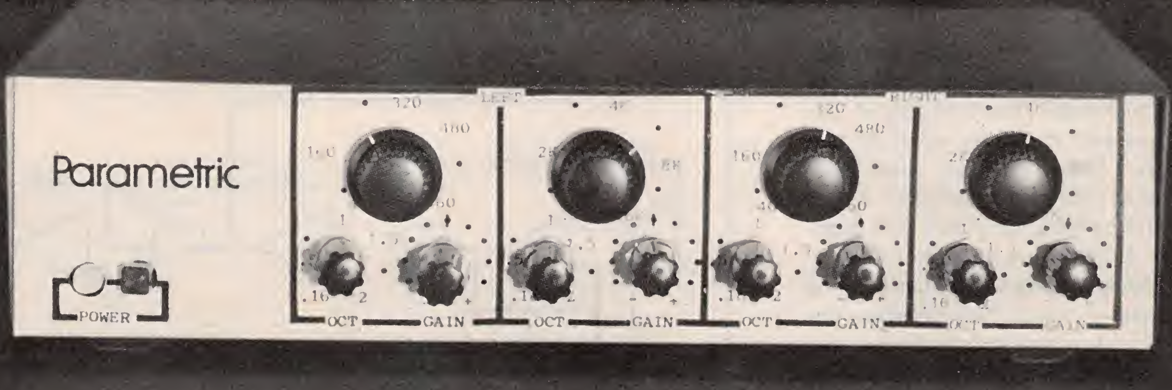
BY JOHN H. ROBERTS



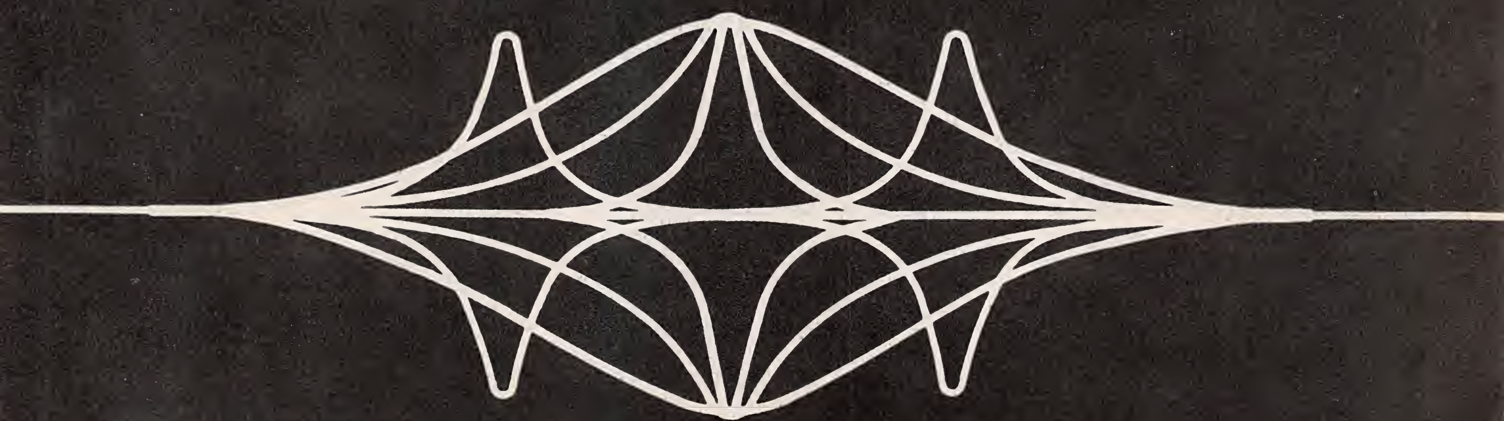
TAILOR THE SOUND OF YOUR AUDIO SYSTEM WITH THIS STEREO PARAMETRIC EQUALIZER

Low-cost, high-performance component employs BIFET operational amplifiers, can be powered by dc or ac sources.

AS THE state of the audio art has matured, whole new families of sophisticated components generically known as *signal processors* have become available for use in sound systems. Among the most popular category of signal processors is the equalizer. And the subcategory that has generated the most excitement among serious audio enthusiasts and sound professionals is the parametric equalizer.

As its name implies, each of the parametric equalizer's key parameters—its center frequency, filter bandwidth or Q, and amount of boost or cut introduced—can be independently adjusted. This provides extraordinary flexibility, allowing the user to tailor equalization to the precise needs for a particular program or room/system combination.

Presented here is a two-band parametric stereo equalizer with several features that commend it to the audiophile. It has been designed so that the Q and BOOST/CUT controls interact to compensate for the perceived change in loudness as filter bandwith increases or decreases. Furthermore, the circuit employs high-performance BIFET op amps, which combine the best of both junction-field-effect and bipolar-junction transistors in each amplifier. It can be powered by either the ac line or a 12-to-30-volt dc supply, making it equally "at home" in fixed, mobile, or portable applications. Finally, the Parametric Equalizer is relatively inexpensive—a line-powered stereo kit costs $99.00.



