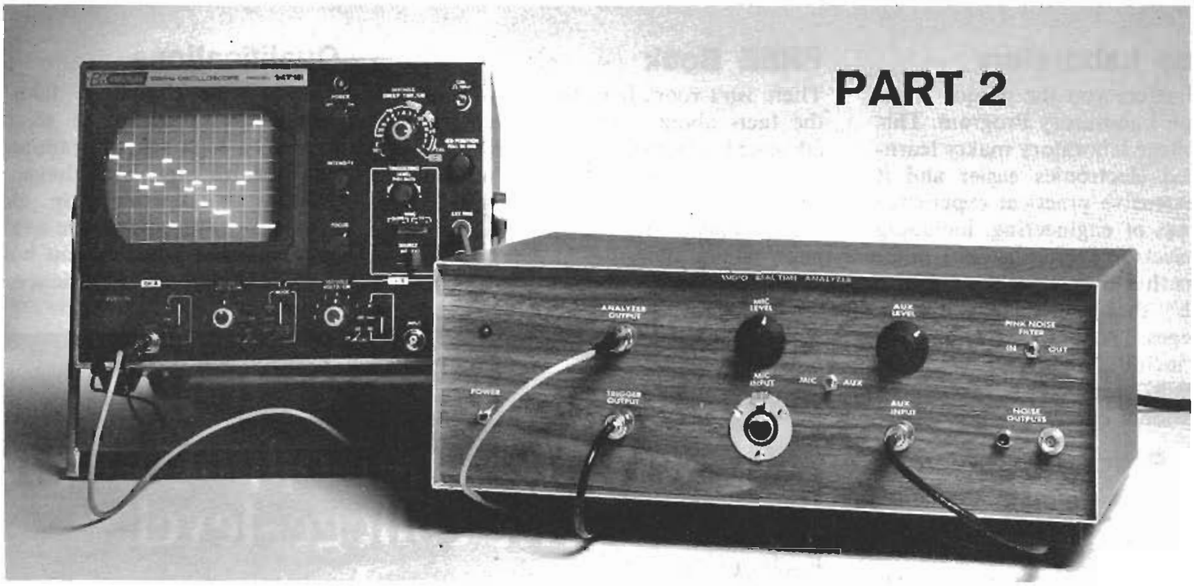
1/2-Octave Real Time Audio Analyzer



Test and calibration procedures, typical applications and how to add an optional logarithmic converter.

BY BOB JONES AND RICHARD MARSH

LAST month, we discussed the circuitry of the Real Time Analyzer, examined overall system operation, and presented construction details. Now we'll describe the optional Logarithmic Converter and outline test and calibration procedures. Also, typical applications for the Analyzer will be suggested.

The Log Converter, shown schematically in Fig. 11, is a useful accessory which allows display of amplitude variations on the scope directly in dB. The heart of this linear-to-logarithmic converter is *IC36*, a 76502 integrated circuit. One half of *IC35A* is used as a buffer for log converter *IC36*. This buffer is powered by a bipolar 5-volt supply, so its output (and thus the input to *IC36*) is limited to +5 volts maximum. The ORIGIN ADJUST control (*R144*) and op amp *IC35B* determine the amount of dB per division of scope display. Stages *IC37A* and *IC37B* provide gain and rectification, respectively. The rectifying action of *IC37B* prevents any negative voltages from reaching the scope's vertical input. However, "negative" outputs are generated by *IC36* whenever its input signal drops below the ORIGIN level.

Power for the log converter is derived from the RTA, with zener diodes *D26* and *D27* providing the required ±5 volts dc. Etching and drilling and parts placement guides for the log converter pc board are shown in Fig. 12. Use IC sockets or Molex Soldercons to facilitate installation of the integrated circuits. Pay attention to pin basing and polarities.

Tests and Calibration. With all IC's removed from their sockets (except the voltage regulators), plug the line cord into a wall socket and close *S2*. Measure the following regulated dc voltages: +5 volts across *C112*; −15 volts across *C111*; +15 volts across *C110*. Then see if *LED1* lights. If not, check the polarity of the LED. If all is well, turn off the ac power and insert all IC's.

If you are installing the optional log converter, perform the following steps (1) through (7). Otherwise, they can be bypassed.

(1) Decide how many dB/division you want displayed on the scope, and determine how many dB will be shown in a full-scale deflection. For example, if the vertical scale of the scope is 6 cm and 4 dB/cm is desired, 24 dB will be displayed full-scale.

