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BUILD A 5- TO 850-MHz SPECTRUM ANALYZER

Low-cost TV tuners make this project a snap!

A spectrum analyzer can be a useful and helpful tool. It lets you look at any part of the RF spectrum and see at a glance just what signals are there. Normally, a good used or new spectrum analyzer would run over a thousand dollars—placing it out of the reach of most pocketbooks. But, by using commonly available varactor-tuned TV tuners, you can put one together with ease!

A major cost component is represented by the CRT display section. If you already have a good shop scope with DC coupling and XY inputs, you have half of a spectrum analyzer already in hand. By adding a CATV tuner and a UHF TV tuner, along with some simple support circuitry, you can cover from 5 to 850 MHz in two bands! The block diagram is shown in **Figure 1**. Either tuner can be selected, and its output amplified by the 62-MHz IF strip and detected. The detected signal feeds the vertical (Y) input of the scope. The tuners are swept across their tuning range by a sawtooth waveform generator that's also used to drive the scope horizontal (X axis) input.

More about TV tuners

Photo A shows a typical CATV tuner module. These devices can be found surplus at very low cost. You can also salvage suitable tuners from discarded cable-ready TV sets that have electronic tuning. In **Figure 2**, I show a block diagram depicting what goes on inside one of the CATV tuners. The input signal first passes through a high-pass filter with a cutoff at 40 MHz. A low-pass filter limits signals above 500 MHz. The internal VCO is used to up-convert signals in this passband to a fixed first IF at 612 MHz. A second fixed LO down-converts the IF to an output on TV channel 3.

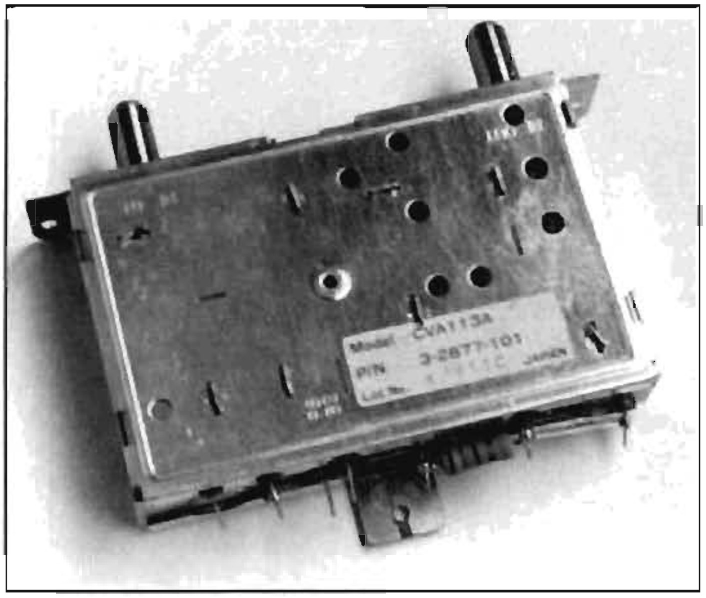
Photo A. A typical CATV tuner has F connectors for RF input and output. Power requirement is +12 volts 75 mA.

Removal of the input high-pass filter will allow operation down to as low as 5 MHz. Simply take out two small coils and three chip capacitors. A coupling capacitor replaces the high-pass filter section (see **Figure 3**). The VCO that drives the first mixer is varactor tuned by a tuning voltage of from 2 to 20 volts. This was originally tuned by a PLL system, and a divide-by-256 ECL prescaler chip in the mod-

