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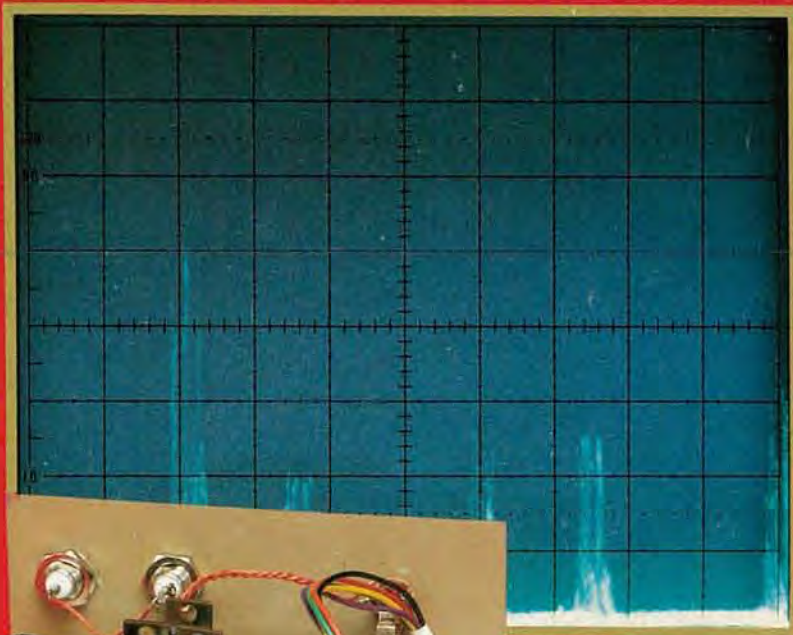
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BUILD THIS

SPECTRUM MONITOR

WE HAVE ALL, AT ONE TIME OR ANOTHER, needed some of the capabilities that a spectrum analyzer offers. Unfortunately, sophisticated analyzers can cost more than a new car! So most of us have managed to live without the benefits that those instruments offer. After all, a meter, oscilloscope, frequency counter, and RF probe can actually give quite a bit of information about a signal environment. But none of those instruments can depict the total spectral content clearly and unambiguously, and give you information on modulation or spurs.

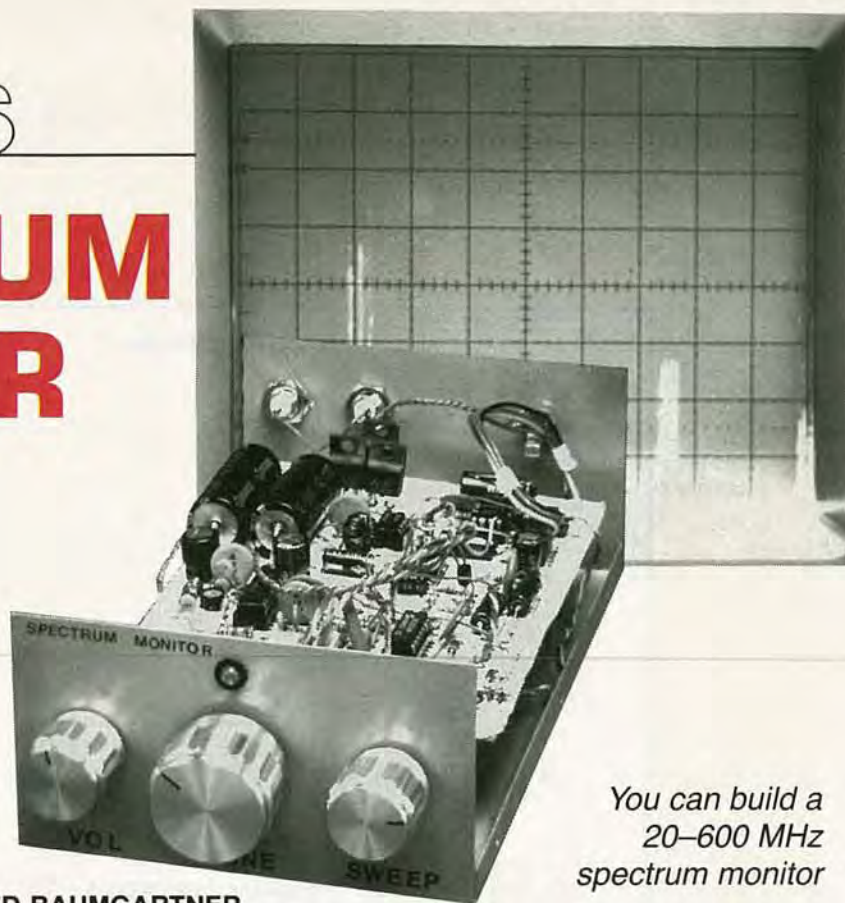
The solution is the spectrum monitor presented here. It doesn't have the frequency or amplitude resolution of a professional version, but it costs only around \$200, and you'll be able to view the 20-600 MHz range and compare relative levels.

