

# Electronic Crossover Circuit

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□EVER SINCE THE INITIAL SUCCESS BY THOMAS ALVA EDISON at sound reproduction, and as that art was constantly upgraded into hi-fi, it was recognized that somehow the audio band of frequencies should be split into smaller frequency bands in order to faithfully reproduce the complete audio spectrum. In fact, that was Alexander Graham Bell's original approach to the telephone. Because of their electromechanical origin, speakers were the first audio component to establish that practice. In early stages of electronics, vacuum-tube amplifiers had the same trouble dealing with such a wide band—10 octaves. Most of the troubles existed in the power-amplifier sections, so it was logical then to divide the audio frequencies and feed a separate power amplifier for the low- and high-frequency bands, a technique known as biamping. Lower intermodulation distortion, better coupling to the speakers, and freedom of the high-frequency units from low-frequency overloads were quickly realized benefits. Biamping was used in professional sound systems, but it was too large, heavy, complicated, and expensive for the average electronics and hi-fi enthusiast.

With the advent of the transistor, the problem was lessened, but still remained complicated. Not until the arrival of the linear integrated-circuit chip could such a project be built easily and inexpensively. Even then, the available IC's didn't deliver the performance for true hi-fi. With the introduction of BIFET and hybrid IC's at affordable prices, the construction of a biamp system is a reality for the hobbyist, and a home-made project can deliver excellent sound fidelity.

This article is a description of an Electronic Crossover Circuit and an optional power-amplifier setup for a complete biamp project.

## The Electronic Crossover Circuit

An audio source, such as a mixer, preamplifier, equalizer, or recorder, is fed to the Electronic Crossover Circuit's input (Fig. 1). That signal is either AC- or DC-coupled, depending on the setting of switch S1, to the non-inverting input of buffer-amplifier U1-a, one section of a quad, BIFET, low-noise TL074 op-amp made by Texas Instruments. That stage has a gain of 2, and its output is distributed to both a lowpass

