

CANCEL RUMBLE WITH THIS BASS-SUMMING AMPLIFIER

Versatile project can also be used as an electronic crossover for a subwoofer power amp.

BY JOHN H. DAVIS

THE presence of deep bass in the output of an audio system adds a satisfying "floor" to reproduced program material. However, designing a system to reproduce low frequencies well heightens the probability that rumble will make itself disconcertingly apparent. Presented here is the Bass Summing Amplifier, a project that can attenuate rumble without adversely affecting the low-frequency content or the high-frequency separation of a phonograph disc. It can also be used as an electronic crossover that sums the extreme bass to feed a subwoofer power amplifier. The Amplifier is easily and inexpensively constructed and requires no critical components or adjustments.

Rumble is low-frequency noise that is generated by phonograph recording and playback equipment. High-pass filtering can attenuate subsonic noise to a large extent, but it can't suppress audible rumble without also removing some desired bass content.

Most of the rumble entering a phono cartridge does so as vertical modulation that results in out-of-phase electrical signals at the phono cartridge's outputs. If these low-frequency out-of-phase signals are combined, they will cancel each other. Since recordings contain little or no out-of-phase, low-frequency information, low-frequency summation does not appreciably degrade the program material. What little bass separation exists and is recorded is not audibly

significant to human beings. Psychoacoustic studies indicate that bass localization is mostly a function of attack transients and overtones.

To verify that bass summing will attenuate rumble, play a silent groove on a vinyl disc and increase the volume until the rumble can readily be heard. Then switch your amplifier or preamplifier to its monaural mode. If your left and right channels are balanced and in proper phase, you will hear a drop in the rumble level.

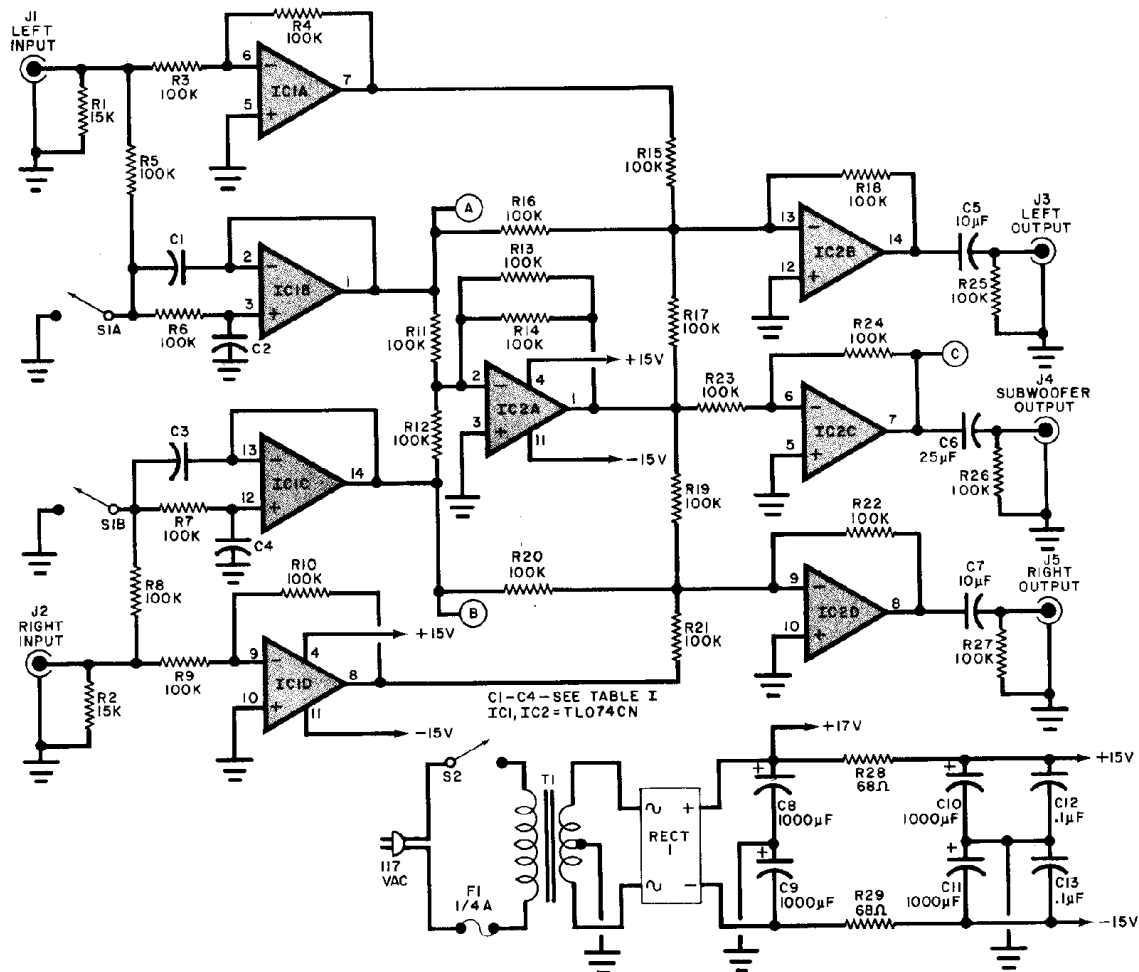
About the Circuit. A schematic of the Bass Summing Amplifier appears in Fig. 1. Line-level stereo inputs are applied to jacks *J1* and *J2*. Unity-gain inverters *IC1A* and *IC1D* shift the phase of the input signals by 180°. However, the unity-gain, low-pass filters comprising *IC1B*, *IC1C* and their associated passive devices do not appreciably alter the phase of those components of the input signals below their cutoff frequencies. If the outputs of *IC1A* and *IC1B* and those of *IC1C* and *IC1D* are combined, the low frequencies will cancel, leaving inverted midrange-and-treble stereo signals.

