Real-Time Spectrum Analyzer for your Hi-Fi

Once you can see the response of your stereo system, you can control it better with your equalizer and flatten your speaker response.

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AFTER YOU SET UP AND LISTEN TO YOUR stereo speakers in your living room, you realize that they don't give the full, just-right sound that you were hoping for. They don't sound nearly as good as they did in the stereo showroom. That situation has become a much-repeated one because your stereo system requires help in obtaining a correct response depending on the room in which it's placed.

That's why the equalizer has become a standard component of the audio system. But the equalizer isn't of any help unless it's adjusted properly to correct the response of the loudspeakers. Adjusting the equalizer for maximum performance can be a tedious and frustrating job. But it doesn't have to be. Proper equalizer adjustment can be done easily in the stereo listening room by using a real-time analyzer.

We'll show you how to build an audio-spectrum analyzer that displays a picture of any audio signal spectrum in 10 octaves. It is an economical, lab-style measuring tool capable of calibrating a wide variety of levels. For those of you with rack-mounted systems, rest assured that the PC board fits into a 19-inch rack-mountable chassis.

Why use an analyzer?

The addition of the real-time audio analyzer to your stereo system, PA, or recording console allows you to see what you're hearing. You can use it as a tool when taping: to match tapes with the original source, or to discover the playback characteristics of a tape machine. Because it reveals the spectral content of the music played, it can be used as an educational, entertaining, and colorful display.

Total system/environment control can be realized by using the analyzer with an equalizer. Analyzing the frequency response of your listening area and adjusting your equalizer is simplified because the ten octave filters are tuned to the standard ISO center frequencies that are used in most equalizers. Music can be analyzed, tape copies can be compared to originals, and equalization of live vocal or instrumental sound can be optimized. Because unwanted extraneous noise will be displayed, it can be removed. When using a microphone with a known frequency response, the built-in diagnostic signal generator provides a visual display of the reproduction characteristics in the listening environment.

The analyzer, with its several input connectors and selectable input mode, allows a variety of hookup options. For example, you can use it with a receiver, preamp, tape recorder/player, equalizer, microphone, compact disc player, home satellite receiver, mixing board or recording console. The 81-LED display forms a picture of any audio signal over a 21-dB range of energy in 3-dB steps in each of the ten standard ISO octaves.

The basics of our analyzer

Figure 1 is a block diagram of the analyzer. As you can see, there are two possible input sources, line and microphone. (As we'll soon see, there is really a third possible input source that can be selected by a front-panel rotary switch.

In the LINE mode, the analyzer will accept standard line-level (1-volt nominal) signals from devices such as preamps, receivers, tape machines, consoles, etc. In the MIC mode, the analyzer accepts the output of a dynamic microphone, which is fed into the built-in preamp. We'll see how and when to use that input shortly.

The front-panel LEVEL control sets the level of the input signal so that the highest-level signal is still in the range of the LED display. The input signal is amplified by the input driver and separated into the ten octaves by the analog bandpass-filter networks. The signals are then rectified and filtered so that the RMS amplitudes can be determined. Next the signals are multiplexed together by the diode analog multiplexer, amplified, and fed to an analog-to-digital (A/D) converter.

Logic circuitry is used to control both the diode multiplexer and the multiplexed display driver. The control logic consists of a timer, a divider, and a 1-of-10 decoder.

The A/D converter takes the analog voltage and drives the 80-LED display. Each LED-step vertically represents a gain in amplitude of 3 dB. The horizontal axis of the LED matrix represents frequency. When a signal in any frequency range drives the device higher than the 21-dB range, the OVERSCALE LED lights. When that happens, simply use the LEVEL control to bring the signal back into the range of the analyzer