(2) Calculate the origin voltage. (See Table II.) The maximum permissible input to the log converter chip (*IC36*) is one volt. In our example, −24 dB referenced to one volt is 0.063 volt.

(3) Apply 0.5 volt dc across the converter input and adjust *R140*, the INPUT LEVEL control, so that the voltage at *TP1* equals the calculated origin voltage.

(4) Adjust *R144*, the ORIGIN ADJUST potentiometer, for zero volt (±0.1 volt) at *TP2*. This is a sensitive adjustment.

(5) Increase the dc voltage applied across the input to 1.5 volts. Then adjust *R140* so that 1.0 volt appears at *TP1*. Monitor the converter output on your oscilloscope and adjust *R148*, the SLOPE ADJUST control until full-scale deflection of the scope trace occurs. Set the scope's vertical sensitivity to whatever value is most suitable for adjustment.

(6) Repeat steps (3), (4), and (5) until all adjustments are correct.

(7) Adjust the INPUT LEVEL control, *R140*, so that the signal voltage at *TP1* *never* exceeds one volt. The RTA's maximum level reference (which appears at the Analyzer output at clock pulses 23 and 24) is 10 volts. You can use this as the signal applied to the converter input for this adjustment. But be sure to back down on *R140* before you apply 10 volts at the converter input. When *R140* is properly adjusted, the 10-volt reference from the RTA will cause full-scale deflection.

Next, adjust all LEVEL ADJUST controls (*R75* through *R94*) on the filter boards to

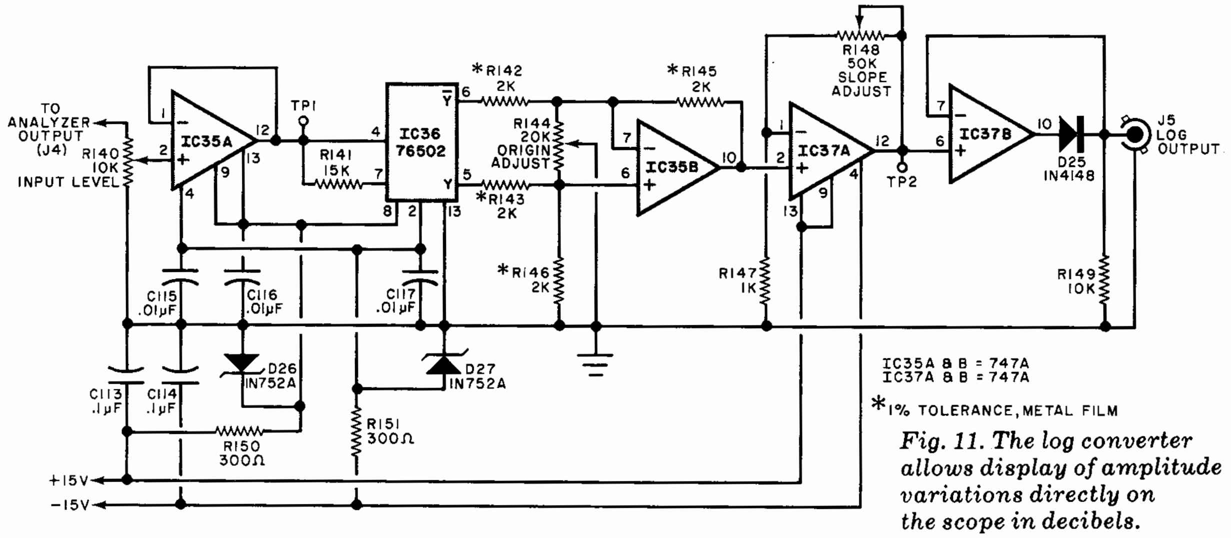


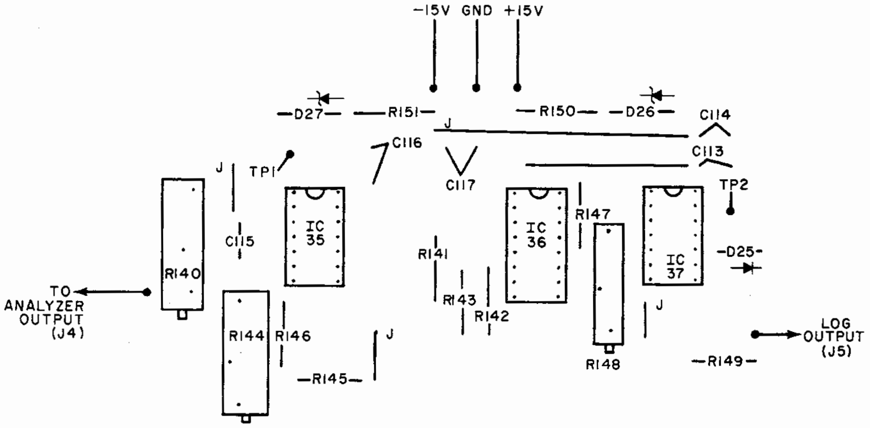
Fig. 11. The log converter allows display of amplitude variations directly on the scope in decibels.