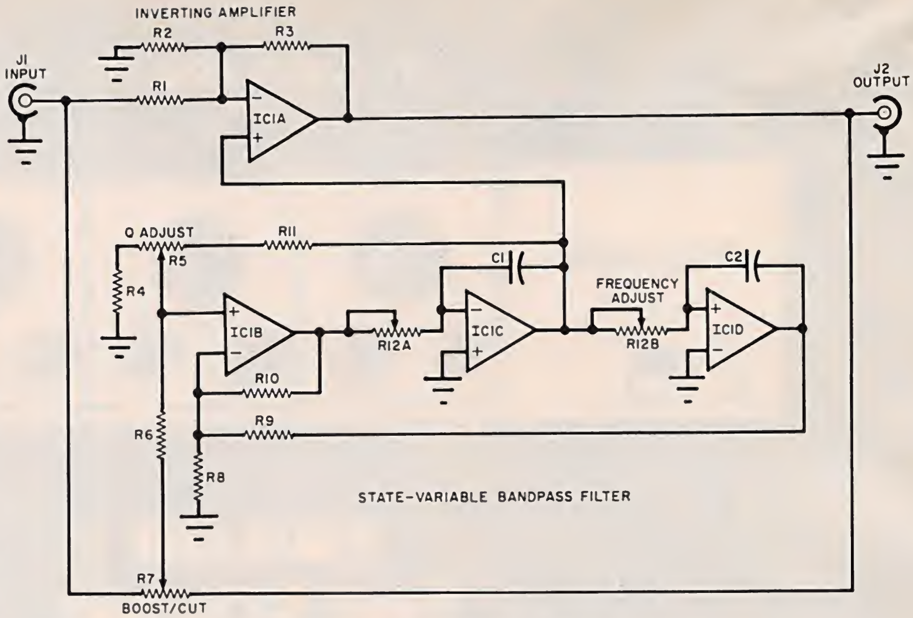
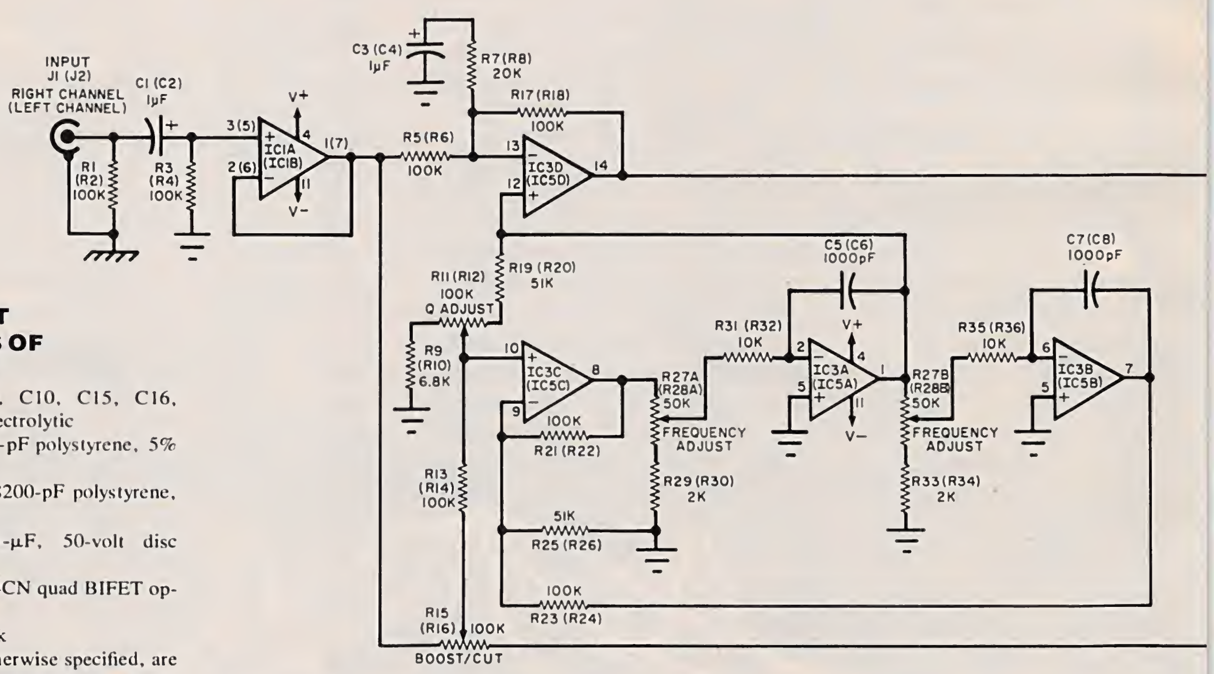


Fig. 1. Simplified schematic of one channel of equalizer shows that an inverting amplifier is interconnected with a modified state-variable active bandpass filter.

A Short Course In Equalization. Here's a brief overview of the subject of audio equalization. The category of signal processors known as equalizer can be broken down into three subcategories: tone control or shelving types; graphic or peaking equalizers; and parametrics. All three are capable of boosting or cutting signal levels, but differ in the manner in which they generate the boost or cut, in the shapes of the frequency-response curves they produce, and in the size of the band of frequencies which they affect.

Tone controls are characterized by a gradual transition between the non-boosted and fully boosted (or unattenuated and maximally attenuated) frequency bands, levelling off to a fixed amount of boost or cut. The resulting frequency-response curve takes on the appearance of a shelf, giving rise to the name *shelving equalizer*.

Graphic equalizers divide the audio spectrum into a given number of bands with individual boost/cut controls for each band. The transition between the unaffected and fully affected regions is determined by the number of bands in the graphic equalizer. An inexpensive five-band or two-octave (so called because each band is two octaves wide) has a lower filter Q and therefore more effect over frequencies somewhat removed from the band of interest than a sophisticated professional equalizer which breaks the audio spectrum down into 30, one-third-octave-wide bands. In most consumer graphic equalizers, the center frequency of each band is fixed, although some more sophisticated units (and most professional graphics) allow the user some leeway in setting the center frequencies. The family of frequency-response curves generated by a graphic



MAIN PARTS LIST (TWO CHANNELS OF EQUALIZATION)

C1, C2, C3, C4, C9, C10, C15, C16, C20—1-μF, 25-volt electrolytic
C5, C6, C7, C8—1000-pF polystyrene, 5% tolerance
C11, C12, C13, C14—8200-pF polystyrene, 5% tolerance
C17**, C18**, C19*—0.1-μF, 50-volt disc ceramic
IC1 through IC5—TL074CN quad BIFET operational amplifier
J1, J2, J3, J4—Phono jack
The following, unless otherwise specified, are ¼-watt, 5% carbon-film fixed resistors.
R1 through R6, R13, R14, R17, R18, R21, R22, R23, R24, R37, R38, R45, R46, R49, R50, R53, R54, R55, R56, R74, R75—100,000 ohms
R7, R8, R39, R40, R63, R64, R67, R68—20,000 ohms
R9, R10, R41, R42—6800 ohms
R11, R12, R15, R16, R43, R44, R47, R48—100,000-ohm, linear-taper potentiometer
R19, R20, R25, R26, R51, R52, R57, R58—51,000 ohms
R27, R28, R59, R60—dual 50,000-ohm linear-taper potentiometer
R29, R30, R33, R34, R61, R62, R65, R66—2000 ohms
R31, R32, R35, R36—10,000 ohms
R69, R70—100 ohms
R71**, R72**, R73*—10 ohms
Misc.—Printed circuit board, pc standoffs, IC sockets or Molex Soldercons, hookup wire, shielded cable, solder, machine hardware, control knobs, suitable enclosure, etc.
*—Dc version only
**—Ac version only

equalizer resembles a series of peaks and valleys. That's why some audiophiles refer to graphic equalizers as "peaking" types.