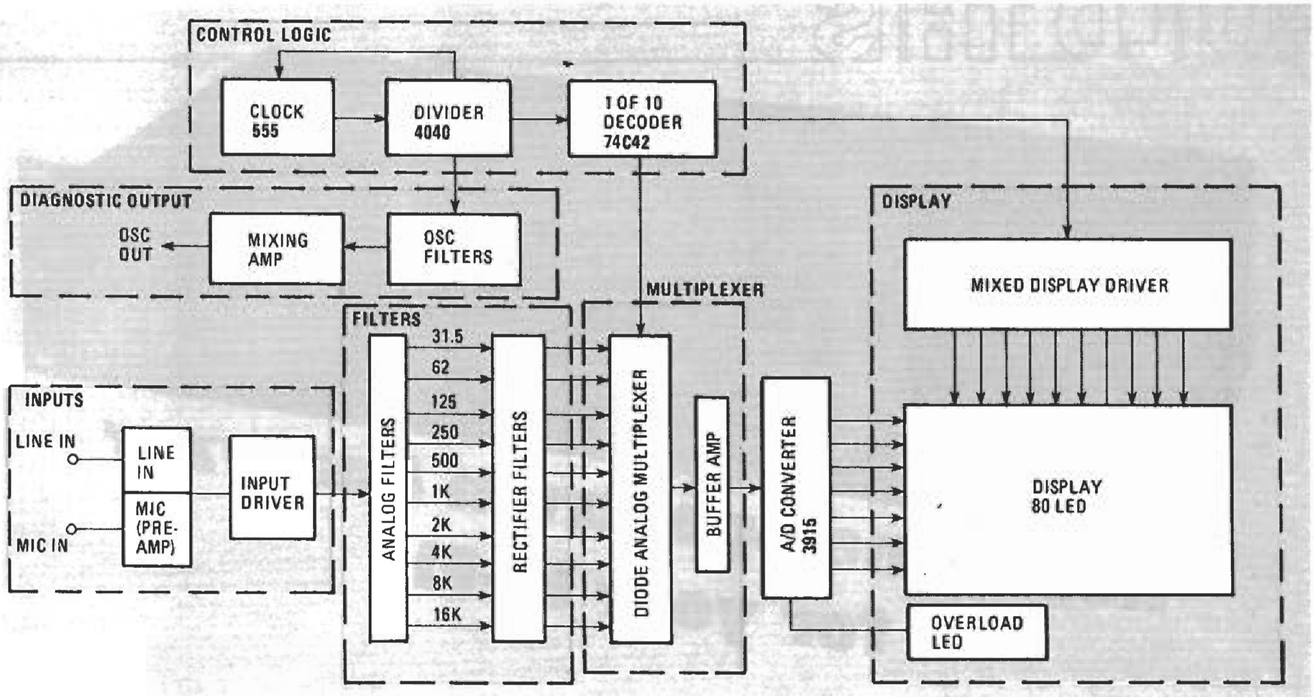


FIG. 1—AUDIO ANALYZER BLOCK DIAGRAM. The diagnostic output can also be used as an input to the analyzer for calibration purposes.

A *diagnostic sweep signal*, which is used to calibrate the equalizer, is controlled by the clock and the divider. A 555 timer is used as an oscillator, which is filtered to obtain frequencies for testing at all 10 octaves. The generated signals are mixed together, filtered, and then sent to the oscillator output. That output can be fed to speakers (via the stereo system) and picked up by a microphone in order to calibrate the equalizer. That diagnostic signal can also be chosen as an input by the front-panel mode switch. That lets you view the response of the analyzer as all the frequencies are swept.

How the circuit works

Figure 2 is the schematic of the analyzer. As you can see there, a three-position rotary switch, S1, selects the appropriate input. The LINE input is configured to allow either separate right- and left-channel inputs or a balanced input. In other words, the input can be the right channel and ground, the left channel and ground, or the right plus left for balanced line in. In either case, the input signal goes into a line buffer or mixing amplifier made up of R11–R15, C6, C7, and IC1-*b*.

A microphone input is also included for low-impedance dynamic microphones. Since the output of a dynamic microphone is at a very low level, the signal must be preamplified. The microphone preamp section is made up of R2, R3, R8, R9, C2, C56, IC1-c, and IC1-d. If you want to use a condenser microphone, then you'll have to add R1, R4, R5 and C1, as shown in the dashed box in Fig. 2.

The 100K front-panel LEVEL control, R113, sets the input level for the input driver stage (which consists of R16, R18, R19, C13, and IC4-a.) That stage supplies a low-impedance signal source for the analog filters. Each basic filter has the same configuration, but the frequency is selected by the value of the capacitors. Figure 3 shows the basic filter, while Table 1 gives the values of C and corresponding filter frequencies.

The rectifier filters and the diode multiplex network are identical for all frequencies. The output of the analog filter op-amp is rectified by a small-signal diode in series with a 10K resistor and a 1-µF capacitor connected to the negative supply. For the 30-Hz frequency, for example, the rectifier filter is D5, R52, and C14. The diode multiplexer buffer amp IC4-b is driven by the diode networks and consists of R17, R20, R21, and IC4-b.