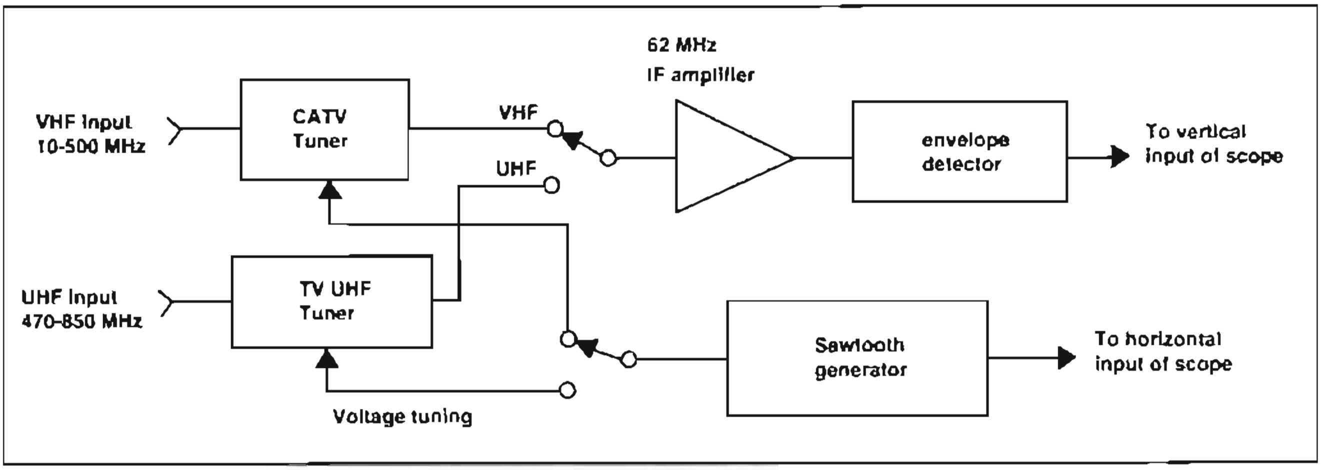

Figure 1. Block diagram of the spectrum analyzer.

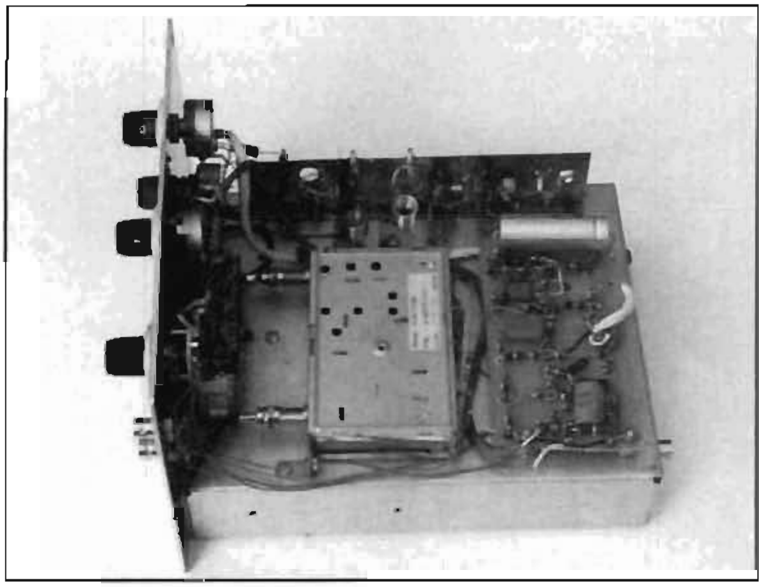

Photo B. The author's spectrum analyzer is built on a 7 x 9 x 2-inch chassis. The power supply is underneath and sweep circuits are on the circuit board at the right. The IF strip runs along the top and the two high-Q air-wound coils, L2 and L3, are clearly visible.

ule was used to drive the divide-by-N portion of the PLL. However, the prescaler isn't used; it's left in the tuner.

Editor's note: CATV tuners used by cable boxes are designed for negative voltage power supplies and also use negative-going tuning voltages—CATV tuners such as the Jerrold 400 or 450 series cannot be used in this analyzer!

My UHF tuner has a bipolar RF stage, mixer, and local oscillator. All three stages are tunable and tracked by varactor diodes. The input coupling loop is for 300-ohm line. By reducing this to one turn, a better match is had for 50-ohm lines. Enough turns were removed from the mixer output coil to raise its frequency from the normal TV IF of 43 to 62 MHz, or channel 3. Other than a minor alignment touchup, these are the only modifications needed for the UHF tuner.