The parametric equalizer is a variation on the graphic equalizer theme. In addition to an individual boost/cut control, each band of a parametric equalizer also has center-frequency and bandwidth or filter Q controls. This means that the amount of boost or cut introduced, the center frequency of the band of equalization, and the bandwidth within which the equalization is applied (as well as the transition between the frequencies that are unaffected and those which are boosted or cut the most) are all independently variable. The parametric equalizer thus gives its user the ultimate in control over the sound recorded on tape or reproduced by his speakers.

About the Circuit. A simplified schematic of the Parametric Equalizer is shown in Fig. 1. Only one equalizer section of one channel's circuit is shown, and input buffering and output decoupling details are omitted. Similarly, power supply connections are not shown. It can be seen that the simplified schematic is that of an inverting amplifier (*IC1A*, *R1*, *R2*, and *R3*) interconnected with a modified "state variable" active bandpass filter. Such a filter is composed of two active integrators connected in cascade (*IC1C*, *IC1D* , and associated passive components) and a differential amplifier (*IC1B* and associated passive components).

PERFORMANCE SPECIFICATIONS
(Supplied by the Author)

Center frequency range: 40 to 16,000 Hz in two bands—40 to 960 Hz, 500 to 16,000 Hz

Frequency response: 3 to 100,000 Hz, +0 dB, −1 dB with all controls at their flat settings

Input impedance: 50,000 ohms

Input/output gain: 0 dB

Intermodulation distortion (SMPTE): Less than 0.007%

Maximum output: 8 volts rms into a 10,000-ohm load when powered by ±15-volt supply

Maximum boost/cut: ±20 dB at 0.16-octave bandwidth

Output impedance: 100 ohms

Output noise: −70 dBm unweighted, −89 dBm "A" weighted

Range of Q adjustment: 0.16 to 2 octaves (−3-dB bandwidth)

Total harmonic distortion plus noise: below 0.04% from 20 to 20,000 Hz

This circuit was chosen for use in the Parametric Equalizer because its center frequency and Q can be varied independently of each other. The filter's center frequency is selected by adjusting dual potentiometer *R12*. Filter bandwidth and Q are dependent upon the values of *R4* and *R11* and the setting of potentiometer *R5*. For the component values employed in this project, filter bandwidth and Q can be adjusted over a range of 0.16 to 2 octaves at the −3-dB points. (The relationship between bandwidth at the −3-dB points and filter Q is given by the simple equation $BW_{-3\,dB} = 1 / Q$.)

To convert a state variable active bandpass filter into the desired all-pass circuit with adjustable boost and cut, a potentiometer (*R7*) is connected between the inverting input and the output of unity-gain amplifier *IC1A*. The wiper of this potentiometer is connected to the input of differential amplifier *IC1B*. Signals appearing at the output of integrator *IC1C*, which are inverted with respect to those appearing at its input, are applied to the noninverting input of *IC1A*.

When the wiper of *R7* is at the *J1* extreme of its travel, the bandpassed signal adds to the input signal, boosting the amplitude of signals within the filter's passband. When the wiper is at the *J2* extreme of its travel, the bandpassed

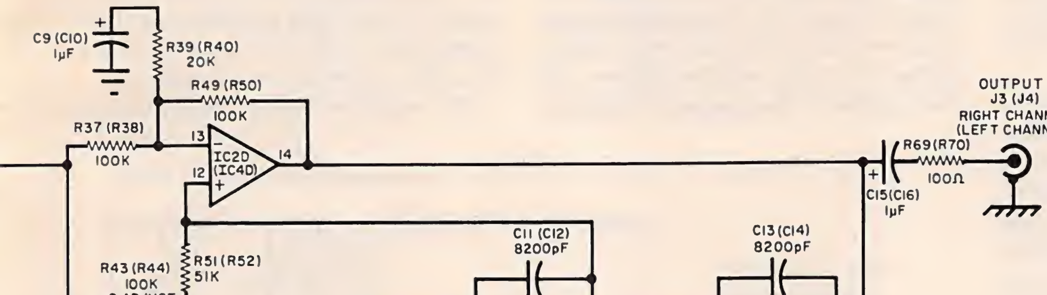


Fig. 2. The complete circuit for a two-channel equalizer. Part numbers not in parentheses are for right channel of a stereo system, others are for left channel. For components with asterisks, see Figs. 3 and 4.

Parts Availability

Note—The following are available from Phoenix Systems, 375 Springhill Road, Monroe, CT 06468 (203-261-4904): Complete kit of parts including enclosure for ac-powered stereo equalizer (No. P-94-S) for $99.00; Complete kit of parts including enclosure for dc-powered stereo equalizer (No. P-94-SC) for $89.00. Also available separately: etched and drilled main printed circuit board (No. P-94-AB) for $8.00; 20-volt center-tapped stepdown transformer (No. P-94-T) for $6.50; etched and drilled ac power supply board (No. P-94-PSB) for $4.00; TL074CN quad BIFET operational amplifier IC (No. P-94-C) for $2.50; dual 50,000-ohm, linear-taper, closely tracking potentiometer (No. P-94-2X50KB) for $2.50; etched and drilled dc power supply board (No. P-94-PSBC) for $4.00; 100,000-ohm, linear-taper potentiometer (No. P-94-100KB) for $1.00; p.c.-mount, push-on/push-off power switch (No. P-94-S1) for $1.00. Add $1.00 handling charge for orders less than $10.00. Add $1.00 for COD orders. Canadians add $2.50 postage. Connecticut residents add state tax.