The control logic determines which frequency's signal is presented to the multiplexer buffer amp. The 555 timer, IC8, is controlled by R74, R75, and C44 to operate as a 16-kHz oscillator, triggered and reset on the trailing edge of each pulse.

The output of the 555 feeds IC5, a 4040 12-stage ripple-carry binary counter. As the counter counts up, resets and repeats, the output pin 1 is fed back through R80 and C3 to the frequency-modulating pin 5 of IC8. That causes the oscillator's output to warble up and down about 1/2 octave. The output pins of IC5 (pins 2, 3, 4, and 13) are fed to IC6, a 74C42 BCD-to-decimal decoder. The 74C42 converts the signal at its A, B, C, and D inputs to a logic zero on the appropriate output from 0–9.

Those outputs are connected both to the diode multiplexer and the display multiplexing network. As the 74C42 counts from 0-9 it enables each of the frequencies in turn to feed through the multiplexer buffer amp, thereby presenting each octave's analog voltage to IC7, an A/D converter. Resistors R77 and R78 form a voltage divider to provide IC7 with a reference voltage; the IC senses the analog voltage input and fires the output LED corresponding to that voltage. Each output corresponds to a 3 dB step in a 21 dB range.

At the same time, the 74C42 enables the particular octave to be sensed by the A/D, it also enables the display driver for that frequency. The multiplexed display driver consists of PNP transistors Q2–Q11, which are biased by R81–R90.

Overscale is indicated by Q1, R76, and D36. The base of Q1 is enabled by the 4040 (IC5), and the collector is connected to the output of the A/D converter corresponding to the highest analog level. When that output is activated the transistor is forward biased and turns on D36, the OVERSCALE LED.

The diagnostic sweep signal is generated and controlled by the logic circuitry as well. Ten oscillator filters are formed by R91–R110 and C26, C29, C32, C35, C38, C41, C45, C48, C51, C54. Those filters convert the squarewave outputs of IC5 to ramp waves. Table 1 shows the relationship between filter capacitance and frequency.

The 555 timer fires and pulses a signal to the first filter then, as the counter counts, the 16 kHz is divided down to produce a center oscillating frequency for all the octaves. The resulting signals are presented to the mixing amp formed by