If the bass outputs of *IC1B* and *IC1C* are combined, a composite, summed bass signal results. This summed bass contains all of the in-phase information but no difference information. If this composite bass is recombined with the middle-and-high-frequency stereo signals, the resulting stereo outputs are almost in-

distinguishable from the original—except for the lack of rumble components. Because the operation of *IC1A* and *IC1D* involves phase inversion, *IC2B* and *IC2D* perform an additional compensating inversion.

The performance of the project in the rumble-suppressing mode is summarized by the graphs of Fig. 2. The heavy curve shows the extent to which low-frequency difference information is cancelled when the low-pass filters have cutoff frequencies of 220 Hz. The lighter-weight curve shows the extent to which channel separation is maintained as a function of frequency. Two dashed curves show the measured separation available from modestly priced and premium phono cartridges. These latter curves demonstrate that, above bass frequencies, the project does not adversely affect realizable separation.

A monaural signal that can be used to drive a subwoofer power amplifier is available at the output of *IC2C*. This filtered and summed bass signal is in phase with respect to the bass components of the stereo input signals. However, in this application, resistors *R17* and *R19* must be deleted so that the summed bass is not also present in the stereo outputs. Accordingly, the stereo system handles only the upper bass, midrange, and high frequencies. Figure 3 shows the low-pass-filter response that characterizes the output presented at *J4* for a cutoff frequency of 110 Hz. The stereo out-



PARTS LIST

Components denoted by an asterisk can be deleted if the optional, dynamic separation indicator is not to be built.

C1,C2,C3,C4—Metallized polyester, metallized Mylar, monolithic ceramic or polystyrene capacitor, 10% or closer tolerance (see Table I for capacitance)

C5,C7—10- μ F, 50-V, axial-lead, nonpolarized electrolytic

C6—25- μ F, 50-V, axial-lead, nonpolarized electrolytic

C8,C9,C20*—1000- μ F, 25-V, radial-lead electrolytic

C10,C11—1000- μ F, 25-V, radial-lead electrolytic

C12,C13—0.1- μ F, 50-V disc ceramic capacitor

C14*,C15*—0.033- μ F, 100-V Mylar capacitor

C16*,C17*—0.33- μ F, 35-V tantalum capacitor

C18*,C19*—0.68- μ F, 35-V tantalum capacitor

C21*—0.15- μ F, 100-V Mylar capacitor

C22*—0.001- μ F, 100-V Mylar capacitor

D1*,D2*,D3*—1N300 silicon switching diode

D4*—1N4001 rectifier

F1— $\frac{1}{4}$ -ampere fast-blow fuse

IC1,IC2,IC3*—TL074CN quad BiFET operational amplifier

IC4*—LM324N quad operational amplifier

J1 through J5—RCA phono jack

LED1*—Red light-emitting diode

LED2*,LED3*—Green light-emitting diode

The following, unless otherwise specified, are $\frac{1}{4}$ -watt, 5% tolerance, carbon-film fixed resistors.