LOG CONVERTER PARTS LIST

C113, C114—0.1-µF, 50-volt disc ceramic capacitor
C115 through C117—0.01-µF, 50-volt disc ceramic capacitor
D25—1N4148 silicon diode
D26, D27—5.6-volt, ¼-watt zener diode (1N752A, HEP Z0212 or equivalent)
IC35, IC37—LM747A dual operational amplifier IC
IC36—SN76502 linear-to-logarithmic converter IC (Texas Instruments)**
J5—BNC connector
The following fixed resistors are 5% tolerance, carbon composition components.
R141—15,000 ohms, ½ W
R147—1,000 ohms, ½ W
R149—10,000 ohms, ½ W
R150, R151—300 ohms, ¼ W
The following fixed resistors are 1% tolerance, ½-watt metal film components
R142, R143, R145, R146—2000 ohms
The following resistors are multi-turn, ½-watt Cermet trimmer potentiometers (Spectrol type 43Y or equivalent).*
R140—10,000 ohms
R144—20,000 ohms
R148—50,000 ohms
Misc.—Printed circuit board, IC sockets or Molex Soldercons, hookup wire, pc board spacers, coaxial cable, machine hardware, solder, etc.
Note: The following is available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, TX 78216: etched and drilled pc board LC-2b for $3.25 ppd.
*Available through distributors such as Allied Radio or Newark Electronics.
**Consult a Texas Instruments local distributor or sales representative.

their maximum or full clockwise positions, and all Q ADJUST potentiometers to their minimum or full counterclockwise positions. Apply ac to the RTA by closing *S2*. Connect your dc-coupled oscilloscope to the RTA output. Set the front panel AUX LEVEL potentiometer to its full clockwise position. Adjust the scope's vertical sensitivity for approximately ⅔-scale display of the 10-volt reference signal from the RTA. Place *S1* in the AUX position, and apply a 0.1-volt rms, 22.4-Hz sine wave to the AUX input.

Adjust *R15* (the Q ADJUST potentiometer for filter one) until an increase in dc level occurs. (There may have already been a dc level at the RTA output if there was an offset at *IC31*.) As the control is