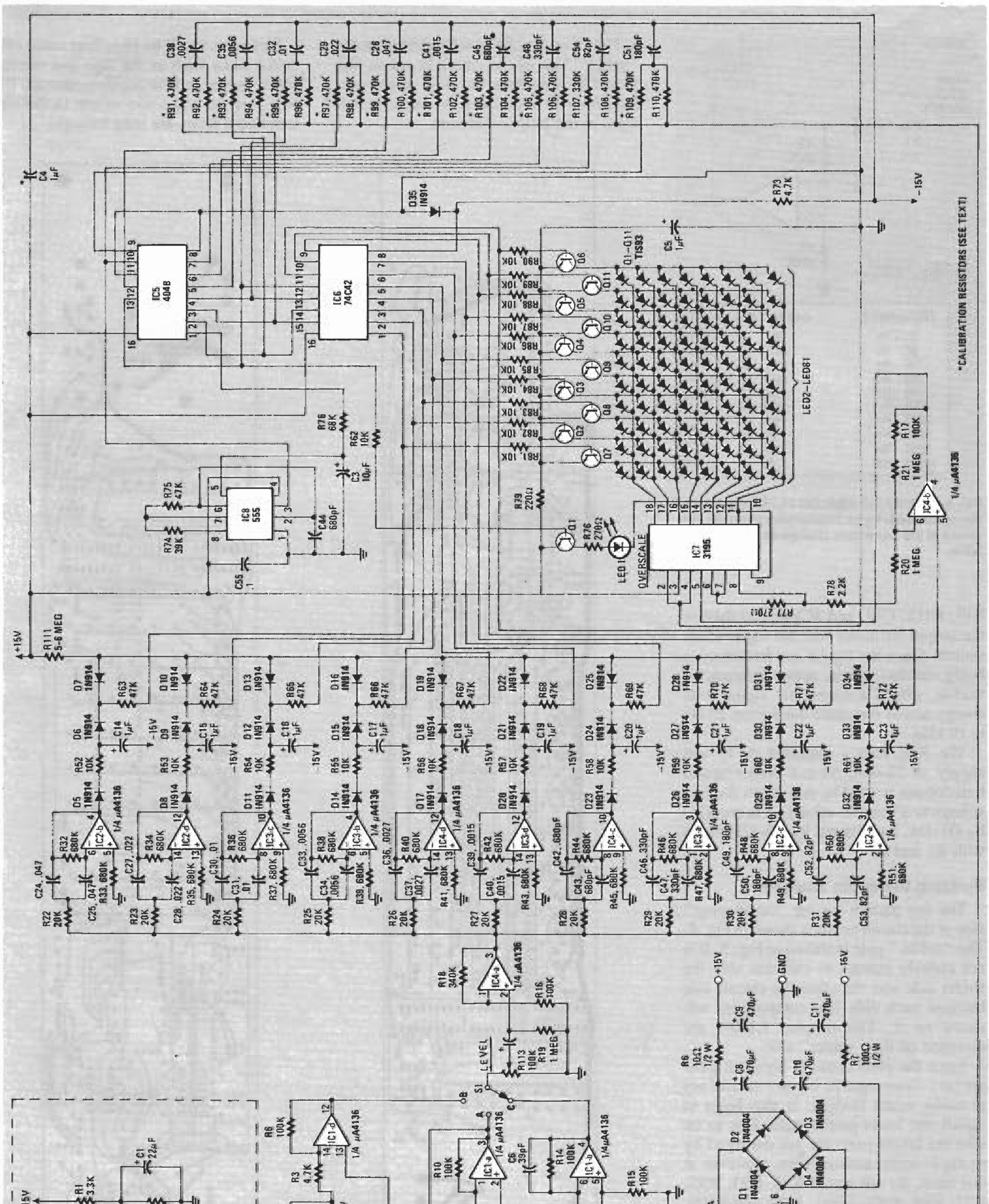
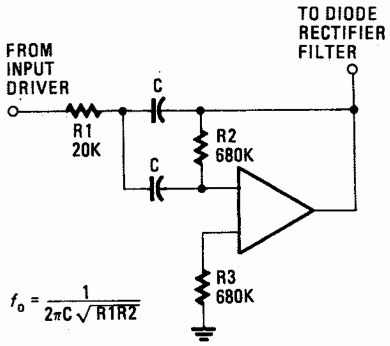


FIG. 2—THE AUDIO ANALYZER SCHEMATIC. If you want to use a condenser (or electrostatic) microphone, the components shown in the dashed box must be installed.



FREQUENCY	CAPACITANCE
31.5 Hz	.047 μF
62 Hz	.022 μF
125 Hz	.01 μF
250 Hz	.0056 μF
500 Hz	.0022 μF
1000 Hz	.0015 μF
2000 Hz	680 pF
4000 Hz	330 pF
8000 Hz	180 pF
16000 Hz	82 pF

FIG. 3—THE BASIC ANALOG FILTER configuration is the same for all frequencies. However, the values of the capacitors change as shown in the table.

R10, R112, C12, and IC1-a, and then to the output terminals and the input-select switch. Since the top-octave frequency is being warbled, all the octave frequencies warble, giving a diagnostic signal with energy across the audio band from 25 Hz to 19 kHz.

The 1081 uses a standard ± 15 volt supply. A 22-volt, 50-mA center-tapped transformer is used to step down the line voltage to a useable value that is rectified by D1–D4, and filtered by C8–C11 along with R6 and R7.

