If you have an idea for its use, a new or different modification, or a particularly well-built version of the W4UCH/WA2PZO project, send me the details.

references

1. Michael E. Gruchalla, "NE-5205 Wideband RF Amplifier", *ham radio*, September, 1986, page 30.
2. Joe Carr, K4IPV, *How to Design and Build Electronic Instrumentation*, Second Edition, Tab Books, Blue Ridge Summit, Pennsylvania 17214. ($17.95 from the author, publisher, or Ham Radio's Bookstore, Greenville, New Hampshire 03048. Add $3.50 shipping and handling for HR Bookstore orders.)
3. For ideas on building your own, see also Wayne Ryder's "Spectrum Analyzer Tracking Generator," *ham radio*, September, 1978, page 30.

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