To keep things simple, no further frequency conversion stages are used after the tuners; that is, the IF runs straight through at 62 MHz. I felt this reduced the likelihood of generating spurious signals in the analyzer. As it is, there are no

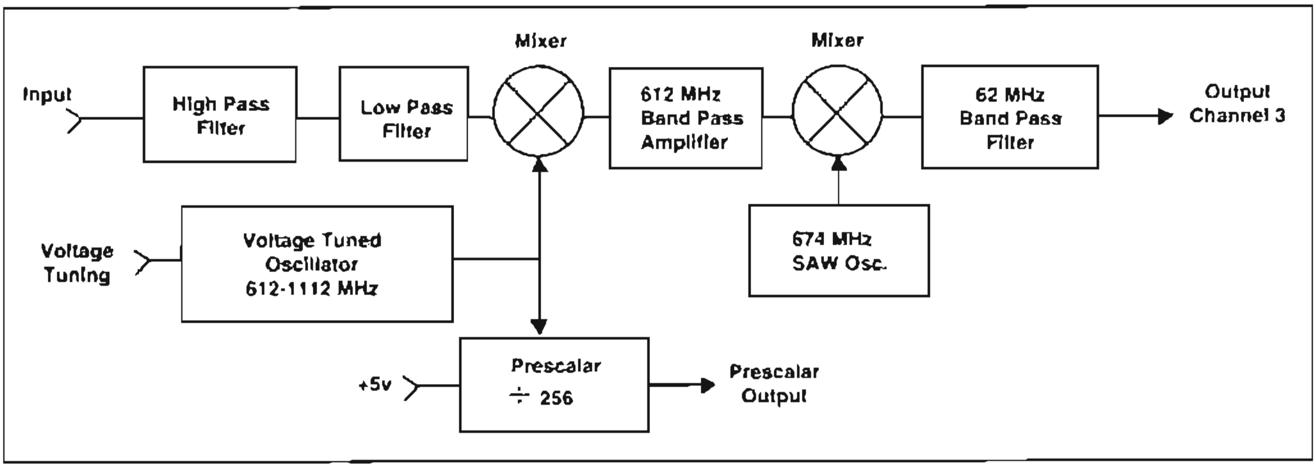

Figure 2. Block diagram of a CATV tuner.

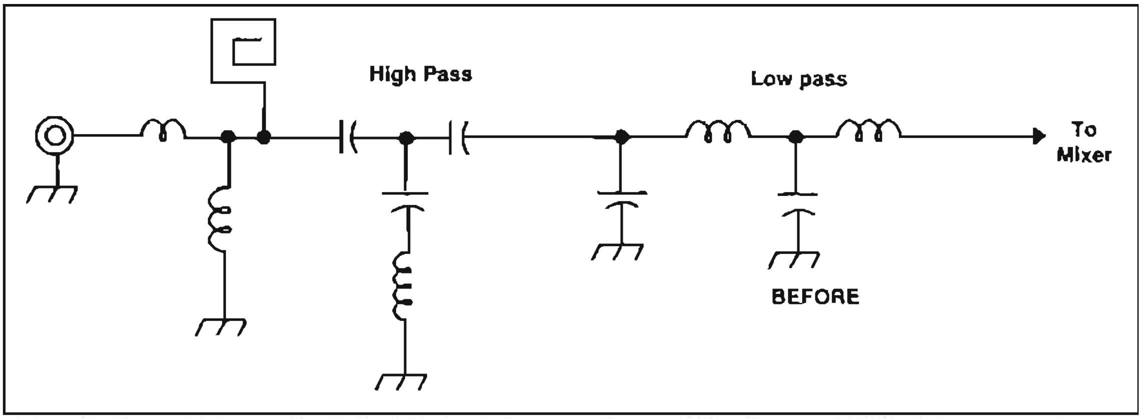

Figure 3. Before and after configuration of the CATV converter front end. The high-pass 40-MHz filter components are removed and replaced with a 1 nF capacitor to extend the frequency response down through HF.

spurious blips anywhere within the analyzer range. Using Hi-Q coils, with light loading, in the IF stages yielded a passband with a 3-dB bandwidth of 180 kHz. This may seem overly broad, but for most ham applications it's entirely satisfactory. You might be able to improve the resolution using crystal or SAW filters, but this would increase the complexity and cost of this project. The lack of an RF stage in the CATV module, and the broad IF bandwidth, limits the sensitivity of the analyzer to about 3 μV—signals weaker than this are lost in the "grass" (noise above the analyzer display baseline).