Building the audio analyzer

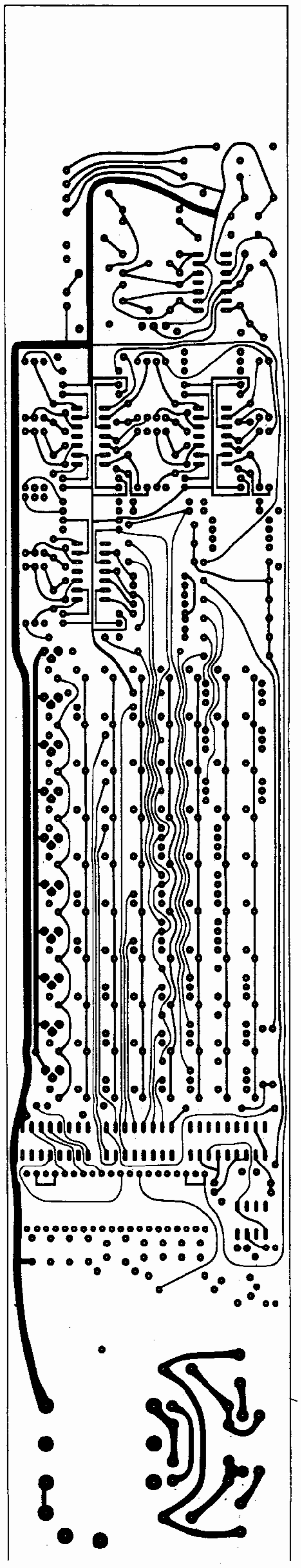
The foil pattern for the "component" side of the circuit board is shown in Fig. 4. The "solder" side is shown in Fig. 5. It is not entirely correct to call one side the solder side and the other the circuit side because each side has components soldered to it. The display LED's are mounted on the "solder" side.

Since the parts count is high and parts are very close together be *very careful* not to cause solder bridges. It also helps to install the lower-profile parts first to be sure the larger parts are not damaged by trying to solder around them. However, at this time, do not install R91, R93, R95, R97, R99, R101, R103, R105 and R109. You can put them in position, but do not solder them. We will return to those devices when we calibrate the unit.

We should remind you that the 74C42 and 4040 (IC6 and IC5) are CMOS devices. Because CMOS devices can be easily damaged by static discharges, they must be handled with proper care.

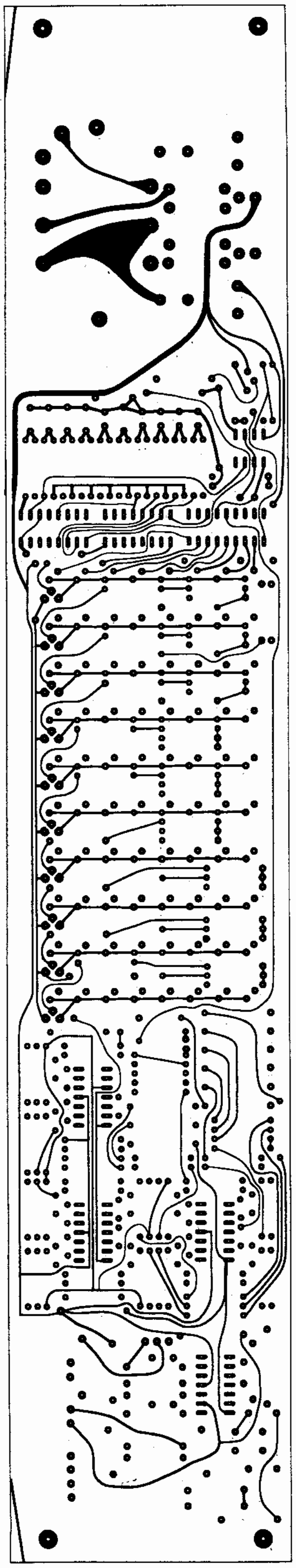
A parts-placement diagram for the audio-analyzer circuit board is shown in Fig. 6. Note that the LED's are mounted on the "solder" side of the circuit board so that they'll be seen from the front of the cabinet. As with any diodes, be sure to install them in the proper direction.

Note that you'll be installing some off-board jacks such as the line and microphone inputs and the oscillator output. Be sure that the wires you mount in the circuit-board holes are long enough!



|←——3 INCHES——→|

FIG. 4—THE COMPONENT SIDE of the analyzer circuit board is shown here half-sized.



|←——3 INCHES——→|

FIG. 5—THE SOLDER SIDE of the analyzer circuit board is shown here half-sized.

PARTS LIST

All resistors are ¼ watt, 5% carbon-film types unless otherwise indicated.