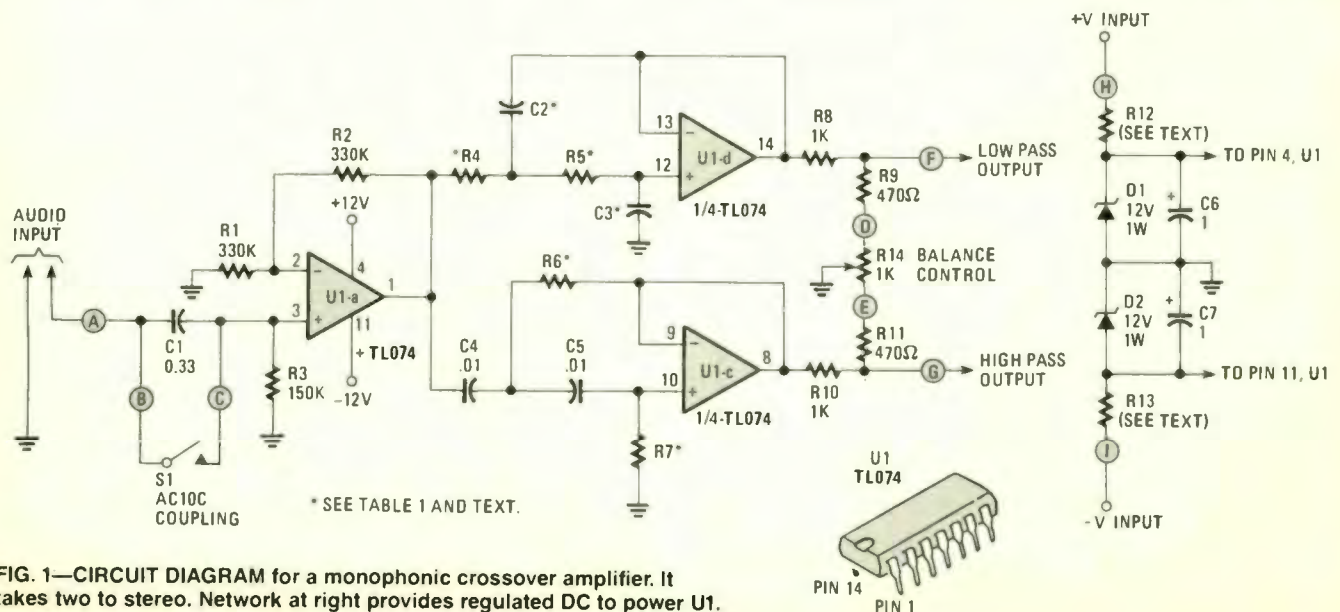


FIG. 1—CIRCUIT DIAGRAM for a monophonic crossover amplifier. It takes two to stereo. Network at right provides regulated DC to power U1.

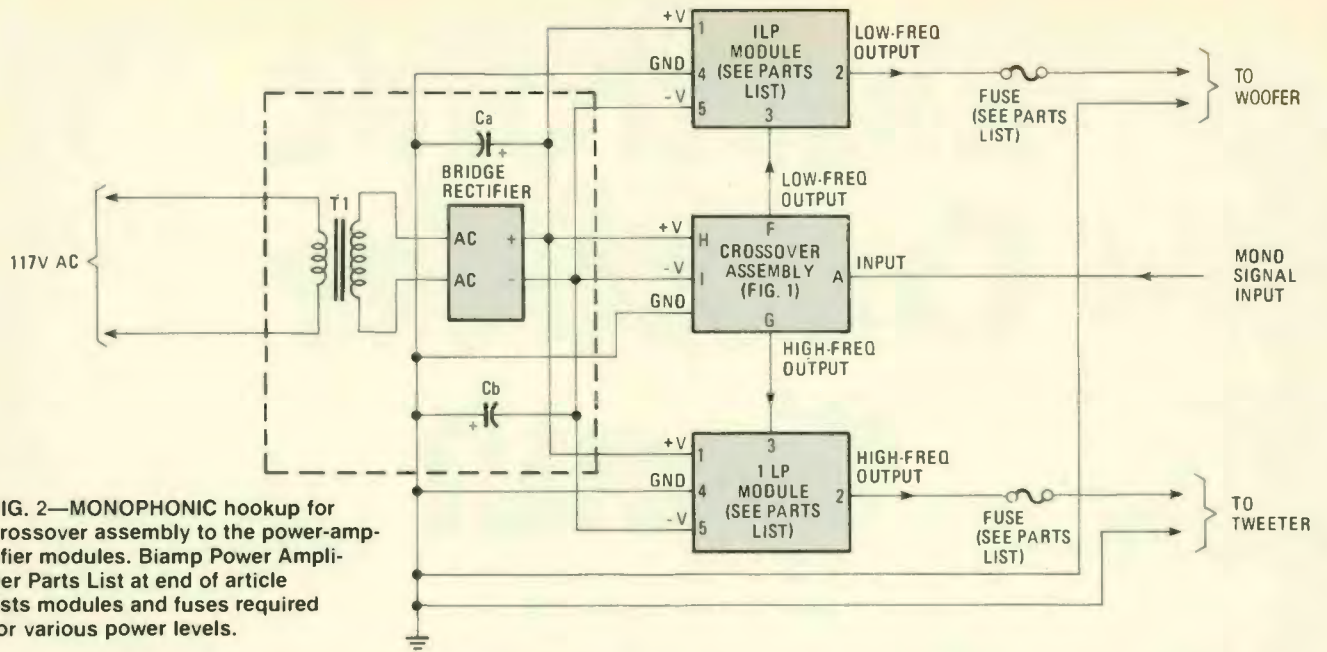


FIG. 2—MONOPHONIC hookup for crossover assembly to the power-amplifier modules. Biamp Power Amplifier Parts List at end of article lists modules and fuses required for various power levels.