Figure 4 shows the complete analyzer circuit diagram. **Photos B** and **C** show the exterior and interior views of my completed analyzer. The sawtooth waveform generator has an 80 Hz repetition rate. Transistors Q1 and Q2 perform this function. This scan rate is high enough to avoid flicker but low enough that rise time isn't a problem. The sawtooth waveform is amplified by the op amp, U1. It was nesessary to use an FET-input op amp because of the high impedance level of the sawtooth oscillator circuit. The output of U1 provides a voltage swing of +2 to +20 volts when scan width control, R1, is set for maximum sweep. This sawtooth is then combined with a variable DC voltage, from the center frequency control, R2, so any part of the RF spectrum can be examined in detail. The TV tuner modules have a fairly linear tuning voltage-to-frequency curve. **Photo D** illustrates linear tracking up to approximately 400 MHz. The discrepancies above 400 to 500 MHz could have been compensated for by using op-amp drivers with nonlinear diode feedback schemes. But, again, the results are livable for my applications.

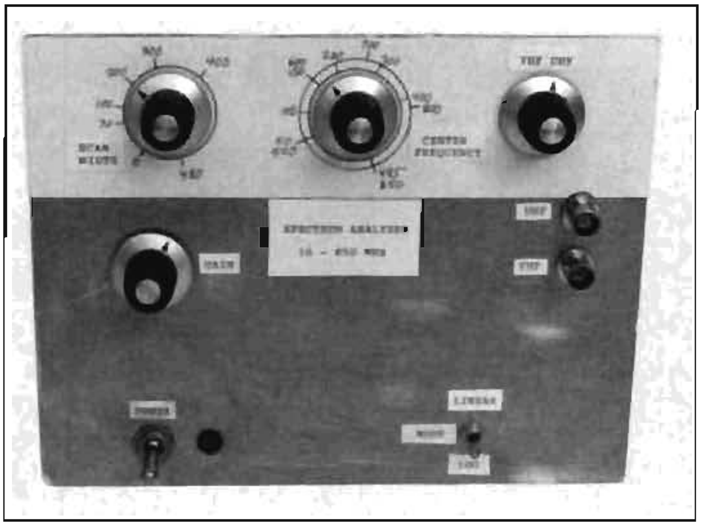

Photo C. The front panel measures 8-1/4 x 6-1/2 inches. The center frequency control has two scales—one calibrated for VHF and one for UHF.

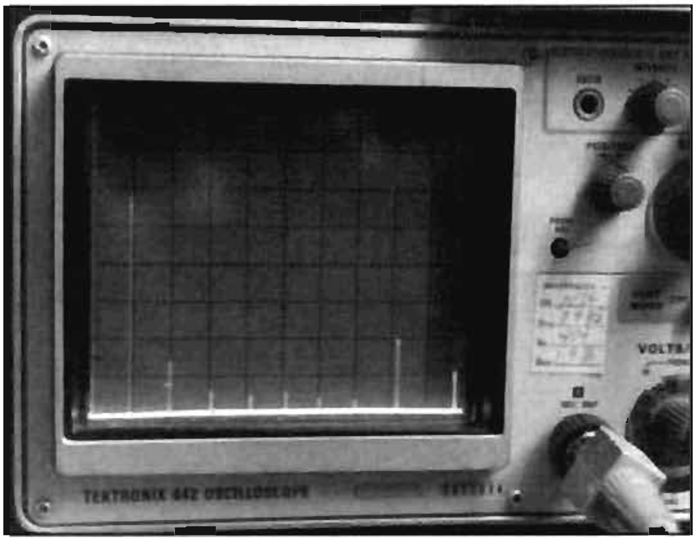

Photo D. This shows the harmonic structure of a 50-MHz crystal-controlled oscillator coupled to a step-recovery diode harmonic generator. Note that the spacing of the harmonics is quite uniform from zero up to almost 400 MHz, but the sweep rate falls off at higher frequencies as evidenced by wider spacing between harmonics.