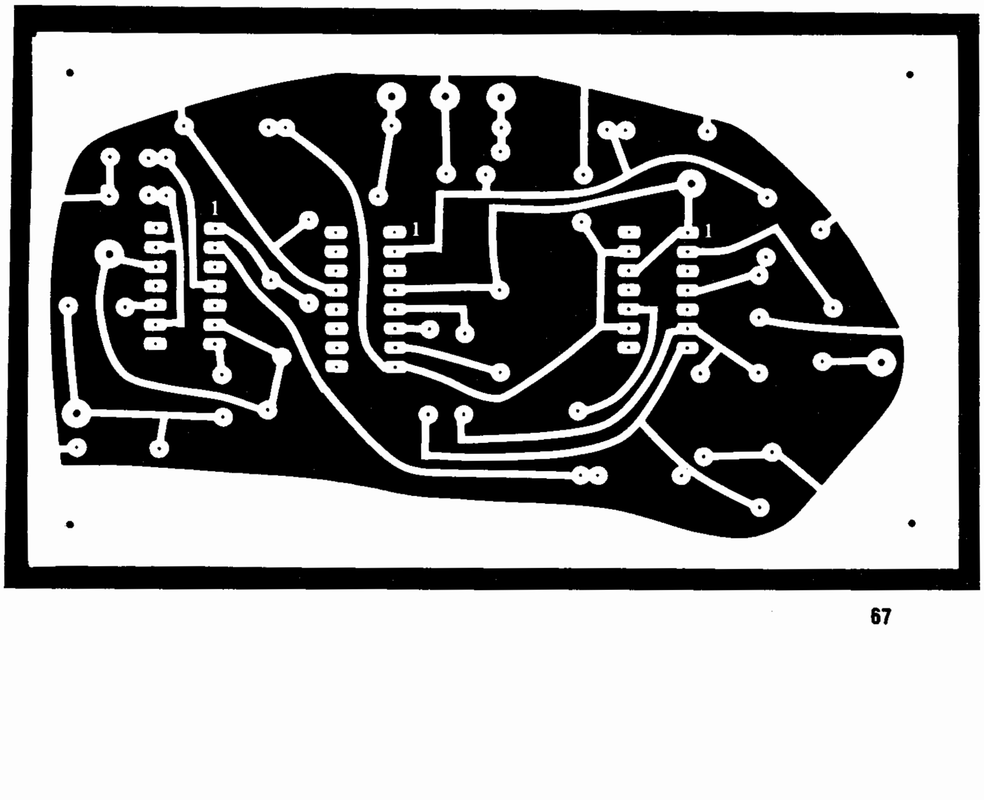


Fig. 12. Etching and drilling guide for the pc board is at right. Component layout shown above.

further adjusted and filter Q increased, the dc level will rapidly increase. Eventually, if the Q is set to high, the filter will break into oscillation. When you notice the increase, retune the sine-wave oscillator for a peak dc reading. Read the frequency off the oscillator control dial or with a frequency counter. This is the true center frequency of the filter. It may be somewhat different from the calculated f_C due to component tolerances.

As the Q increases, it will be more difficult to locate the center frequency. The band-pass slope will become very steep, so vary the oscillator frequency very slowly to be sure you are on the very top of the filter peak. Note the voltage level on the scope and adjust the vertical position control so the trace is at some convenient reference position. Retune the oscillator so that it is one-quarter octave above the center frequency you have just measured. The output voltage should decrease.

TABLE II—SELECTING LOG CONVERTER ORIGIN POINT

Total cm on Scope Face	dB/cm Desired	Total dB	Origin Voltage (volts)
10	2	20	0.100
10	3	30	0.031
8	3	24	0.063
8	4	32	0.025
6	4	24	0.063
6	3	18	0.126

Origin volts = 1/antilog(total dB/20)
Example: Scope has 6-cm vertical scale.
4 dB/cm desired yields 24 dB total.
Origin volts = 1/antilog (24/20)
= 1/antilog 1.2 = 1/15.8
=0.063 V or 63 mV

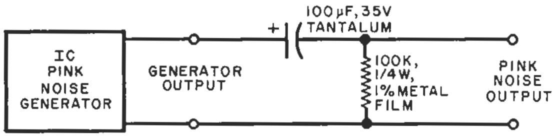


Fig. 13. Modifying the IC pink noise generator for use with the RTA.

Now, adjustments will be made so that the output will be more than 12 dB below that at the center frequency. The ideal value is −18 dB, but it is more critical to adjust the filter for the necessary response. Also, it will then be close to oscillating or ringing when excited by a steep input signal.

Alternately set the oscillator output frequency to the center frequency of the filter and at a frequency one-quarter octave away. Each time you retune the oscillator, trim the Q ADJUST potentiometer to obtain the desired response. You will find that varying this control will change the center frequency gain. Therefore, be sure to reset the center frequency output level to your reference position and/or note the new level. Keep in mind that −12 dB is 0.251 times the center frequency output level, −14 dB is 0.199, −16 dB is 0.159, and −18 dB is 0.128. When the first filter is properly adjusted, move on to the next and repeat the procedure for each remaining filter.

If the log converter has been installed and calibrated, you can use the calibrated dB (vertical) scale on your oscilloscope. Adjust the center frequency output level to equal the maximum reference level at bands 23 and 24 on the right side of the scope trace. Then tune half-way toward the next filter's center frequency and trim the Q for −12 to −18 dB as read directly on the scope. Try to adjust all filters to the same Q or bandwidth, preferably at −18 dB.

Next, the filter output LEVEL ADJUST potentiometers will be trimmed. The best way to do this is to apply pink noise to the AUX input and set the LEVEL ADJUST controls (*R75* through *R94*) to obtain a flat, horizontal scope trace. You can use the pink noise generator which appeared in the July 1977 issue of POPULAR ELECTRONICS, or one of the test records available which have a pink noise cut. If you use the pink noise generator, you must add a high-pass filter (a 100-μF tantalum capacitor and a 47,000-ohm resistor) as shown in Fig. 13. This filter will block the 8.5-volt dc level at the noise generator output, but its cutoff frequency is so low that the spectral content of the pink noise will not be disturbed.