R1—3300 ohms (Optional)
R2, R3, R73—4700 ohms
R4—2200 ohms (Optional)
R5—1000 ohms (Optional)
R6—10 ohms, ½ watt, 5%
R7—100 ohms, ½ watt, 5%
R8–R17—100,000 ohms
R18—390,000 ohms
R19–R21—one megohm
R22–R31—20,000 ohms
R32–R51—680,000 ohms
R52–R62, R81–R90—10,000 ohms
R63–R72, R75—47,000 ohms
R74—39,000 ohms
R76, R77—270 ohms
R78—2200 ohms
R79—220 ohms
R80—6800 ohms
R91, R93, R95, R97, R99, R101, R103, R105, R109—Put in 470,000-ohm units but do not solder them! These are calibrating resistors. See the text for details.
R92, R94, R96, R98, R100, R102, R104, R106, R108, R110—470,000 ohms
R107—330,000 ohms
R111—5.6 megohms
R112—1000 ohms
R113—100,000 ohms, linear potentiometer

Capacitors

C1—22µF, optional
C2, C3—10µF
C4, C5, C12–C23, C56—1µF, 50 volts, electrolytic
C6, C7—39 pF, ceramic disc
C8–C11—470 µF, 35 volts, electrolytic
C24, C25, C26—0.047 µF, Mylar
C27, C28, C29—0.022 µF, Mylar
C30, C31, C32—0.01 µF, Mylar
C33, C34, C35—0.0056 µF, Mylar
C36, C37, C38—0.0027 µF, Mylar
C39, C40, C41—0.0015 µF, Mylar
C42, C43, C44, C45—680 pF, ceramic disc
C46, C47, C48—330 pF, ceramic disc
C49, C50, C51—180 pF, ceramic disc
C52, C53, C54—82 pF, ceramic disc
C55—0.1 µF, ceramic disc

Semiconductors

IC1–IC4—µA4136 quad op-amp (Fairchild, or Exar XR4136)
IC5—4040 ripple-carry binary counter
IC6—74C42—4- to 10-line decoder
IC7—3915 dot/bar display driver
IC8—555 timer
Q1–Q11—TIS93 (ECG159)
D1–D4—1N4004
D5–D35—1N914
D36–D116—miniature red LED

Other components:

S1—2 pole, 3 position rotary switch
T1—transformer, 22 volts, 50 mA center-tapped

The following are available from COTA, 3314 H Street, Vancouver, WA 98663 (206) 693-3834: Circuit board and 28 page manual, $38.50. All orders should add $4.50 shipping and handling.