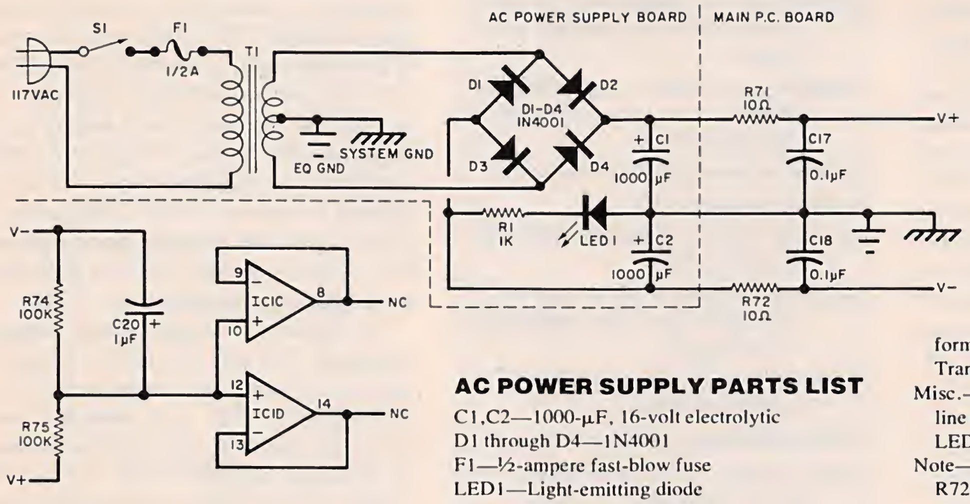


Fig. 3. Schematic of power supply to use with an ac source. It is a conventional full-wave circuit giving plus and minus 15 volts to ground.

AC POWER SUPPLY PARTS LIST

C1,C2—1000-μF, 16-volt electrolytic
D1 through D4—1N4001
F1—½-ampere fast-blow fuse
LED1—Light-emitting diode
R1—1000-ohm, ¼-watt, 5% resistor
S1—Spst switch
T1—20-volt, center-tapped stepdown transformer, secondary rating 100 mA (Signal Transformer No. ST-4-20 or equivalent)
Misc.—Printed circuit board, pc standoffs, line cord, strain relief, hookup wire, solder, LED mounting collar, hardware, etc.
Note— Components C17, C18, C20, IC1, R72, R74 and R75 are mounted on the project's main printed circuit board and are included in the Main Parts List. See Fig. 1 for Parts Availability.

signal subtracts from the input signal, attenuating input signals within the passband of the active filter. Finally, when the wiper of *R7* is at the midpoint of its travel, the output of *IC1A* cancels out that portion of the input signal appearing at the wiper because the two signals are 180° out-of-phase. This means that no signals are routed to the bandpass filter, the filter generates no output, and has no effect on *IC1A*. The result is that inverting amplifier *IC1A* exhibits a flat frequency response.

There are two equalizer sections for each signal channel. (Only one section is shown in Fig. 1.) The center frequency of the low-band equalizer can be adjusted from 40 to 960 Hz, and that of the high-band equalizer from 500 to 16,000 Hz. Both the setting of the BOOST/CUT potentiometer and the value of filter Q determine the amount of boost or cut introduced by each equalizer section. The maximum boost or cut is ±20 dB at a filter bandwidth of 0.16 octave, and ±12 dB at a bandwidth of 2 octaves. This interaction makes the Q control more convenient to use because parametric designs not incorporating it often require readjustment of equalizer gain after the filter Q has been changed.

The master schematic of the main Parametric Equalizer circuit is shown in Fig. 2. The most likely application for this project is in a stereo sound system, so the schematic describes a two-channel equalizer. All components pertaining to the right signal channel have part numbers not shown in parentheses. Those for the left channel, however, have part numbers which are shown in parentheses. The rest of this discussion will refer only to the right signal channel but is equally applicable to the left.

Input signals are applied to jack *J1*, where *R1* and *R3* (which are effectively in parallel) provide a high-impedance load. Capacitor *C1* blocks any dc level that might be accompanying the input signal. Buffering is accomplished by voltage follower *IC1A* which isolates the input from the rest of the circuit. Output signals from the voltage follower are then applied to two cascaded equalizer sections, each of which employs a TL074CN quad BIFET operational amplifier IC.

Each section closely resembles the simplified schematic shown in Fig. 1. That employing *IC3* is the high-band equalizer circuit. Its center frequency is adjustable by means of dual potentiometer *R27* over a range of 500 to 16,000 Hz. Potentiometer *R11* is the filter's Q ADJUST control and potentiometer *R15* (along with the Q of the filter) determine the amount of boost or cut introduced.

The second equalizer circuit (the one

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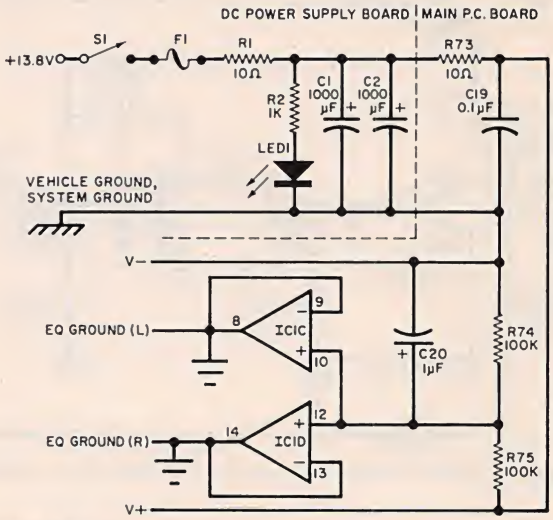

Fig. 4. Use this circuit if a dc supply is to be employed. The IC voltage followers derive an artificial equalizer ground.

DC POWER SUPPLY PARTS LIST

C1,C2—1000-μF, 16-volt electrolytic
F1—½-ampere fast-blow fuse
LED1—Light-emitting diode
R1—10-ohm, ¼-W, 5% resistor
R2—1000-ohm, ¼-W, 5% resistor
S1—Spst switch
Misc.—Printed circuit board, pc standoffs, machine hardware, etc.
Note—Components C19, C20, IC1, R73, R74, and R75 are mounted on the project's main printed circuit board and are included in the Main Parts List. See Fig. 1 for Parts Availability.

employing *IC2*) is the low-band unit. Dual potentiometer *R59* allows adjustment of its center frequency over a range of 40 to 960 Hz. The filter's Q is adjusted by varying the setting of potentiometer *R43*. Signals within the filter passband can be boosted or cut by means of potentiometer *R47*.

