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ACOUSTIC FIELD GENERATOR

Our AFG will turn any livingroom into a full-sized movie theater or concert hall.

TOD T. TEMPLIN

IF YOU'VE SEEN A RECENTLY PRODUCED motion picture presented in a modern theater, then you are undoubtedly aware of the stunning realism and dramatic impact created by the use of the Dolby-stereo surround-sound audio process. The system was developed by Dolby Laboratories for the motion-picture industry to literally surround viewers with sound and place them in the very midst of the action.

For anyone unfamiliar with the concept, the Dolby-stereo surround-sound process works to increase the sensation of "being there" by reproducing distinct sounds toward the front, sides, and rear of the viewer. In practice, it is accomplished by feeding the primary stereo soundtrack to speakers located behind the screen on the left, the center, and the right side of the theater.

Simultaneously, an additional audio channel, decoded from within the primary channels, is sent to a system of smaller speakers located to the sides and to the rear of the audience. That additional surround channel is used to re-create ambient sounds like wind noise or "on location" street sounds as well as special sound effects intended to travel past the audience from front to rear, or even to seem to circle overhead.

Since the mid 1970's, over 1100 motion pictures have been produced with surround-sound tracks. Because the process encodes the surround information into a 2-channel stereo signal, when the movies are transferred to video tapes and laser discs, the encoded information remains intact. However, in order to enjoy surround sound at home, at the very minimum, a stereo VCR; some type of decoder, and additional surround speakers are required.

The basic principle of all surround-sound decoders, from the simplest to the most expensive, is the same. They all reproduce the surround information by recovering the (L − R) difference signal which is encoded into the left and right channels of the movie soundtrack. The decoder presented here goes beyond the capabilities of a simple surround-sound decoder. Besides the surround decoder circuit, additional circuitry is