IF strip

The IF strip uses three dual-gate MOSFETS, Q5, Q6, and Q7. Total gain from IF input to

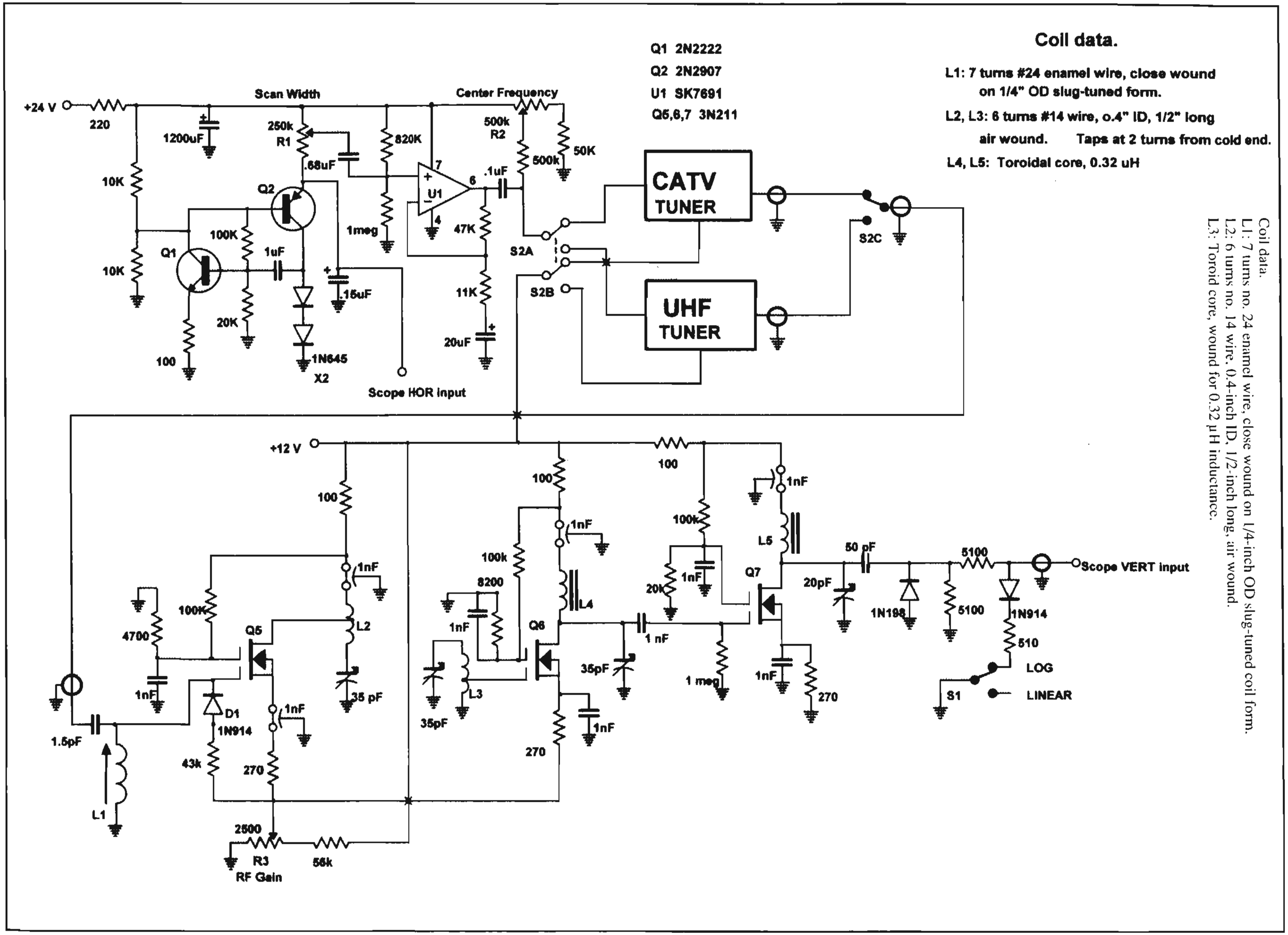

Figure 4. Complete circuit and part values for the spectrum analyzer.