R1,R2—15 k Ω

R3 through R27, R30* through R35*, R41*, R42*—100 k Ω (see text for recommended preselection procedure)

R28,R29—68 Ω , $\frac{1}{2}$ -watt

R36*,R37*,R44*—22 Ω , $\frac{1}{2}$ -watt

R38*—330 k Ω

R39*—120 k Ω

R40*—82 k Ω

R43*—27 k Ω

R45*,R46*,R47*—68C Ω

RECT1—1-A, 100-PIV modular bridge rectifier

S1—Dpdt switch

S2—Spst switch

T1—24-V, 300-mA, center-tapped step-down transformer

Misc.—Printed-circuit board, standoffs, suitable enclosure, fuseholder, line cord, shielded cable, hookup wire, suitable hardware, strain relief, solder, etc.

Note—The following is available from M. H. Marks Enterprises, 315 Thornberry Court, Pittsburgh, PA 15237: complete kit of parts (less enclosure and hardware), No. BSA-3, for \$44.95 plus \$3.00 shipping and handling within U.S.A. Also available separately: etched, drilled and silkscreened printed-circuit board, No. BSA-PC, for \$12.95 postpaid within U.S.A. Allow six to eight weeks for delivery. Pennsylvania residents, add 6% state sales tax.

puts presented at J3 and J5 have complementary (high-pass) responses.

For those who want reassurance that difference information cancelled along with the rumble is audibly insignificant, an unusual, dynamic separation indicator is presented as an option. It responds primarily to the frequencies affected by the bass-summing process, and is shown schematically in Fig. 4. The design of this indicator is based on the fact that separation is reflected as an increase in the level of difference information relative to the level of in-phase information. Differential amplifier IC3A processes the filtered right- and left-channel bass signals to obtain differ-

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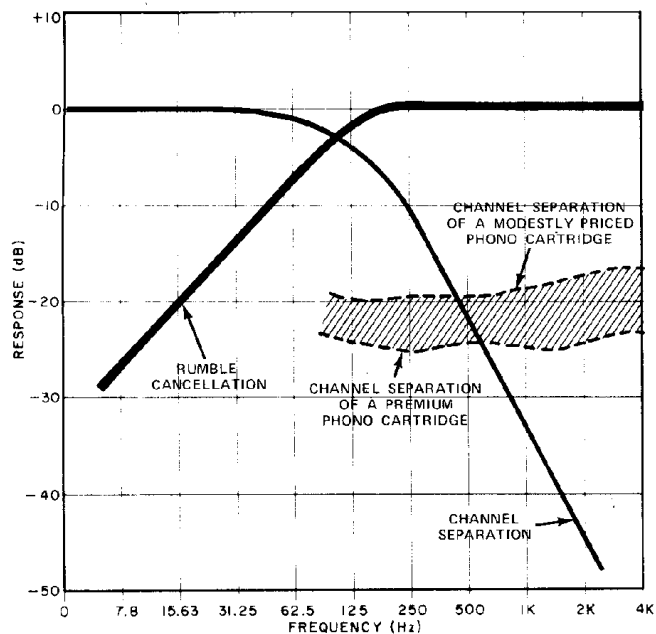


Fig. 2. Performance curves for low-pass-filter cutoff frequency of 220 Hz. Heavy curve shows the extent to which difference information is suppressed as a function of frequency.