TABLE 1—COMPONENT VALUES

Freq. (Hz)	R4, R5 (Ohms)	C2 (μF)	C3 (μF)	R6 (Ohms)	R7 (Ohms)
750	15.0K	0.002	0.01	15.00K	30.00K
1000	10.2K	0.002	0.01	11.25K	22.51K
1250	8.2K	0.01	0.005	9.00K	1.80K
1500	15.0K	0.022	0.01	7.50K	15.00K
2000	5.1K	0.01	0.005	5.62K	11.25K
2500	8.2K	0.01	0.005	4.50K	9.00K
3000	15.0K	0.005	0.0025	3.75K	7.50K

### PARTS LIST FOR ELECTRONIC CROSSOVER CIRCUIT

#### SEMICONDUCTORS

D1, D2—12-volt, 1-watt Zener diode (such as ECG142A)  
 U1—TL074 Quad, BIFET, low-noise op-amp; TL084 (slightly noisier) may also be used

#### RESISTORS

(Fixed resistors are 1/4-watt, 5% units)  
 R1, R2—330,000-ohm  
 R3—150,000-ohm  
 R4-R7—select values given in Table 1  
 R8, R10—1000-ohm  
 R9, R11—470-ohm  
 R12, R13—see text  
 R14—1000-ohm, linear-taper potentiometer

#### CAPACITORS

C1—0.22-μF, 100-WVDC  
 C2, C3—select values given in Table 1  
 C4, C5—0.01-μF.  
 C6, C7—1-μF, 25-WVDC electrolytic

#### ADDITIONAL PARTS AND MATERIALS

S1—SPST switch, very low-current capacity  
 Wire, cable, solder, mounting hardware, printed-circuit materials or perboard, cabinet, etc.

filter made by R4, R5, C2, C3, and op-amp U1-d, and a high-pass filter made by R6, R7, C4, C5, and op amp U1-c. Those are 12-dB/octave Butterworth-type filters. The \*Butterworth filter response was chosen because it gives the best compromise between damping and phase shift. Refer to Table 1 for the values of those capacitors and resistors whose values vary with the selected crossover at which your unit will operate.

The filter's outputs are fed to a balancing network made by R8, R9, R10, R11 and balance potentiometer R14. When the potentiometer is at its mid-position, there is unity gain for the passbands of both the high and low filters.

DC power for the Electronic Crossover Circuit is regulated by R12, R13, D1, and D2, and decoupled by C6 and C7.

\*Active filter theory involves many equations beyond the scope of this short article; readers interested in greater details should read: *Handbook of Operational Amplifier Circuit Design*, D.F. Stout and M. Kaufmann, McGraw-Hill 1976, chapters 10 and 11.

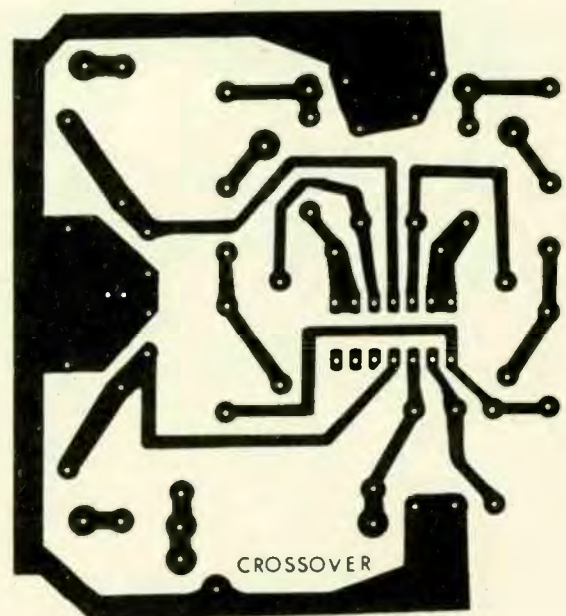
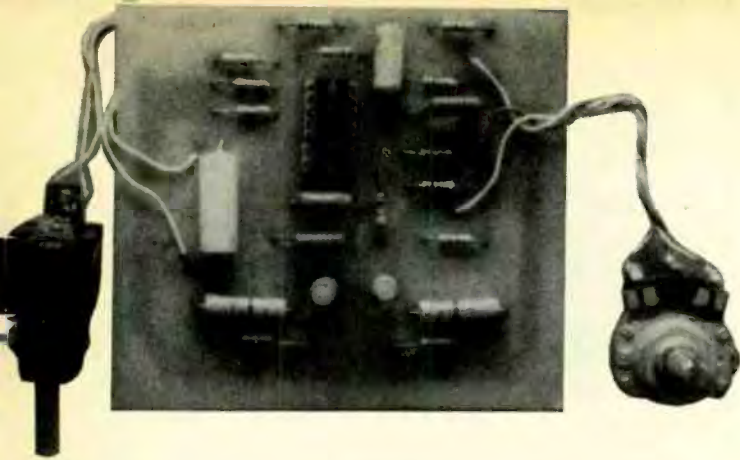


FIG. 3—SAME SIZE foil pattern used by author to fabricate his circuit-board for the crossover circuit.