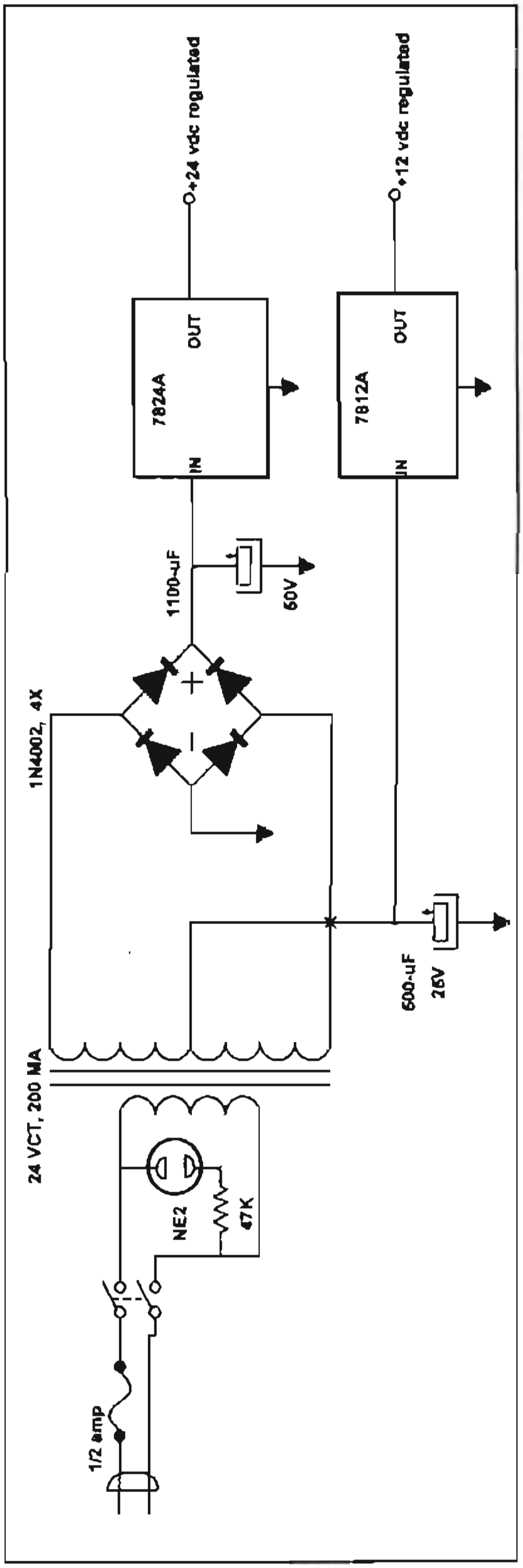

Figure 5. The power supply provides both 12 and 24 volts regulated from one small transformer.

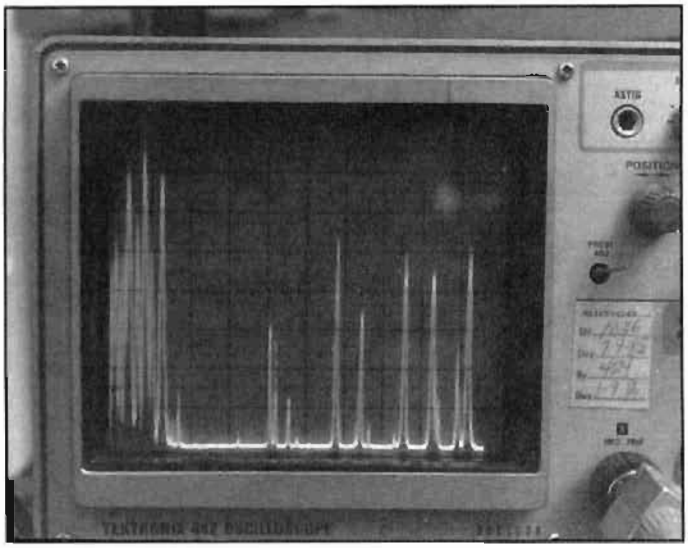

Photo E. This shot of the RF spectrum at the author's QTH was obtained by connecting the VHF input of the spectrum analyzer to a broadband antenna. The sweep is approximately zero to 80 MHz with 50 MHz at the center of the screen. The signals on the left are HF skywave signals. Note that the MUF cuts off at about 18 MHz. The strong signal just to the right of center is the video carrier of channel 2. Next is the sound carrier of channel 2, and the subsequent strong signal is the video barrier of channel 4. This is followed by a couple of communications signals in the 72 to 76-MHz band, which are followed by the video carrier of channel 5.