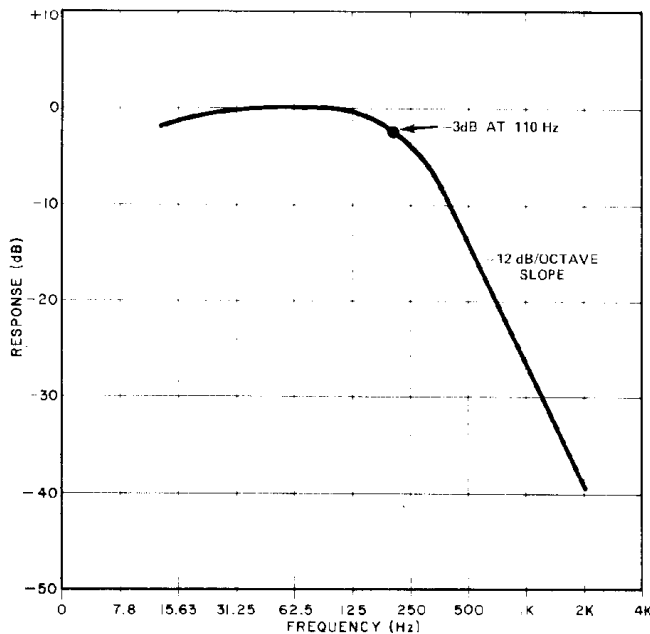


Fig. 3. Low-pass-filter response that characterizes the subwoofer-output channel. Stereo-output channels have a complementary, high-pass characteristic.

ence information. The output of IC3A is rectified by IC3B and D1, and charges C18.

Summed bass is available at the output of IC2C (point C in Fig. 1). It is brought up to an equivalent level by amplifier IC3C. The frequency response of this stage is shaped by capacitors C21 and C22 to attenuate the unwanted higher frequencies. The amplified, summed bass output of IC3C is rectified by IC3D and D2, and charges C19.

Comparators IC4A, IC4B, and IC4C compare the two resulting dc levels and light LED3, LED2, and LED1 at progressively higher levels of separation. The network comprising D3, D4, R43 and R44 maintains a small bias voltage across C19. This prevents random triggering of the comparators by noise at low signal levels. Such triggering would otherwise be troublesome because signal comparison is based on ratios, not fixed voltage levels.

Options and Modifications. Before undertaking construction, you should determine exactly what function(s) you want this project to perform. If you want only to suppress rumble, you will probably want a filter cutoff frequency of 220 Hz (330 Hz if the rumble is severe). Table I shows which values of capacitors and resistors to use for these frequencies. Also listed are component values for a cutoff frequency of 110 Hz, which is a better choice if a subwoofer is used.

In a Bass Summing Amplifier to be used for rumble reduction only, there are a few components which can be eliminated (C6, J4, and R26). To drive a subwoofer power amplifier in addition, however, two resistors (R17 and R19) must be deleted. Whether the project is used for both purposes or only for rumble suppression, you have the option of including the separation indicator. If you choose not to include it, some parts can be deleted. They are denoted by an asterisk in the Parts List.

Construction. There are no high-gain or other stages in which circuit layout is critical. However, the use of a printed-circuit board is recommended because of the rather high parts count. The full-size etching and drilling guide for a suitable pc board appears in Fig. 5. Its corresponding component placement guide appears in Fig. 6. The use of IC sockets or

Molex Soldercons is recommended.

There are a few points to consider concerning component selection. To minimize distortion, the capacitors in the low-pass filters (C1 through C4) should be metallized plastic-film or other high-quality components. For the same reason, C5, C6, and C7 should be nonpolarized electrolytics. Purists will also want to connect 0.1- μ F metallized plastic-film capacitors in parallel with C5, C6, and C7.

Carbon-film, 5%-tolerance resistors are acceptable for use in this project, but a simple preselection procedure requiring only an ohmmeter is recommended. The ohmmeter need not be particularly accurate, but should allow you to resolve slight differences in resistance around a center value of 100 kilohms. Exact values are not as important as close matches.

First, measure the values of some 100-kilohm resistors and set aside four that match very closely for R15

TABLE I
VALUES OF FILTER COMPONENTS FOR SELECTED CUTOFF (-3-dB) FREQUENCIES

Frequency	Recommended Application	R5, R6, R7, R8	C1, C3	C2, C4
110 Hz	Rumble suppression and subwoofer crossover	100 k Ω	0.02 μ F	0.01 μ F
220 Hz	Rumble suppression	100 k Ω	0.01 μ F	0.005 μ F
330 Hz	Suppression of severe rumble	68 k Ω	0.01 μ F	0.005 μ F