The spectrum monitor has two operating modes; you can use it to either visually display an amplitude spectrum on an oscilloscope, or as a receiver to help identify FM signals.

Spectrum analyzer theory

The function of a spectrum analyzer is to tune across a controlled frequency range and display RF amplitude versus frequency on a CRT. Frequency increases from left to right (the + x-direction), while amplitude increases from bottom to top (the + y-direction). The signal being analyzed is applied to the vertical amplifier of an oscilloscope, and the horizontal amplifier is driven by a linear ramp like a triangle or sawtooth.

The simplest spectrum analyzer requires an oscilloscope and two sine/square/triangle function generators, connected as shown in Fig. 1. The oscilloscope time base is set for external sweep, and the scope's horizontal input is grounded. The beam is positioned at the bottom center of graticule, which will be the origin.



*You can build a
20-600 MHz
spectrum monitor*

FRED BAUMGARTNER

If V_1 , the output of the first function generator, is a 1-kHz triangle wave applied to the FM input of the second function generator, and if V_2 is a 10-kHz sine wave, then V_2 would be an FM sinusoid. Varying the frequency of V_1 varies the rate of change about the carrier frequency, and varying the amplitude of V_1 varies the deviation from that center frequency, or the modulation index. However, while the FM waveform is needed to generate a spectrum, it isn't the spectrum itself.

If the 1-kHz triangle wave is ap-

plied to the horizontal oscilloscope inputs, the CRT beam will sweep out a horizontal line along the x-axis of the graticule. Varying the amplitude of V_1 controls the length of the line on the oscilloscope screen. By making the frequency of V_1 high enough and experimenting with its amplitude, you can make the beam occupy the whole length of the bottom of the graticule, and make its retrace completely invisible.

Now take any audio filter or amplifier, a piece of stereo equipment, for example. If you apply V_2 to this filter

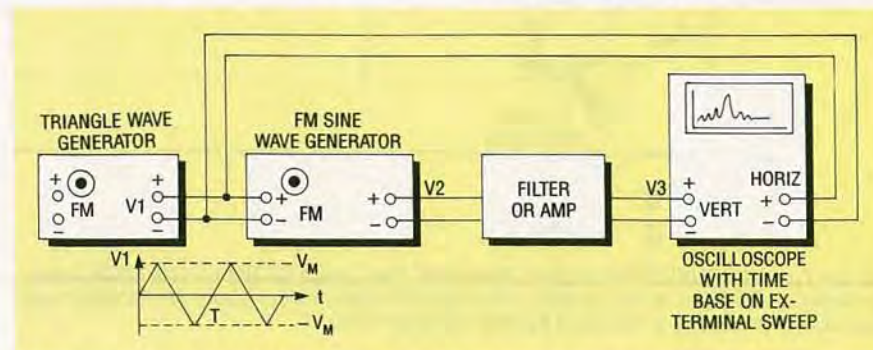


FIG. 1—BASIC SPECTRUM ANALYZER. The first function generator produces a linear ramp waveform (either a triangle or a sawtooth) V_1 . That is applied to the FM input of the second function generator to produce an FM sinusoid, V_2 , which is applied to the inputs of a filter or amplifier. The output, V_3 , is applied to the vertical amplifier of an oscilloscope, the time base of which is set to external sweep. The ramp V_1 is applied to the horizontal amplifier, and the amplitude spectrum appears on the CRT.