Output signals from *IC2D* are coupled to output jack *J3* via *C15* and *R69*. The electrolytic capacitor blocks any dc offset appearing at the output of the operational amplifier and the resistor provides decoupling. Signals can be routed from the output jack back to the tape monitor loop of a preamplifier or receiver, if that is where drive signals were taken, or to the input of the power amplifier if drive is obtained from the preamplifier output.

Power supply details are omitted from the main schematic for simplicity's sake, but each IC's power supply pins are denoted. The Parametric Equalizer can be powered by either the ac line or a 13.8-volt dc automotive electrical system. Schematic diagrams of the ac and dc supplies are shown in Figs. 3 and 4, respectively. The ac supply is a conventional full-wave circuit employing a 20-volt, center-tapped transformer. Diodes *D1* through *D4* rectify the low-voltage ac into bipolar, pulsating dc which is filtered by *C1* and *C2*. Light-emitting diode *LED1* functions as a pilot light. All components except for decoupling resistors and capacitors *R71*, *R72*, *C17* and *C18* are mounted on a separate power supply circuit board. The output of the supply is ±15 volts dc.

The dc supply employs voltage divider *R74R75* and voltage followers *IC1C* and *IC1D* to derive an artificial equalizer ground at one-half the full voltage delivered by the electrical system powering the circuit. Note, however, that the voltage divider should be connected to the noninverting inputs of the voltage followers even if the ac supply is used to power the circuit. This is done to prevent unwanted oscillation. The outputs of the followers are left uncommitted when the ac power supply is employed.

Light-emitting diode *LED1* acts as a pilot light, and electrolytic capacitors *C1* and *C2* filter any noise present on the dc line. Note that decoupling components *R73* and *C19* as well as the "equalizer ground" deriving circuit are located on the main printed circuit board.

In the dc-powered equalizer, the negative supply voltage pins of the quad operational amplifier IC's are connected to the vehicle and sound system ground (shown in the schematics as "earth

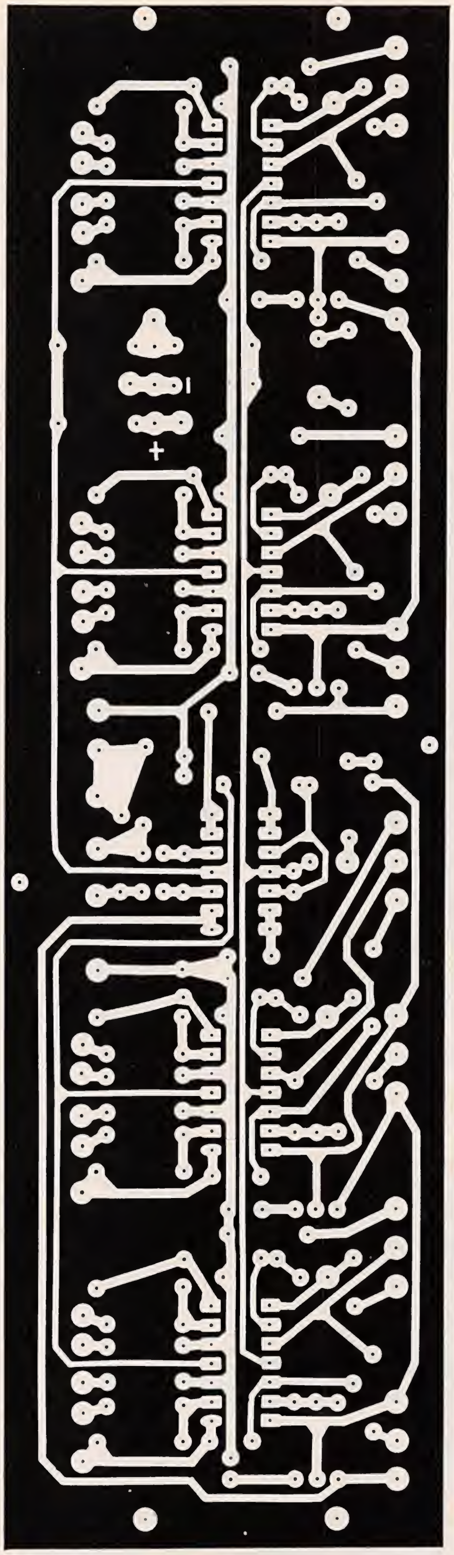

Fig. 5. Actual-size etching and drilling guide for the main printed circuit board.

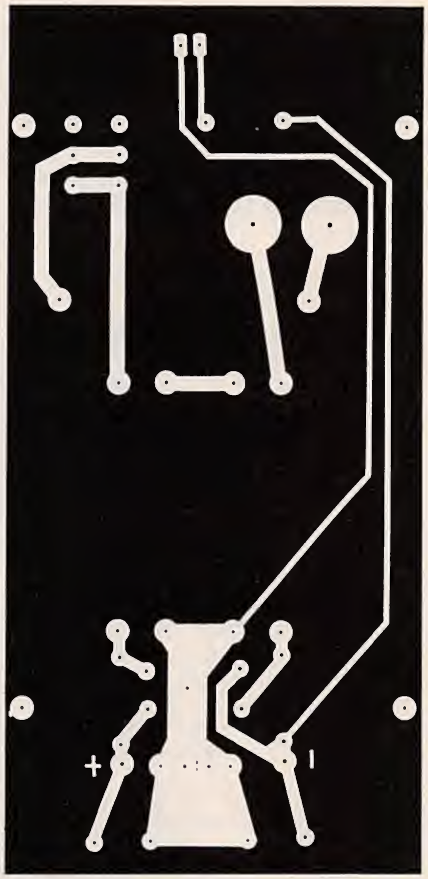

Fig. 6. Use this board for an ac power supply.