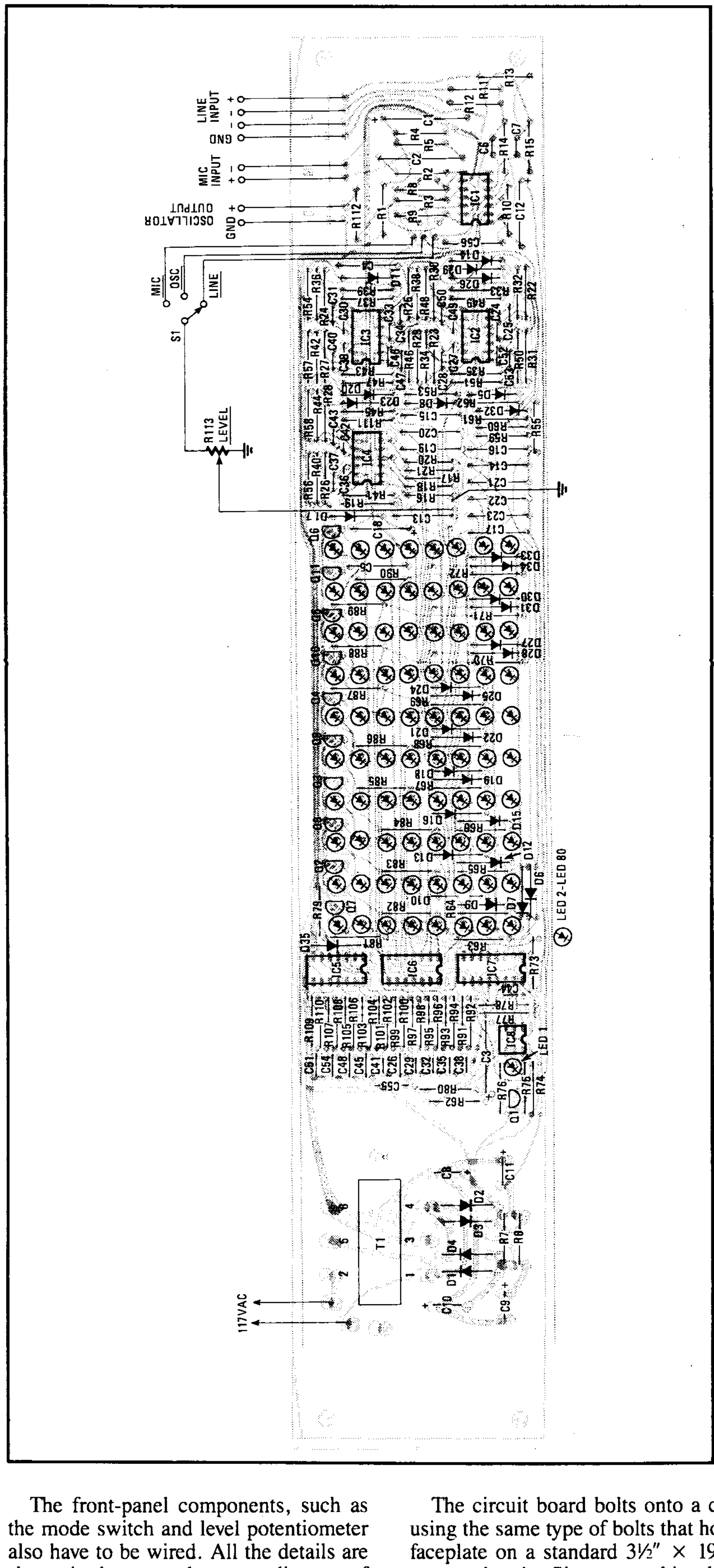


FIG. 6—PARTS PLACEMENT DIAGRAM. Note that the LED's are mounted on the solder side of the board so they can be seen when it is mounted in a cabinet.

The front-panel components, such as the mode switch and level potentiometer also have to be wired. All the details are shown in the parts-placement diagram of Fig. 6. The same is true for the connections to switch S1.

The circuit board bolts onto a chassis using the same type of bolts that hold the faceplate on a standard 3½" × 19" rack mount chassis. Since everything but the select switch and level control are circuit-

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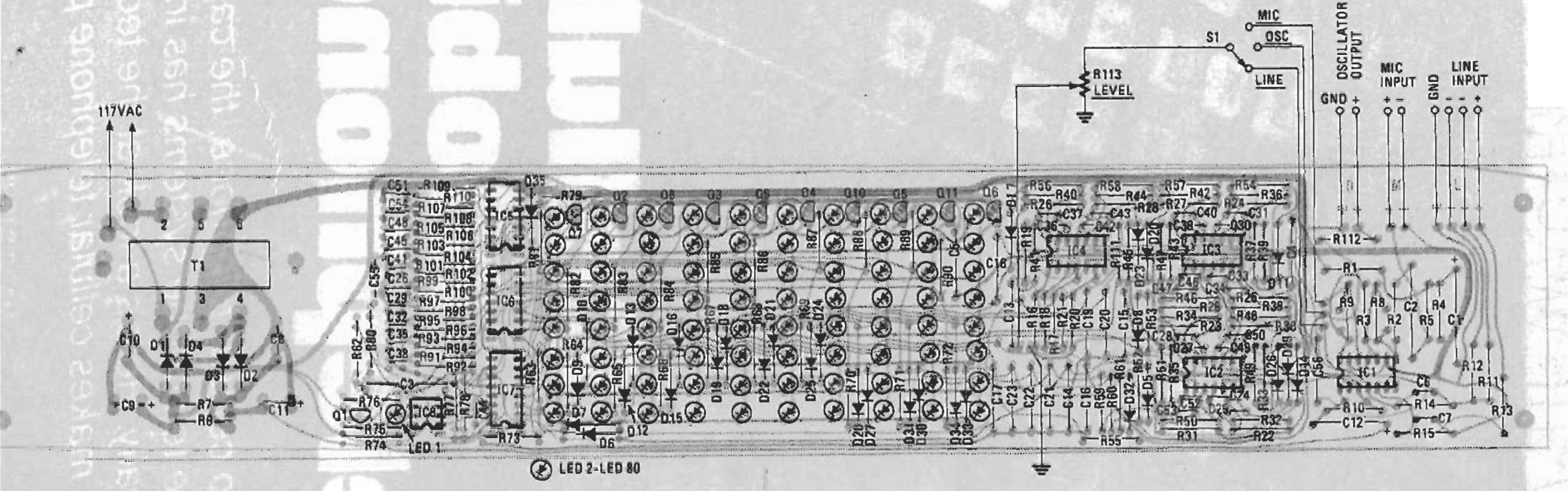
117VAC
T1
MIC
OSC
LINE
S1
R113
LEVEL
OSCILLATOR
OUTPUT
GND
MIC
INPUT
LINE
INPUT
LED 1
LED 2-LED 80