ZENITH SX SERIES 175-2292A TUNER/CONVERTER

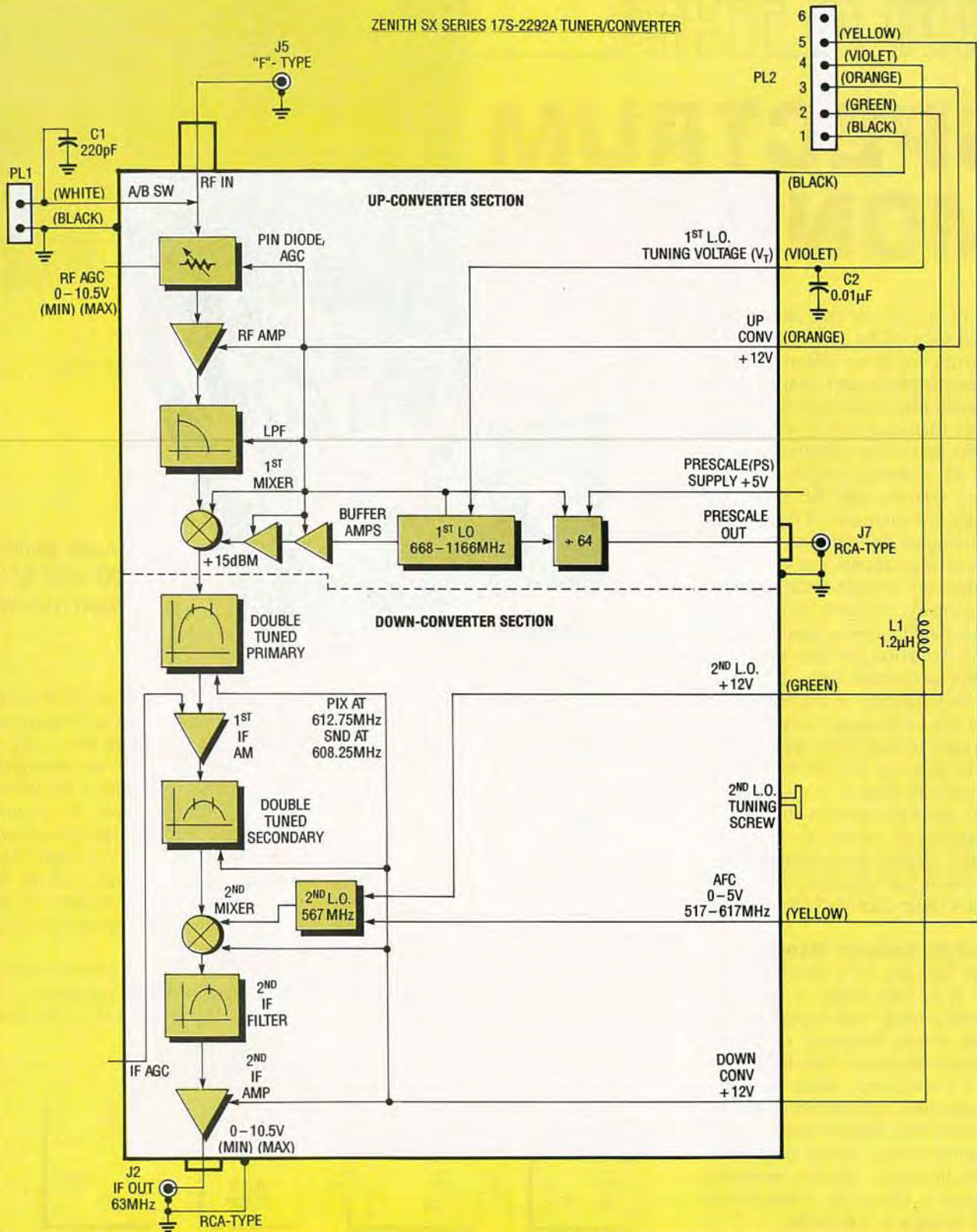


FIG. 2—TUNER/CONVERTER BLOCK DIAGRAM. The Zenith SX Series 175-2292A tuner/converter is the heart of the project. It accepts RF signals from about 55–553 MHz and downconverts them to a standard 63-MHz constant-level IF.

or amplifier, and apply the filter or amplifier's output V_3 to the oscilloscope's vertical amplifier, you should see some smooth continuous

curve with valleys and plateaus in its shape. That is the amplitude frequency-response of the filter or amplifier, a visual depiction of the amplitude of

the FM signal coming out as a function of frequency. The voltage gain in decibels (A_{dB}) as a function of frequency is equal to 20 times the base-10 logarithm (\log) of the ratio of V_3 to V_2 . Or:

$$A_{dB} = 20 \times \log_{10}(V_3/V_1).$$

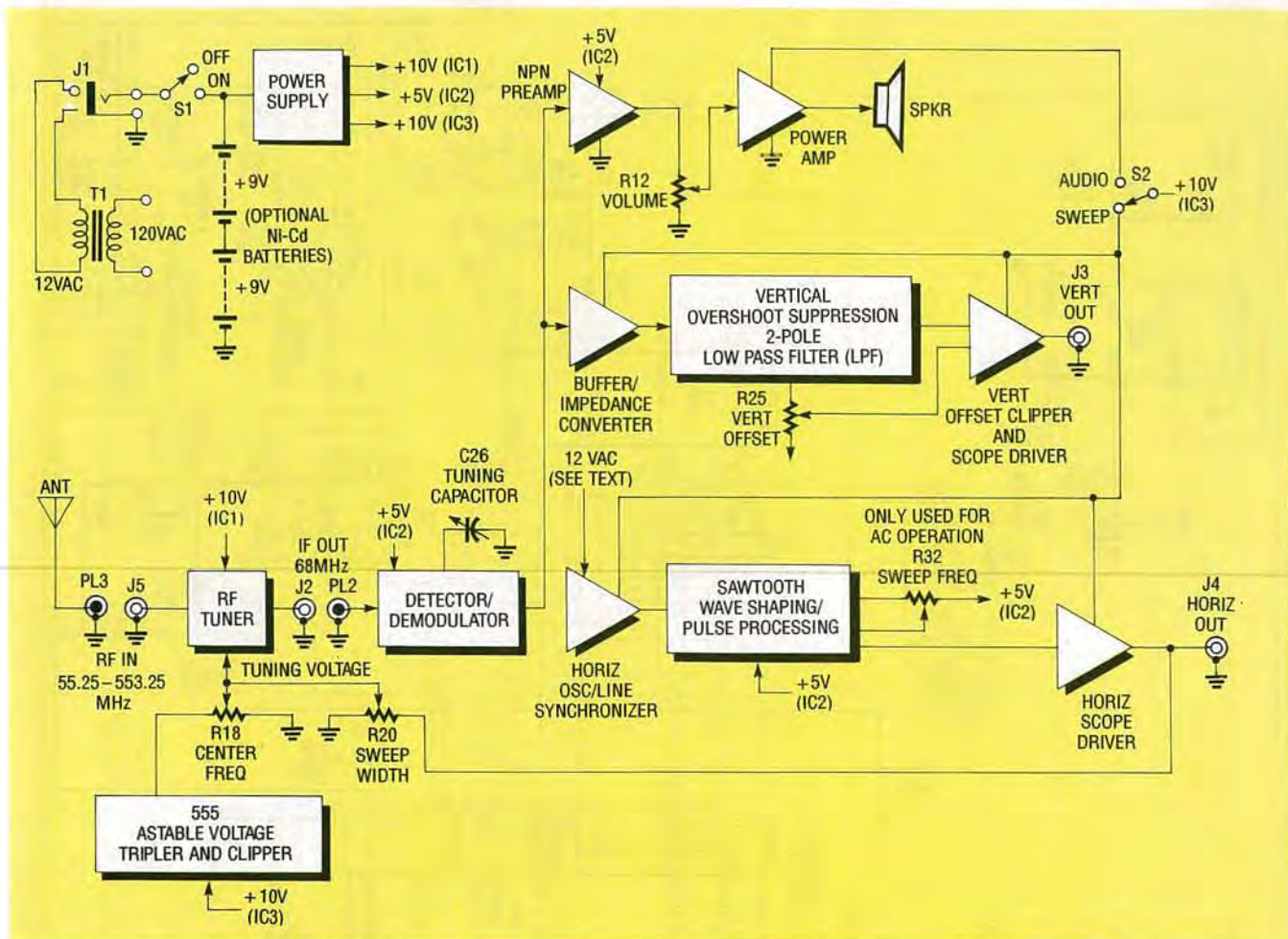


FIG. 3—SPECTRUM MONITOR BLOCK DIAGRAM.

Note that A_{dB} is a function of *frequency*, not time. That ratio (or the log of it) is called the amplitude spectrum of a signal, and is a plot of how a filter, amplifier, or any other electronic component responds to variations in frequency.

Tuner/converter principles

The previous example was at audio frequencies, while the spectrum monitor discussed here works at RF. Certain variations in the previous idea are necessary to make spectral analysis practical at such frequencies. An RF spectrum analyzer ordinarily uses a sawtooth wave rather than a triangle wave as the horizontal scanning waveform, since that waveshape is easier to generate at RF. Also, rather than generating an FM sinusoid as the driving waveform which generates the spectral response, most spectrum analyzers use a tuned receiver to scan over a frequency range.

The real object behind using a triangle or sawtooth waveform is that their slopes are essentially linear, so

the resulting FM generation is also. The minimum frequency for a triangular waveform corresponds to the negative-most point of each cycle, and the maximum frequency to its positive-most point. The frequency range for a sawtooth waveform goes from minimum to maximum during its long rise time, with a sharp retrace at the end of a cycle. In both cases, the duration of each ramp must occupy the entire length of the x-axis of the CRT graticule.