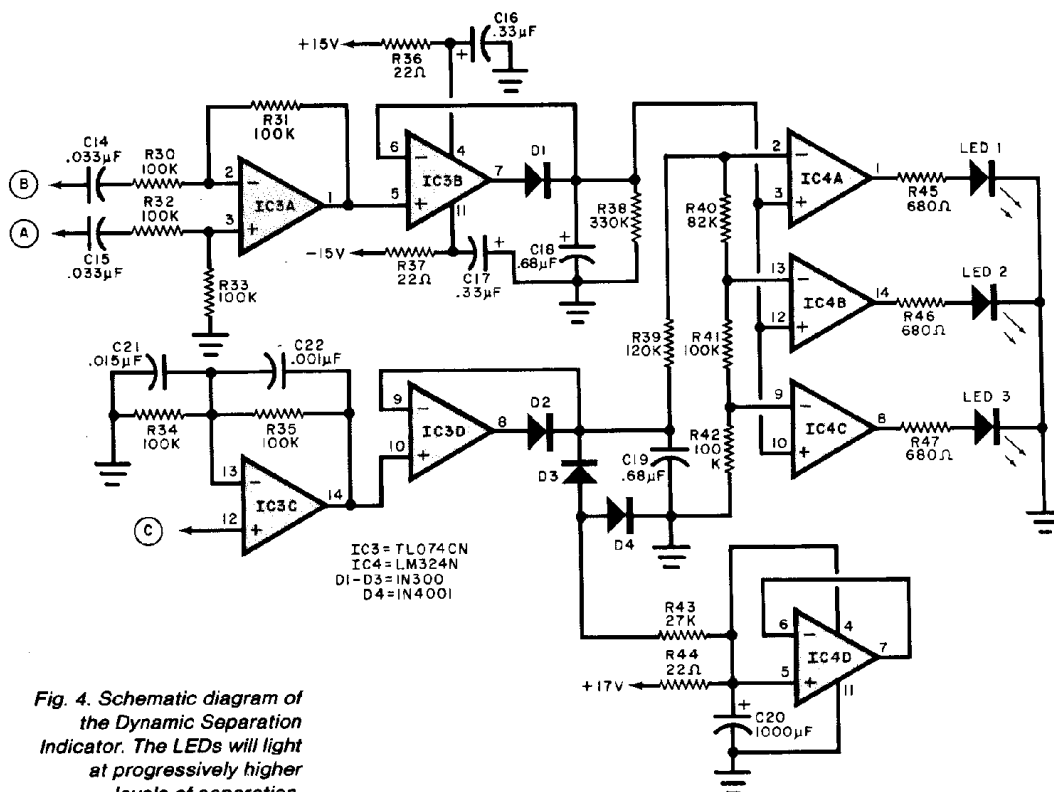


Fig. 4. Schematic diagram of the Dynamic Separation Indicator. The LEDs will light at progressively higher levels of separation.

through *R18*. Select another matching group of four as *R19* through *R22*. Select a third group of four as *R11* through *R14*. Finally, select two closely matched pairs, one pair for *R3* and *R4*, the other for *R9* and *R10*.

The project will perform reasonably well even if this process is not followed, but the more closely matched in value the members of a given group, and the closer the tolerances of *C1* through *C4*, the smoother the frequency response.

When mounting the components on the printed-circuit board, take note of device orientation and the presence of the two short jumpers at pins 5 and 10 of *IC1*. Also note that *R1* and *R2* are soldered across each of the input jacks—they are not mounted on the board. Similarly, *R25*, *R26*, and *R27* are soldered across the appropriate output jacks. The project should be housed in a metal enclosure with shielded cable connecting the pc board to the input and output jacks and switch *S1*.

Testing. Doublecheck the circuit assembly. Then apply power and verify that the positive and negative supply voltages are equal and less than 18 volts. A one-volt, 30-Hz signal applied to *J1*, the LEFT INPUT jack, should result in the appearance of half-volt signals at both *J3* and *J5*, the LEFT and

RIGHT OUTPUT jacks. If the project has been built for subwoofer use, the half-volt signal should appear at *J4*, the SUBWOOFER OUTPUT jack, *only*. If a 30-Hz, one-volt signal is applied to *J1* and *J2* simultaneously, the outputs at *J3* and *J5* or the output at *J4* should increase to one volt.

If you have built the dynamic separation indicator, you can test its operation by applying a 30-Hz signal. When the input signal is applied to either *J1* or *J2* (but not both), all three LED's should glow. Ideally, they should all extinguish when both channels are driven by the same input signal. Check to see if this happens.