THE CIRCUIT BOARD could be made smaller, but there's no need to crunch the circuitry into a small box. You may want to use shielded leads to limit hum and crosstalk pickup.

### Construction

Wire-wrap or printed-circuit board construction may be used to build the Electronic Crossover Circuit's board, although the latter technique is recommended. The foil pattern and parts-location diagrams are shown in Figs. 3 and 4. The power-amplifier section is so easy to build that point-to-point wiring may be used. For the power amplifiers' high-current sections, use at least #18 wire for the V-, V+, ground, and output connections. The electronic crossover may use #24 wire, but use of shielded cable for the input, output, and switch connections is advised to avoid hum and noise pickup. It is extremely important that *all* ground connections be made by individual wires back to the power supply's common terminal. If AC coupling is always desired, delete switch S1. If DC coupling is always desired, delete switch S1 and replace capacitor C1 by a jumper.

### Power Amplifier Circuit

Although it's possible to build the electronic crossover circuit only (Fig. 1), and to use power amplifiers you have, you should be interested by the diagram of the amplifier circuit shown in Fig. 2. That simple circuit is centered around the new ILP power modules. Those modules are extremely easy to use, have built-in heatsinks, offer true hi-fi performance, and are reliable enough to be backed by a 5-year warranty. The modules are available in power ratings from 15 to 240 watts, including some ultra-low distortion MOSFET types. With only five connections per amplifier, only the power supply has to be built—plus the Electronic Crossover Circuit, of course. Contact the address in the Parts List for pricing and a brochure.

Note also that balancing potentiometer R14 is mounted outside the circuit board. Mount the Electronic Crossover Circuit's board away from the power transformer. The performance of the circuit is dictated by the quality of its components, so metal-film resistors, and polystyrene, mica or NPO-ceramic capacitors are strongly recommended. The resistor values are non-standard, so if you want to avoid expensive precision resistors, use a digital multimeter (DMM) to hand-pick usable resistors from a sample of standard-value resistors that are within 5% of the target value. Remember, the circuit will work with standard parts, but it will work better if you follow this sampling suggestion.

A bipolar supply of any voltage greater than 15 volts is needed to power the Electronic Crossover Circuit. Resistors R12 and R13 (Fig. 1) drop the excessive voltage to a correct level via the action of the Zener diodes, D1 and D2. Calculate the ohmic value of those resistors by subtracting 12 volts from your supply's rated voltage, and