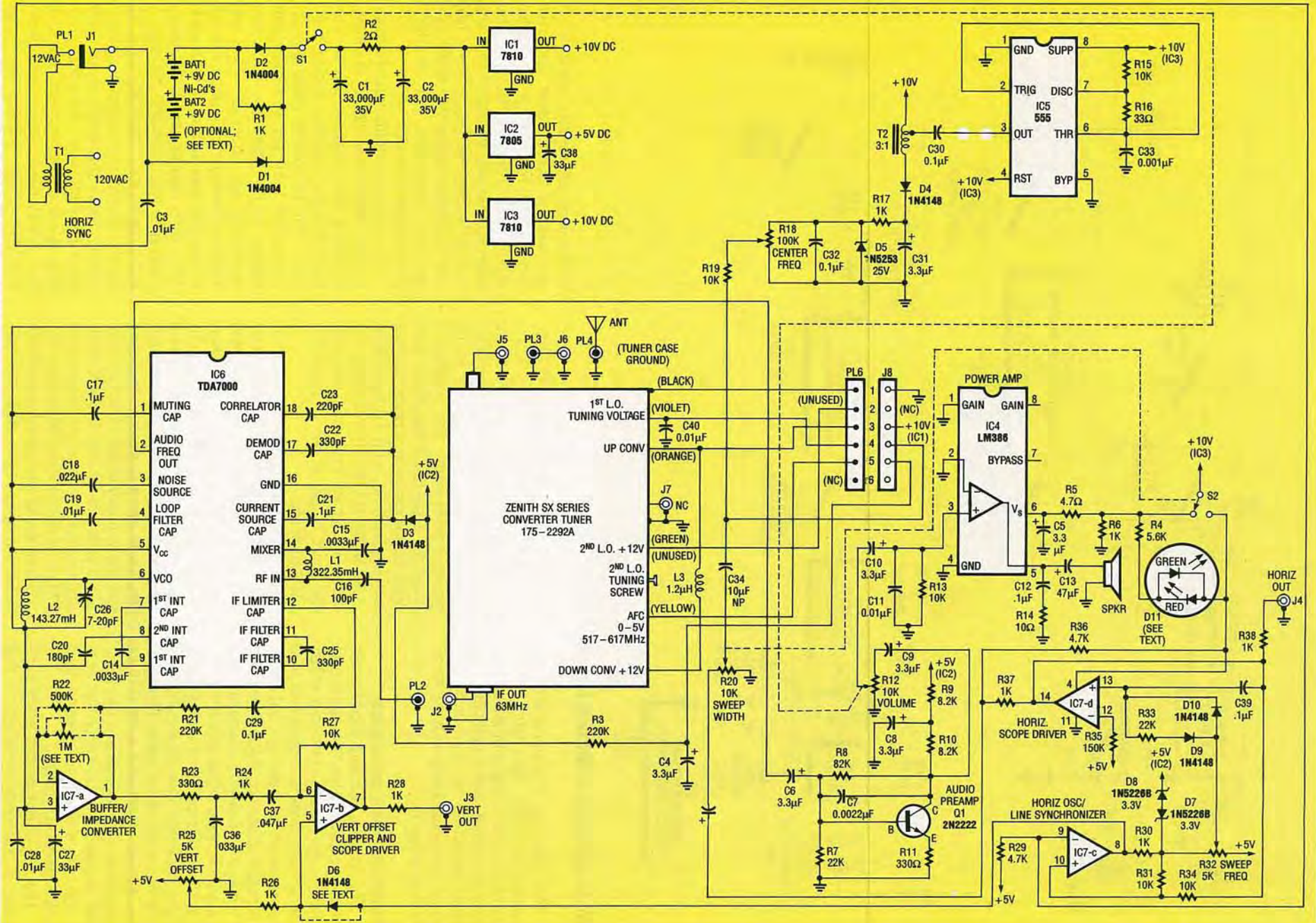
The spectrum monitor uses a commercially available tuner/converter normally found in TV's, VCR's, and cable converters to down-convert normal RF to a standard 63-MHz constant-level IF, tunable over the desired frequency range. As mentioned earlier, there are two distinct operating modes; you can either observe a signal in sweep mode regardless of modulation type, or you can demodulate FM using the internal FM receiver IC.

There are all sorts of ways to obtain tuner/converters from cable converters and TV or VCR front ends; the rest

of the parts are readily available. If you use the Zenith tuner discussed here, enough information is provided regarding its internal circuitry and pinouts so that you shouldn't have any real difficulty. Without proper test gear and some reasonable familiarity with RF electronics, you shouldn't use a different model.

The spectrum monitor can be made to work with a wide variety of tuners, including those that use bipolar supplies or need negative tuning voltages. The important tuner characteristic to look for is continuous tuning. Many tuners also have band switching, like those for TV's and VCR's, although they require a switch to supply band-change voltages. Also, there may be gaps in frequency coverage, like between channels 5 and 6, or between the VHF and UHF bands. Cable converters use those spaces, so a cable-ready set or cable tuner probably won't have that problem. However, they may not tune all of the UHF band (approximately 470-850 MHz). Ideally, the tuner should reach at least 550 or 600 MHz.

FIG. 4—SCHEMATIC OF THE SPECTRUM MONITOR.



PARTS LIST

All resistors are 1/4-watt, 5%, unless otherwise indicated.

R1, R6, R17, R24, R26, R28, R30, R37, R38—1,000 ohms
 R2—2 ohms
 R3, R21—220,000 ohms
 R4—5600 ohms
 R5—4.7 ohms
 R7, R33—22,000 ohms
 R8—82,000 ohms
 R9, R10—8200 ohms
 R11—330 ohms
 R12-S1—cabinet-mounted 10,000-ohm potentiometer with SPST switch
 R13, R15, R19, R27, R31, R34—10,000 ohms
 R14—10 ohms
 R16—33 ohms
 R18—cabinet-mounted 100,000-ohm 10-turn potentiometer
 R20-S2—cabinet-mounted 10,000-ohm potentiometer with SPDT switch
 R22—1 megohm
 R23—330 ohms
 R25, R32—5000-ohm PC-board potentiometer
 R29, R36—4700 ohms
 R35—150,000 ohms
Capacitors
 C1, C2—3300 μ F, 35 volts, electrolytic
 C3, C11, C19, C28—0.01 μ F, 25 volts, ceramic disc
 C4—C6, C8—C10—3.3 μ F, 25 volts, electrolytic
 C7—0.0022 μ F, 25 volts, ceramic disc
 C12, C17, C21, C29, C30, C32—0.1 μ F, 25 volts, ceramic disc
 C13—47 μ F, 25 volts, electrolytic
 C14, C15, C24—0.0033 μ F, 25 volts, ceramic disc
 C16—100 pF, 25 volts, ceramic disc
 C18—0.022 μ F, 25 volts, ceramic disc
 C20—180 pF, 25 volts, ceramic disc
 C22, C25—330 pF, 25 volts, ceramic disc
 C23—220 pF, 25 volts, ceramic disc
 C26—7–70-pF PC-board trimmer capacitor