SPECTRUM ANALYZER

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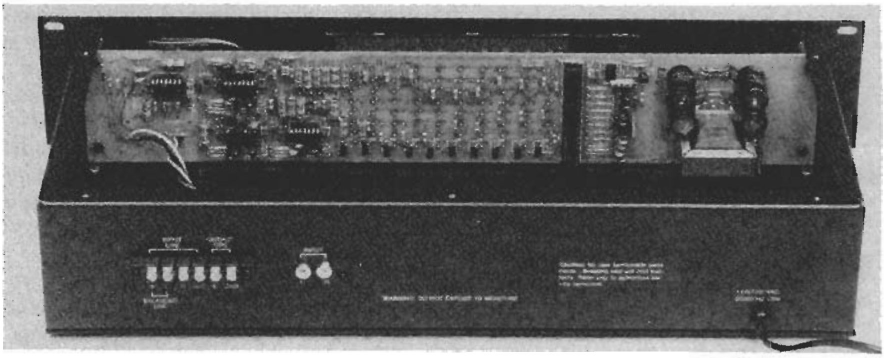

FIG. 7—THE COMPLETED ANALYZER, mounted in a 19-inch rack cabinet. Since most of the components are mounted on the circuit board, there is a lot of room inside the cabinet.

board mounted, the depth of the switch and potentiometer will determine the length of the standoffs you'll require. If you use very low-profile parts for that section, you'll be able to bolt the circuit board very close to the faceplate. That will give excellent visibility to the LED's. A red plastic filter may be glued on the back of the window for a professionally finished display.

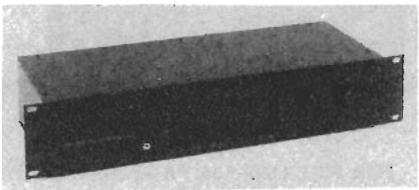

FIG. 8—THE REAL-TIME AUDIO ANALYZER as seen from the front. It is very clean in appearance and will look right at home with your stereo system.

Calibrating the analyzer

The following resistors should be placed in position but not soldered: R91, R93, R95, R97, R99, R101, R103, R105 and R109. To calibrate the analyzer:

- The unit should be powered up with the selector switch in the oscillator-output position (AUX). That will display the oscillator output.
- The LEVEL potentiometer, R113, should be adjusted until the LED's make the straightest possible horizontal line with one LED lit per octave. The level should be played up and down until the straightest line is achieved.
- It is normal for some of the LED's to be higher or lower than what is desired.
- Table 1 lists the resistors for each respective octave. Using the chart, replace the resistor for the lowest octave that has a LED too low with a 430K calibrating resistor. Be sure to remove power from the unit anyting you replace resistors!
- Readjust the level control for the straightest possible line. Since all of these parts are interactive, each change may alter the line. Repeat the process for all of the LED's that are too low, lowest octaves first, until all that is remaining is a straight line and LED's that are too high.
- The procedure is again repeated for the high LED's, beginning with the lower octaves. The resistors removed for the high LED's are to be replaced with 520K calibrating resistors.

TABLE 1

Octave	Resistor
31.5	R99
62	R97
125	R95
250	R93
500	R91
1K	R101
2K	R103
4K	R105
8K	R109

To re-iterate, the steps are to: a) Find the lowest octave that has a LED too low. b) Find the resistor number for that octave. c) Replace that resistor with a 430K calibrating resistor. d) Readjust level control for straightest line. e) Repeat until only straightest line with LED's too high remain. f) Find the lowest octave that has a LED too high. g) Replace that resistor with a 520K ohm calibrating resistor. h) Readjust level control for straightest line. i) Repeat until only a horizontal straight line of LED's is visible.

The audio analyzer is now calibrated. The calibration resistors can now be soldered in place and the leads clipped to proper length.

The addition of the real-time analyzer to a stereo system, PA, or recording console allows you to see what you're hearing (or what you're not hearing). It can be used as a tool when taping (to match tapes with the original source, or to discover the playback characteristics of a tape machine). As it reveals the spectral content of the music played it can be enjoyed as an educational, entertaining, and colorful display. **R-E**