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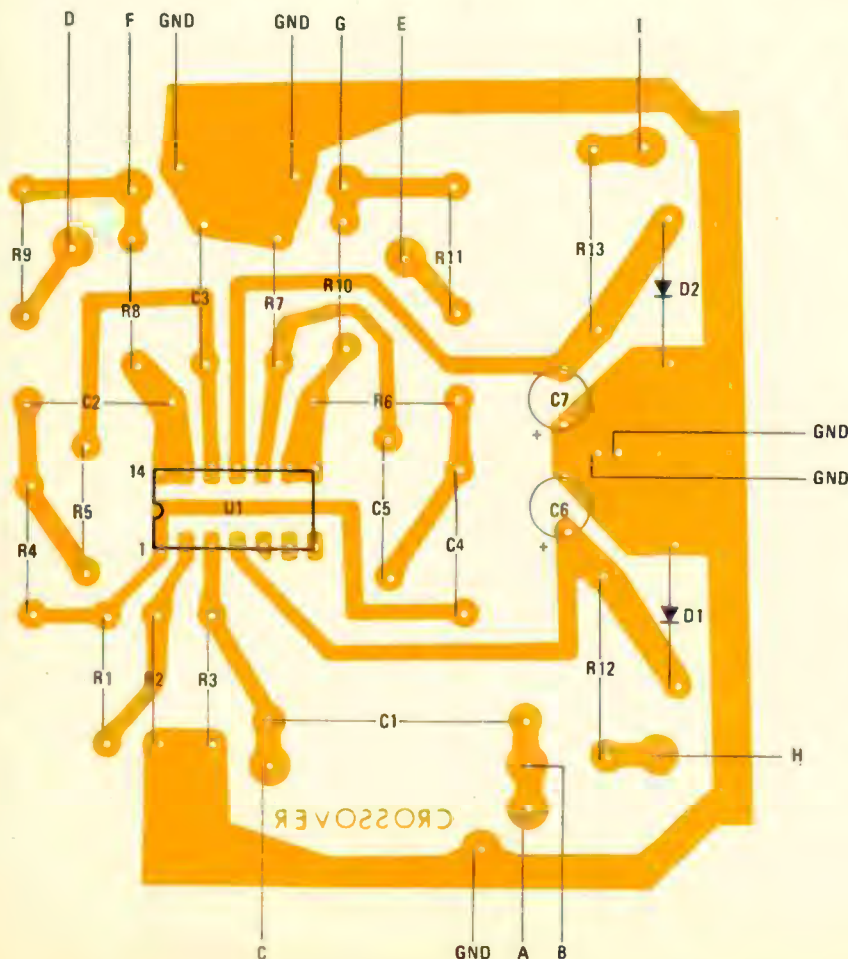


FIG. 4—ENLARGED VIEW of flopped foil pattern pinpoints parts location on the printed-circuit board. Considering that two are needed for stereo, it's a good idea to make several boards—two for yourself, and some for friends.

## ELECTRONIC CROSSOVER CIRCUIT

(Continued from page 79)

divide by a 60-mA current. Use the nearest standard-value resistor. The power rating for the two resistors is determined by the equation  $I^2 \times R$ , but allow a safety margin of at least 50% of your calculations.

To dissipate better the heat produced by resistors R12 and R13, mount them with their body axes about  $\frac{3}{16}$ -inch away from the circuit board.

The schematic diagram (Fig. 1) for the Electronic Crossover Circuit is monophonic, so a second circuit board should be built for each audio channel used.

### PARTS LIST FOR BIAMP POWER AMPLIFIER

(Specifications for matching parts in power amplifier)

Power Rating (Watts)	Module Type and Quantity	Supplied Parts	Fast-Blow Fuses—2 Amperes
15/15	2 HY30	PSU36	1.0
30/30	2 HY50	PSU50	1.5
60/60	2 HY120	PSU70	2.0
120/120	2 HY240	PSU180	2.5
240/240	2 HY400	PSU180*	3.0

\*2 sets of supplied parts required.

The modules and supplies are available from Gladstone Electronics, 901 Fuhrmann Blvd., Buffalo, NY 14203. The *Supplied Parts* include all parts plus a toroidal-wound transformer designed for compactness and high efficiency. Send a stamped, self-addressed business-size envelope for a quote on prices.



**POWER MODULE** connects to crossover circuit providing from 15- to 240-watts output depending on which module type is selected. Refer to Parts List.

### Putting It to Work

Once everything is assembled, it's wise to check the audio system's frequency response with an audio oscillator and a scope before connecting it to a speaker. That test could save an expensive tweeter from being overheated by a high-frequency spike, due to oscillations. Slight frequency deviations are of no importance. When connections to the speakers are made, start with the balance control at its mid-position and adjust to suit the "liveness" of the room. Unless the audio source is of high quality with no DC leakages, and the subsonic frequencies of very low levels, it's best to AC-couple the amplifier. In a 3-way system, the best of both worlds can be achieved: Use the Electronic Crossover Circuit between the low- and midrange-high frequencies, while a standard, passive network between the midrange and high frequencies will do the remainder of the job.

One last word of caution: Since phase shift occurs in any filter, and additional phase shift may occur in the speaker-enclosure combination, reverse the leads (polarity) at the woofer terminals should you detect a "notch" in the crossover region. ■