C27, C38—33 μ F, 16 volts, electrolytic
 C31—3.3 μ F, 50 volts, electrolytic
 C33—0.001 μ F, 25 volts, ceramic disc
 C34—10 μ F, 50 volts, nonpolarized electrolytic
 C35—10 μ F, 25 volt, electrolytic
 C36—0.033 μ F, 25 volts, ceramic disc
 C37—0.047 μ F, 25 volts, ceramic disc
 C39—0.1 μ F polystyrene
 C40—0.01 μ F polystyrene
 C41—220 pF ceramic disc

Inductors

L1—12 turns, 1/8-inch, No. 26 enamel wire
 L2—8 turns, 1/8-inch, No. 26 enamel wire
 L3—1.2- μ H RF choke

Transformers

T1—RODCO Class 2 power transformer, Model DV-1260, 120-volts AC/12-volts AC, 60-Hz, Digi-Key catalog number T201-ND
 T2—3:1 toroidal auto-transformer using No. 26 enameled wire on a toroidal core (Mouser Electronics 542-T68-2), with eight turns for the primary and 24 turns for the secondary (see text)

Semiconductors

D1, D2—1N4004 silicon diode
 D3, D4, D6, D9, D10—1N4148 germanium diode
 D5—1N5253B 25-volt Zener diode
 D7, D8—1N5226B 3.3-volt Zener diode
 D11—combination red/green LED (Mouser Electronics ME351-261)
 Q1—2N2222 NPN transistor
 IC1, IC3—7810 10-volt DC regulator
 IC2—7805 5-volt DC regulator
 IC4—LM386 audio amplifier
 IC5—555 timer
 IC6—Signetics TDA7000 FM receiver (Radio Shack 276-1304)
 IC7—NE5514 quad op-amp

Modules

MODULE1—multipurpose cable TV/VCR tuner/converter (Motorola SX Series 175-2292A)

Other components

PL1—miniature monophonic plug
 PL2—RCA-type monophonic plug connecting to braided-shield coaxial cable
 PL4-ANT—folding monopole antenna with BNC plug (optional)
 PL5—2-socket PC-board-mounted SIP version, not a separate item, attached to the tuner (MODULE1), intended for A/B SWITCH (unused)
 PL6—6-socket PC-board-mounted SIP version, not a separate item, attached to the tuner (MODULE1), used for the majority of the tuner pinouts
 J1—miniature monophonic jack
 J2—RCA-type monophonic jack, not a separate item, built into cabinet of the tuner (MODULE1), used for IF OUT
 J3, J4—BNC jack
 J5—"F"-type jack, not a separate item, built into cabinet of the tuner (MODULE1), used for IF OUT (63 MHz)
 J7—RCA-type monophonic jack, not a separate item, built into cabinet of the tuner (MODULE1), used for PRESCALE OUT
 J8—6-pin PC-board-mounted Single-Inline Package (SIP) jack
 PL3-J6—adapter with "F"-type plug and BNC jack (optional)
 SPKR—8-ohm loudspeaker, 2- \times 2-inch
Miscellaneous: Cabinet (minimum size 8- \times 4.5- \times 2.5-inches), large knob (for R18), small knob (for R25 and R32), four 1-inch standoffs, LED bezel, wire, solder, etc.

NOTE: The following is available from FM Broadcast Services, 3825 South Olathe Street, Aurora, CO, 80013: A complete spectrum monitor kit with all parts, PC board, hardware, tuner, cabinet, transformer and postage for \$187.00. The PC board alone is \$12.00.

Third, you'll want a usable output IF. TV Channel 3 (63 MHz) is popular, but Channel 4 (69 MHz) is suitable and within the range of the project. Also, you'll want relatively stable gain characteristics and few images or spurs.

Some adjustment of the spectrum monitor may be necessary for use with your tuner. Automatic Gain Control (AGC) voltages can be brought out to a front panel control to set RF

gain, or tied to a voltage representing full gain. Measuring the local oscillator output with a frequency counter will enable you to calculate the center frequency.