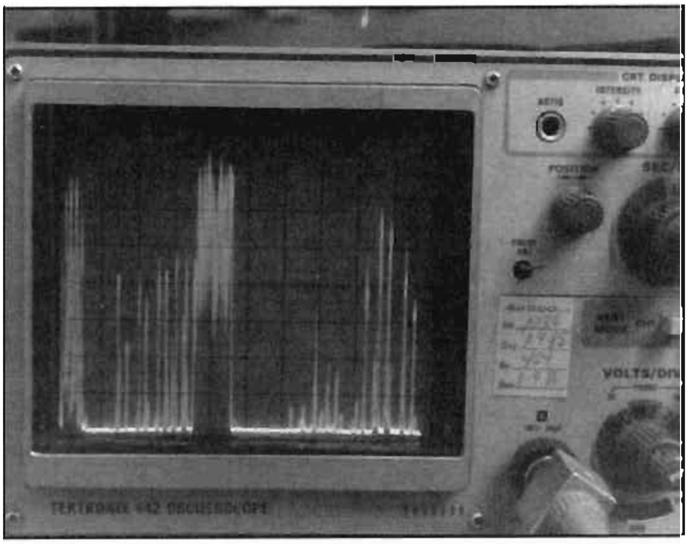

Photo F. This scan is from zero to 230 MHz and shows all the VHF TV channels plus many communications signals. The part that's saturated with signals, just to the left of center, is the FM broadcast band.

DC output is about 75 dB. The two high-Q coils, L2 and L3, form a two-pole filter and provide most of the selectivity. It was necessary to tap Q5 and Q6 down on these coils to maintain a high Q. It was also necessary to place a shield between the two coils to reduce the coupling. If there's too much coupling, you end up with a double-hump response curve. Because of the high Qs of L2 and L3 (about 250), optimum coefficient of coupling is very small. RF toroids were used for L4 and L5; this avoids stray magnetic fields, but solenoidal coils could also be used if shielding is adequate.

The IF assembly is built on a 1-1/2 by 7-inch section of pc board. Each amplifier is individually shielded. The liberal use of feedthrough capacitors helps to maintain the needed isolation. With 75 dB of in-line gain, you need at least 7 dB of isolation between the input and output. Isolation also affects the skirt selectivity! Any spectrum analyzer will have a large blip at a zero frequency. At this point, the LO reaches the first IF frequency and saturates the analyzer. The skirt bandwidth of this "blip" determines the lowest observable signal. (Editor's note: The baluns used in the construction of the diode mixers may also play a role here.)

RF gain control R3 provides a control range of more than 70 dB, while maintaining good linearity in the IF stages. As the arm of R3 nears the 56-k resistor, the DC source voltage of Q5 and Q6 increases—reducing the gain of those stages. Additionally, as the voltage on the arm of R3 nears 1/2 volt, diode D1 begins to conduct, shunting the input signal to prevent overloading of the Q5 IF stage.

The detector is a simple germanium diode! Techies may use a Schottky device here, but the results will remain the same. Capacitor C1 and resistor R4 determine the detector time constant about 1/4 μsec for the values shown.

A reasonably logarithmic response results from switching in diode D2, providing a log response over a 40-dB range. There are better methods, but this offers simplicity and is adequate for my needs. **Photos E** and **F** show off-air signals received on two different scan ranges.

The analyzer power supply is shown in **Figure 5**. A center-tapped 24-volts AC transformer provides the needed 24 volts DC and 12 volts DC regulated outputs. The 24-volt supply filtering is especially critical, because it's used for developing the tuner varicap tuning voltages.

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