Next, change the frequency of the

test signal to 3000 Hz but keep its amplitude at one volt. Apply this signal to *J1*. A one-volt signal should now appear only at *J3*. Then apply the signal to *J2* and verify that an output appears only at *J5*. At this frequency, none of the LEDs should glow, even if only one channel is driven. If *LED3* does glow, decrease the level of the input signal to see if it extinguishes. (These statements assume, of course, that *S1* is open.)

If you don't have access to test equipment, you can patch the project into your system at a line-level point in the signal chain. The Bass Summing Amplifier should be connected *after* any signal-processing components such as an equalizer, a dynamic-range expander, etc. Then find a quiet groove on a vinyl disc and play it. Listen for rumble, and open and close switch *S1*. A difference in the rumble level should be noticeable. During such a test, *LED3* might flicker, but the other two LEDs should flash only very rarely.

Use. For the Bass Summing Amplifier to function properly, your audio system needs to be well balanced at the point at which signals are routed to the inputs of the Bass Summing Amplifier. Use the monaurally recorded bands of a test record, or listen to a quiet groove of a standard disc

AUTHOR'S SPECIFICATIONS

Input Impedance: 10 K Ω

Recommended Load Impedance: 10 k Ω or greater

Input-signal Level: 0.3 to 3.0 volts rms; 1.0 volt recommended

Total Distortion: Less than 0.05%

S/N: Better than 70 dB (unweighted)

Frequency Response: 50 Hz to 16 kHz $\pm 1/4$ dB at stereo outputs with *R17* and *R19* in project; filter resistors preselected according to procedure described in text; both channels driven, *S1* open.