If you don't have a pink noise generator or a suitable test record, here's a "ballpark" adjustment procedure. Find the one-half octave filter center frequency with the *lowest* output level and adjust the other filter output levels so they equal this minimum. (The variation in filter gain is partly due to the roll-off at high frequencies of the operational amplifiers' open-loop gains.)

Using the RTA. Now that you've built the RTA, how is it used? First of all, you will need a signal or sound source. This can be a frequency-swept oscillator or a wideband noise generator. There are two types of wideband noise. White noise is defined as having equal energy at all frequencies, and is thus represented on a frequency vs. amplitude plot as a straight horizontal line. Pink noise, on the other hand, is wideband noise with an amplitude characteristic that decreases 3 dB per octave.

This Analyzer is a "constant percentage bandwidth" type. That is, the bandwidth of each filter is an unchanging percentage of its center frequency. This implies that, as the center frequency increases, so does the bandwidth. If a white noise input is applied to the RTA, the "flat" signal will show a rising amplitude characteristic (see Fig. 14) as the multiplexer samples the output of higher-frequency filters. However, pink noise has a complementary decreasing characteristic (−3 dB/octave) that produces a flat display on the scope. Pink noise also more closely approximates the energy distribution of natural sounds, and thus is a more accurate source for measurements.

You will also need a microphone to pick up the sounds you want to analyze. (A microphone stand or camera tripod is very useful.) One microphone characteristic that must be known is its random-incidence response. This describes the output signal voltage generated by the

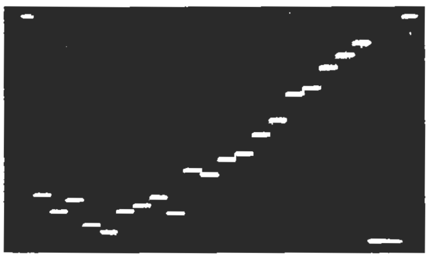


Fig. 14. Typical RTA output on a dc-coupled oscilloscope when "semi-white" noise from an FM tuner is applied to the Analyzer.

microphone when it is placed in a diffuse sound field—the most common type due to the effects of nearby reflecting surfaces. In such a field, the flow of sound energy in any direction is (almost) equally probable.

Several companies, such as General Radio and Bruel & Kjaer, supply microphones with flat random-incidence response, as well as flat 0° (perpendicular) or flat grazing (90°) incidence responses. These measurement microphones are omnidirectional. Unfortunately, most other manufacturers only supply the on-axis (0° incidence) responses of their omnidirectional microphones. This is fine if you want to perform, say, loudspeaker measurements when most of the sound comes from one direction—in the outdoors or in an anechoic chamber. Otherwise, the random-incidence response should be known.

For a high quality, wide bandwidth, omnidirectional microphone, the 70°-incidence response closely approximates the random-incidence response. Suitable dynamic measurement microphones include the AKG Model D160E (calibration curve $10 extra), the Beyer Model 101 (calibration curve included), the Electro-Voice Models RE55 and 654A (calibration curves $15 extra), the Shure Model SM76 (no charge for calibration curve) and the Sennheiser Model MD 21N (calibration curve $1 extra).

Experience has shown that rooms are best equalized first by employing acoustic methods, followed by graphic equalizer adjustments. For example, you should first try repositioning the loudspeakers, modifying the absorption coefficients in the room, and adjusting the loudspeakers' crossover level controls. Only after these steps are taken should you begin to compensate with the equalizer.

Most often, a lack of deep bass and extreme highs will show up on the scope trace. This is usually due to the limitations of dynamic drivers, and is less severe when sub-woofers and electrostatic or piezoelectric tweeters are employed. Don't use your equalizer to try to force flat response at these audio extremes. The results of such attempts frequently include overloaded amplifiers, excessive distortion, and blown voice coils. Remember—equalization should be used only as a last resort, and must not be used with a heavy hand.

There are many other uses for the RTA, as mentioned earlier. Avenues of RTA-aided research include noise pollution analysis, psychoacoustics, and circuit design. ◇

A COMPONENT CHANGE

With reference to the "Real-Time ½-Octave Analyzer" that appeared in the September and October 1977 issues of POPULAR ELECTRONICS, please be advised that there has been a component substitution. An SN76502 was originally specified for *IC36*. This particular IC has been discontinued. The new part number is TL4441CN.

Also, Table I in the article had two errors in it. The filter capacitors should be labelled *C8* and *C28* (not *C9* and *C29*) and should be 0.068 μF (not 0.047-μF). —*Richard Marsh*