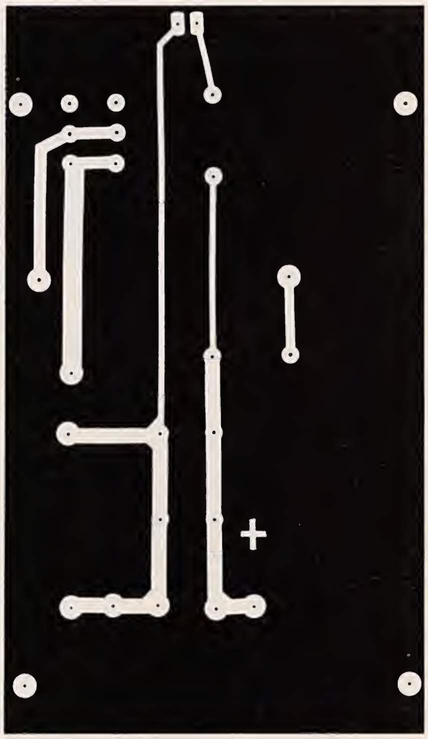

Fig. 7. If a dc supply is available, use this board.

Audio Project □ □ □

ground" symbols). The artificial grounds derived by *IC1C* and *IC1D* are shown as conventional "chassis ground" symbols. Note that the grounds within the equalizer sections (for example, the noninverting inputs of the op amp integrators) are artificial grounds above vehicle and system ground.

Capacitive coupling between the input jack and the op amp input buffer and between the output of the high-band equalizer and output jack prevents dc offsets both internal and external to the equalizer from having a deleterious effect on the performance of the entire system. It is because of the dc offsets present in the dc-powered equalizer that the "hot" sides of the input and output jacks are returned to system ground but the signal

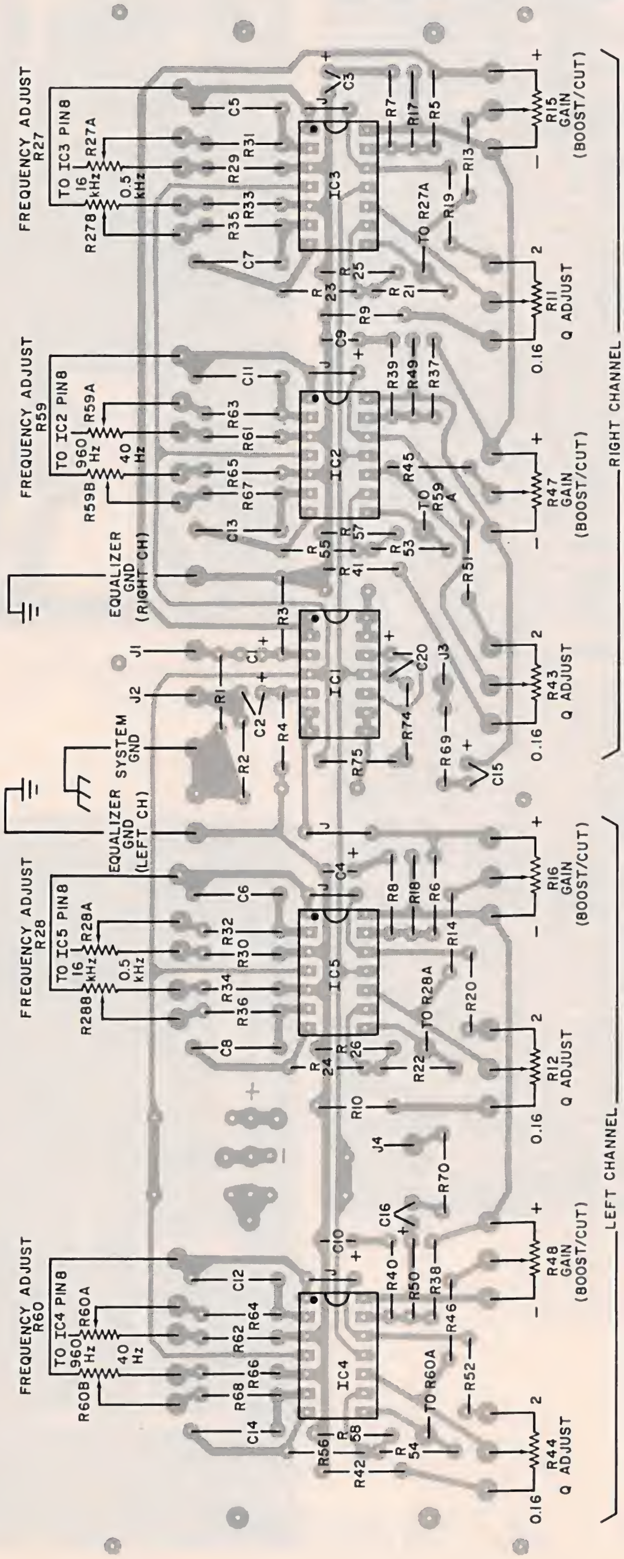

Fig. 8. Component placement for the main pc board for the equalizer. Note vacant pads near upper left to make connections to power supplies.

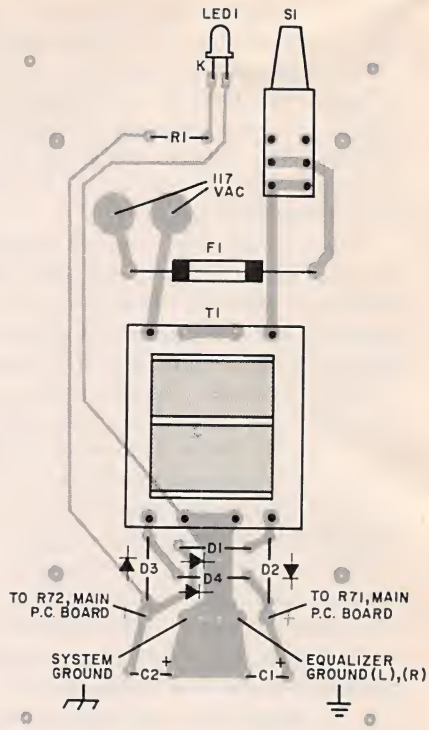

Fig. 9. Component placement for the ac power supply.