Zenith SX tuner/converter

The Zenith SX series tuner/converter (part number 175-2292A) used in the prototype is representative of a suitable tuner; a block diagram is shown in Fig. 2. It can be bought with

the kit described in the Parts List, or directly from Zenith Corp. It contains both up- and down-converter sections, and fits into a 4.25- \times 2.78- \times 1.05-inch aluminum shell with one "F"-type and two RCA-type jacks.

The "F"-type jack (J5) is the RF IN, with a frequency range of 55.25–553.25 MHz. One RCA-type jack (J2) is the 63-MHz IF OUT, and the second (J7) is the PRESCALE output,

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which isn't used here.

There are two PC-board plugs supplied with the tuner. One is a two-pin version, PL5, used for A/B SWITCH, which along with C1 is unused. The other is a Single-Inline-Pin (SIP) plug, PL6, which connects to most of the pinouts. Pin 1 (black) of PL2 is ground, pin 2 (green) is the SECOND LOCAL OSCILLATOR +12-volt supply (unused), pin 3 (orange) is the UP-CONVERTER +12-volt supply, pin 4 (violet) is the FIRST LOCAL-OSCILLATOR TUNING VOLTAGE, and pin 5 (yellow) is the AUTOMATIC FREQUENCY CONTROL (AFC) voltage for tuning the second local oscillator over the range 517–617 MHz. Pin 6 is not wired.

Even though the up- and down-converter supplies are labeled as nominally needing +12 volts, +10 volts proved to be adequate. The AFC potential on pin 5 of PL2 should nominally be +2.5 volts, to keep the second local oscillator at 567 MHz. Enough information is provided to let you look into suitable replacements if you can't get this version, or want to experiment with others.

Spectrum monitor operation

The block diagram of the spectrum monitor is shown in Fig. 3. It can operate using *either* 12-volts AC or +12-volts DC, and provision is also made for optional Ni-Cd batteries. An RF signal over the frequency range 55.25–553.25 MHz is applied to the Zenith tuner via J5. The tuner will down-convert to a 63-MHz IF, the center frequency being adjusted using R18, and the sweep width using R20;

the IF exits the tuner via J2. It is then fed to an FM receiver IC that acts as detector/demodulator. The input resonant frequency of the IC is adjusted using trimmer capacitor C26.

The output of the detector/demodulator IC is applied simultaneously to a discrete NPN transistor preamplifier and an op-amp buffer/impedance converter. The preamplifier output goes to an IC power amplifier and speaker, the volume being adjusted using R12. This is the FM-receiver audio output, letting you listen to FM broadcast stations, TV audio, two-way FM communications, etc.

The buffer/impedance converter is part of the vertical output section, and is followed by a two-pole low-pass filter which suppresses any signal amplitude overshoots, preventing the spectrum monitor from forcing the oscilloscope beam off the graticule. That's followed by a vertical offset clipper and oscilloscope driver amplifier, which is adjusted using R4. The output of this amplifier is fed to the VERT OUT jack J3.

Note that S2 feeds power to either the audio amplifier for receiver operation, or IC7 for sweep operation in spectrum monitor mode. The two operating modes are mutually exclusive; you can't use the monitor to simultaneously observe a region of the RF spectrum, and listen to whatever station is at the center frequency of the display. However, it is a simple matter to switch between modes.

The horizontal circuitry begins with a horizontal oscillator, which also acts as a line-voltage synchronizer. When the spectrum monitor is powered by 60-Hz AC, the 12-volts AC from the secondary of T1

is coupled into the horizontal oscillator, locking it to the 60-Hz power-line frequency automatically. When 12-volts DC is applied directly to J1, synchronization to 60 Hz becomes impossible, so the horizontal oscillator will be free running.

The horizontal-oscillator waveform then passes through a network that generates the sawtooth waveform used for horizontal scan/retrace. That sawtooth is amplified by a horizontal driver and appears at HORIZ OUT jack J4. The sweep frequency is adjusted using R32, but the adjustment is effective only when the spectrum monitor is operated using AC.

Circuit description

The complete schematic of the spectrum monitor is shown in Fig. 4. The spectrum monitor uses 12-volts AC or +12-volts DC, allowing operation from a car battery, or a plug-in 12-volt AC adapter. It also can operate off of a Ni-Cd power pack.

Diode D1 is the power rectifier for 12-volts AC, D2 and resistor R1 provide a charging path for the Ni-Cd cells, and S1 is an SPST ON/OFF switch. While a full-wave rectifier would be much easier to filter, it would prevent AC/DC compatibility. The filter is composed of R2 and capacitors C1 and C2. Also, C3 samples AC to synchronize the sweep oscillator to 60 Hz. The three voltage regulators provide regulated +10-volts DC to the tuner, and +5-volts DC to the sweep circuits. The TDA7000 receiver uses +4.5 volts; the drop across D3 provides +4.3 volts, which is adequate.