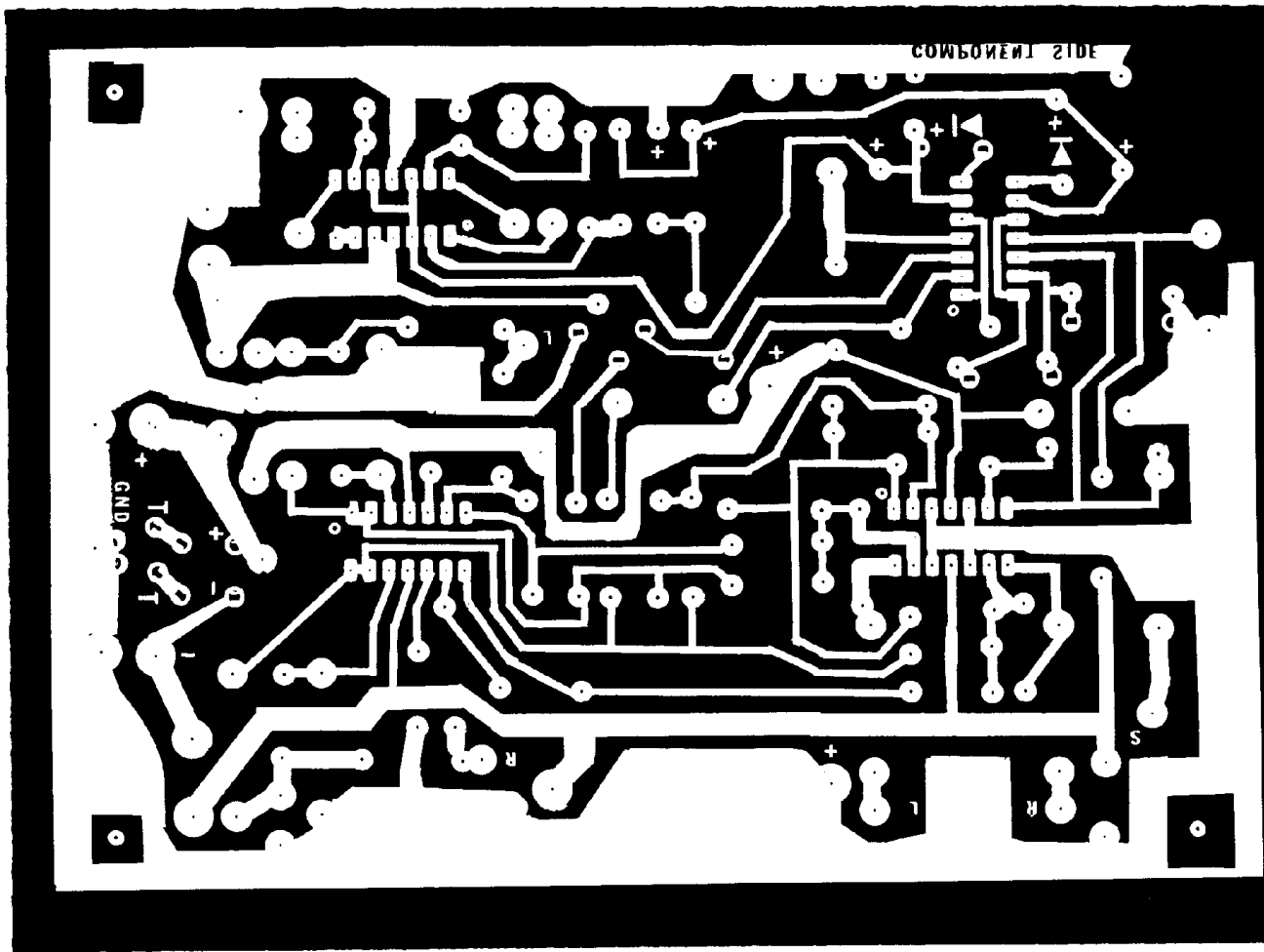


Fig. 5. Full-size etching and drilling guide (above) for the Bass Summing Amplifier and Dynamic Separation Indicator.

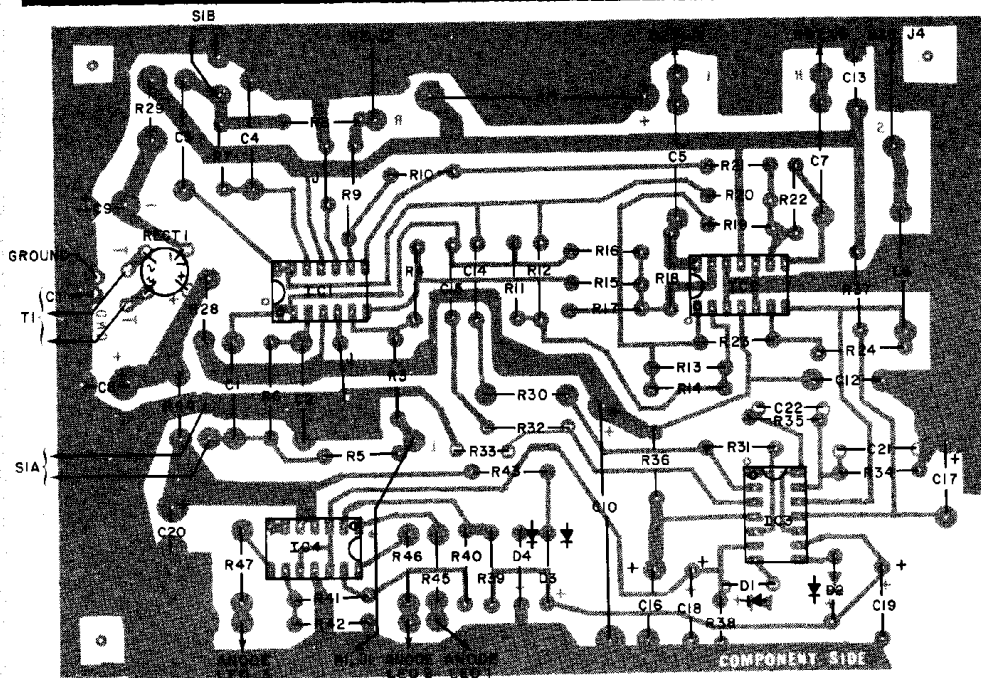


Fig. 6. Component placement guide to be used with the printed-circuit board.

while adjusting interchannel balance. Maximum cancellation occurs when the channels are exactly balanced. Even high-quality phono cartridges have some imbalance, and as much as

2 dB will degrade the rumble-cancellation capability of the project.

The net result of your efforts will be quieter and more satisfying bass. As a bonus, the bass summing amplifier

can be used to reduce rumble on tapes that have been dubbed from noisy turntables or from FM broadcasts generated using outdated studio equipment. ♦