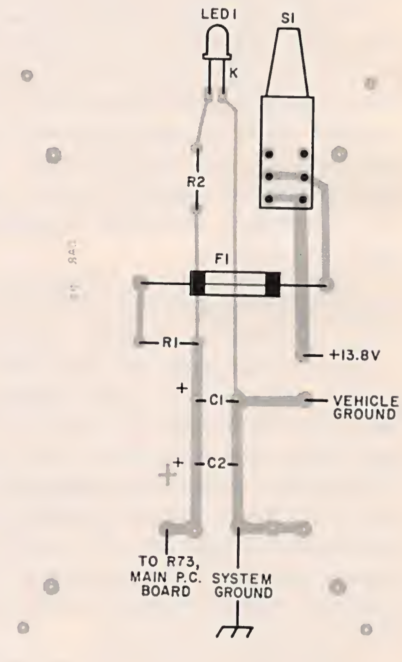

Fig. 10. Component placement for the dc power supply.

paths within each equalizer circuit are referenced to the artificial grounds. In the ac-powered equalizer, however, the bipolar dc voltages furnished by the power supply obviate the need for separate system and equalizer grounds. The two are shown connected together in the schematic of Fig. 3.

Results of tests on the prototype performed by the author at his own lab are shown in the box. You will note that all performance specifications but one are identical for both the dc and ac versions of the Parametric Equalizer. The one area in which the two differ is in the maximum voltage swing that can be generated at the output jack. The reason for this is that in the ac-powered equalizer the potential difference between the V+ and V− supply rails is 30 volts, but the potential difference between the supply rails in the dc-powered equalizer is less than half of this value if the dc power source delivers 13.8 volts. However, even in this situation there exists substantial headroom—most (if not all!) autosound power amplifiers require far less drive than 13.8 volts peak-to-peak to develop their maximum levels of output power. Greater output voltage swings can be obtained by increasing the voltage provided by the dc source. The circuit as shown can be used with supplies from +12 to +30 volts.

Construction. The use of printed circuit assembly techniques is recommended. Full-size etching and drilling guides for the main, ac power supply, and dc power supply circuit boards are shown in Figs. 5, 6, and 7, respectively. The corresponding parts placement guides are shown in Figs. 8, 9 and 10.

Mount all components on the circuit boards as shown in the parts placement guides. Begin by installing the jumpers on the main pc board. Then install the fixed resistors and nonpolarized capacitors. Taking care to observe polarities and pin basings, mount the electrolytic capacitors and semiconductors. The use of IC sockets or Molex Soldercons will facilitate replacement of ICs should that become necessary. Interconnection between the main board and the phono jacks and potentiometers can be made using flexible hookup wire. If desired, signal paths between the board and the jacks can be made with shielded cable.

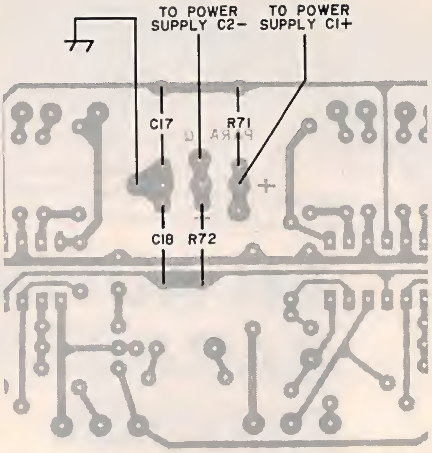

Fig. 11. Special wiring of the main pc board for use with an ac power supply.

This will not be necessary, however, if the project is housed in a grounded metallic enclosure. Special wiring of the main board for ac-powered operation is shown in Fig. 11. Wiring details for dc operation are shown in Fig. 12.

Assemble either the dc or ac power supply to fit the intended application of your Parametric Equalizer. Observe the polarities of electrolytic capacitors and diodes, including the LED pilot light. Fuse *F1* mounts directly on the board and should be soldered to it using pigtail leads. The author designed the power supply boards to accommodate a special push-on/push-off power switch, but any panel-mount switch can be used.

When assembling the circuit boards, be sure to use the minimum amount of heat and solder consistent with the formation of good solder connections. Scrutinize your work after the boards have been completed, paying close attention to polarities, pin basings, power supply wiring and interconnection between the two circuit boards. Make sure that no solder bridges have been created inadvertently.

When all wiring has been completed, mount the circuit boards, jacks and controls in a shielded enclosure. A photograph of the author's ac-powered prototype is shown in Fig. 13. Route power leads out of the enclosure using a protective strain relief. Connect the power leads to a suitable source. Using shielded patch cords, route line-level signals from the tape monitor output of your preamplifier or receiver (or from the preamplifier output) to input jacks *J1* and *J2*. Similarly, patch signals from output jacks *J3* and *J4* back to the tape monitor loop or to the input of the power amplifier. The project is now ready for use.

Using the Parametric Equalizer. Because this project is so flexible, there is no one "correct" way to use it. Its variable Q and center frequency allow the user to boost or attenuate a select group of frequencies. A high Q restricts the boost or cut introduced to a narrow part of the spectrum (less than one octave). A low Q causes broader changes to be introduced.

Adding some sharp boost at the very low and high ends of the audio spectrum allows the user to compensate for speaker rolloff. A broad dip inserted at the midband makes possible the simulation of a loudness contour to enhance low-level listening. The Parametric Equalizer is also adept at compensating for unwanted room resonances. A high-Q cut can reduce audio output at the resonant frequency with little effect on nearby frequencies.

The usual technique for coping with room resonances is as follows. Drive the system with a wideband audio signal

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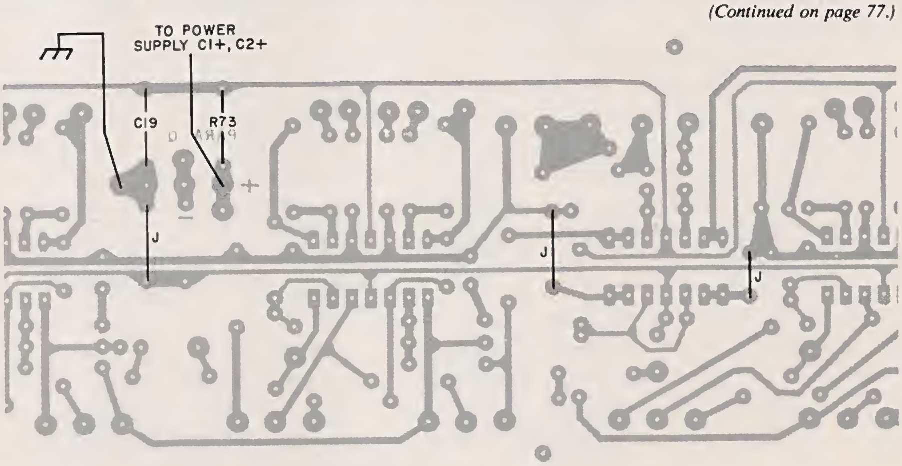

Fig. 12. Special wiring of the main pc board for use with a dc power supply. Note two jumpers on IC1 at right.