While the 555 timer (IC5) is con-

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SPECTRUM MONITOR

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figured as an astable, its real purpose is to function as an additional voltage source. It works in conjunction with T2, a 3:1 toroidal auto-transformer, to provide the tuning voltage. Most tuner/converters need 0–25 volts for full-range control. The primary of T2 is supplied by the +10 volts from IC3, and the 143.056-kHz oscillation superposes an additional 20 volts, producing 30 volts across C31. The duty cycle is very low to conserve power. Next, D5, a 25-volt Zener, clamps and regulates the tuning voltage, and R18 controls the tuning voltage for the first local oscillator in the tuner.

For tuners requiring negative or multiple voltages, T2 will have to be modified. For a different maximum amplitude required, change the ratio of T2, and for a negative voltage, reverse D4 and D5 and also the non-tap terminals on the auto-transformer. This will force the auto-transformer to generate negative-going pulses, which will be superposed upon the

+10-volts DC. Reversing D4 and D5 allows current to be passed in the reverse direction, and the Zener voltage of D5 could be changed if needed. The horizontal sweep generator produces both sawtooth and pulse waveforms, and can be externally synchronized.

The purpose of D9, D10, and R33 is to allow the negative and positive slopes to be set independently. Note that R33 is in series with D9, but that there's no comparable resistor in series with D10. Thus, R33 extends the duration of the sawtooth waveform up-ramp so the CRT beam fits on the horizontal axis of the graticule. Then, D10 permits a steep, rapid discharge, minimizing the sawtooth waveform fall time and permitting fast horizontal retrace. Sweep-frequency potentiometer R32 allows the time constant to be varied.

Zener-diodes D7 and D8 clamp the output of the oscillations from IC7-c, D7 the negative-going direction, and D8 the positive-going direction. Then, IC7-d buffers the sawtooth generated across C39, and IC7-c switches C39 from charge to discharge based on the feedback through

R34. Finally, D6 routes the blanking/sync pulse to the vertical section (IC7-a and IC7-b) for vertical retrace. Note that D6 may need to be shorted or left out for faster vertical retrace, although some oscilloscopes will experience vertical overshoot as a result. You'll have to experiment with whatever oscilloscope you use, in order to decide.

True "Z"-axis control (blanking or brightness) is difficult to obtain on many oscilloscopes. If yours permits external blanking control, it's available as a positive pulse from pin 8 of IC7-c. This pulse drives the CRT beam vertically off the screen during retrace and turns the vertical amplifier off, preventing retrace from being seen.

The Signetics TDA7000, IC6, is a complete FM receiver on a chip. The tank L1-C26 for the Voltage-Controlled Oscillator (VCO) on pin 6 is the only RF adjustment. Only L2, C15, and C16 are required on IC5 as external components to create the RF input filter and perform matching. If the IF is 45 MHz, the value of L1 may need to be increased. By altering L1, any IF from 30–110 MHz may be

used. It's also possible to similarly adapt L2.

The TDA7000 reduces the received signal deviation from ± 75 kHz to ± 15 kHz (suitable for the internal IF of 70 kHz), using an internal Frequency (*not* phase) Locked Loop (FLL). The TDA7000 greatly simplifies the circuitry for many tuned circuits and filters, and neither needs nor uses AGC. In its place, a sample of IF limiter voltage is fed back to the IF LIMITER CAPACITOR input (pin 12), after being buffered and amplified by IC7-a. The gain of IC7-a is controlled by R22. The prototype used 500 K for R22, but the gain can be varied by using a potentiometer.

The positive signal portion of the IF envelope is amplified by IC7-b to produce the vertical drive. Potentiometer R25 sets the base line to "rectify" the signal from IC7-a. Between IC7-a and IC7-b, a two-pole low-pass filter smoothes DC ripple and reduces vertical overshoots. Also, IC7-a converts the high-impedance receiver section AGC, where the RF level is derived, to something low enough for proper filter design, while also providing some gain. Overall, IC7-a and IC7-b

provide a gain of about 40.

The tuner is the heart of the spectrum monitor. It accepts the RF IN (J5) and produces a 63-MHz IF OUT (J2). The FIRST LOCAL-OSCILLATOR TUNING VOLTAGE controls the first local oscillator. Remember that there are two operating modes, FM receiver and spectrum monitor. In the former, the tuning voltage is steady DC and is determined by center frequency potentiometer R18. In the latter, the tuning voltage is swept.

Sweep-width potentiometer R20 controls the tuner sweep-voltage and how much of the spectrum is displayed. The SPDT switch S2 selects between modes, not merely by selecting between the outputs for each with both sections (IC4 and IC7) operating simultaneously, but actually switches power between them, saving power and avoiding any coupling problems.

Well, we regret that we must stop here for now, as our space has come to an end. However, next month we will continue with complete construction details, including PC Service. We'll also show you how to troubleshoot any problems. We will then, of course, show you how to use it. **R-E**