EQUALIZER . . . *(Continued from page 23.)*

and boost the bass region using the Parametric. Using a high Q setting, vary the center frequency of the low-band equalizer until you discover the room's fundamental resonant frequency. (That's the one at which the walls start shaking and the furniture moves around the floor.) Now reduce the setting of the BOOST/CUT control for more even-sounding bass. The high-band equalizer can be used to brighten up a room that is too "dead" acoustically or to attenuate treble response in a room that is too "alive."

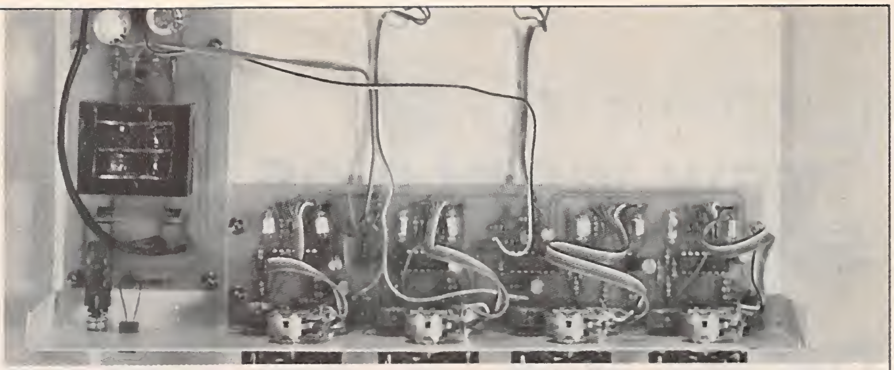

Fig. 13. Interior view of prototype using ac power supply.

You will undoubtedly find other uses for this versatile project. Those who listen to music analytically will appreciate the ability to zero in on one particular instrumental (or human) voice. Amateur recording engineers can employ the Parametric to tailor the sounds of a mix. And, of course, anyone whose speakers have response irregularities will be able to smooth them out.

One word of caution—don't blindly apply large amounts of deep bass and extreme treble boost in an attempt to flatten the response of your system at the upper and lower limits of the audible spectrum. Experience has shown that room/system combinations are best equalized by first employing acoustic methods, followed by electronic equalization. For example, you should first try repositioning the loudspeakers, modifying the absorption coefficients of the room, and adjusting the speakers' crossover level controls (if any).

Most often, a lack of deep bass and extreme highs is due to the limitations of dynamic drivers. Don't try to force flat response out of your speakers by cranking up the BOOST/CUT controls. The results of such attempts frequently include overloaded amplifiers, excessive distortion, and blown voice coils. Remember—equalization should be introduced *intelligently*.

In Conclusion. We have presented a stereo Parametric Equalizer project that is well suited for home, mobile, and portable applications. It provides a high level of performance and the flexibility of control inherent in the parametric design, enough flexibility for most readers. Those who require more bands of equalization per channel can reproduce two or more complete equalizers and connect them in cascade for even greater control over the sounds they record or reproduce. ◇

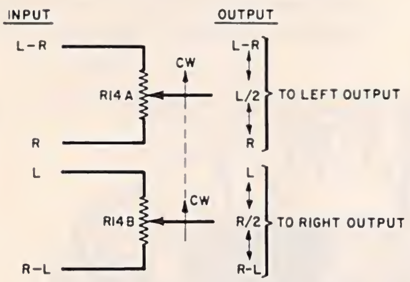

Fig. 3. The left and right signals and the composite are applied to R14 as shown. Note how the resulting output signals on each control wiper vary over potentiometer range.

Construction. The circuit can be assembled on a printed circuit board of your own design or on a perforated board using pencil wiring techniques. In either case, it is a good idea to use sockets for the IC's. Mount the potentiometer controls, input and output jacks, and POWER and IN/OUT switches on the box in which the circuit is housed. Use a dry-transfer lettering kit to label the controls, jacks, and switches according to function and operation.

Application. The Roto-Blender unit should be connected to suitable high-level inputs and outputs for optimum results. You can connect it between a preamplifier and power amplifier or, lacking this facility, into the tape-monitor loop. It is a good idea to hook it up ahead of the headphone amplifier, since the Roto-Blender is best appreciated using headphones.

For proper operation, the Roto-Blender should be nulled to counteract imbalances in the source material and preceding electronics. This can be done by disconnecting the right channel output of the Roto-Blender and, with the ROTATE and BLEND controls fully clockwise, adjusting the NULL ADJ control to exactly cancel the center sounds of the program source. If a mono source is used, adjust for minimum sound. Excessive distortion heard at this time indicates either a worn record or stylus or some other deficiency in the source material or amplifier's electronics.

Cancellation of center sounds with some recordings is not possible when the sounds are reproduced differently in each channel, using reverberation techniques. This case should not be confused with the case where distortion prevents nulling with a raspy sound.

Once nulling is accomplished, the right channel can be reconnected and the ROTATE pot should be centered for normal stereo reproduction. If an instrument on the left—a trombone, for example—is to be emphasized, rotate the sound to the right by turning the ROTATE control clockwise. This moves the trombone to the center, where it will be more dominant. At this point, if the BLEND control is rotated fully counterclockwise, the trombone will remain centered while the left and right channels will be effectively transposed.

The effects achieved by the Roto-Blender are a function of the source material and cannot be fully described here. Perhaps the most fascinating aspect of the Roto-Blender is its ability to bring forth sounds that were never noticed before. ◇