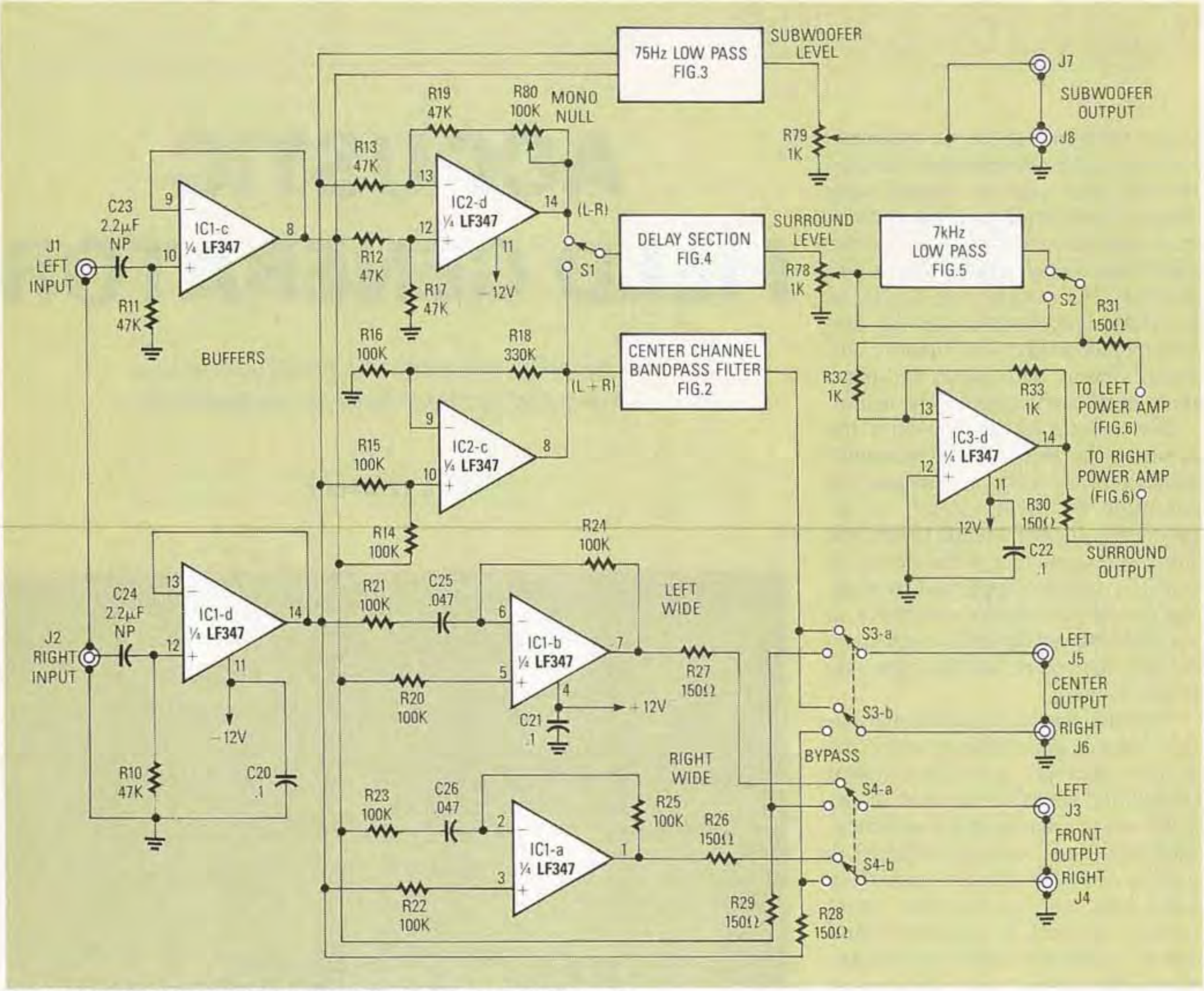

FIG. 1—THE AFG IS MADE UP OF 10 relatively simple circuit elements.

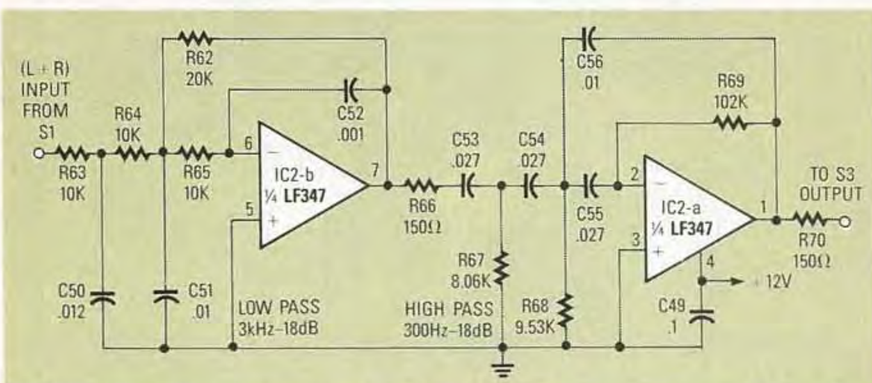

FIG. 2—THE CENTER-CHANNEL SPEECH FILTER is built by cascading a 3-kHz low-pass filter with a 300-Hz high-pass filter to form a band-pass filter.

used to create wide-left, center-dialogue, wide-right, and subwoofer signals. Presenting those signals through six properly arranged speakers results in the acoustical illusion of a large, almost boundless, three-dimensional listening environment, even in a small room; hence the name, "*A*coustic *F*ield *G*enerator," but we'll call it the AFG for short. This article is not intended to provide an in-depth tutorial or technical description of the surround-sound system. Rather, it is intended to show you how to construct and install a high-quality, multichannel sound decoder for use in your home.

The AFG offers two different modes of operation; "matrix" and "concert." In the matrix mode, the (L − R) difference signal is recovered from surround-encoded source material and is then passed through a 2048-stage bucket-brigade delay line. The delay is continuously adjustable from about 5 to 35 milliseconds, and has a bandpass of 50 Hz to 15 kHz. That enables the accurate decoding and presentation of the surround-channel information present within the source material. The (L + R) sum signal is also recovered to be sent through the delay section of the AFG when the concert mode is selected. That imparts the ambience and realism of a live concert-hall performance to musical material played through the AFG. In either mode, the output of the decoder/delay section is sent to a pair of 10-watt-per-channel power amplifiers, included on the main circuit board, for driving a pair of surround-channel speakers.

The AFG also provides a means of greatly increasing the apparent separation or "width" of the stereo image presented by the front speakers. In an ordinary decoder, the left- and right-channel signals are sent to the front speakers unaltered, and the center channel, if present at all, is fed a simple sum of the left and right signals. Although that technique provides a very solid front soundstage, it severely limits the system's ability to convincingly present extreme-left or -right sound effects. And, because the screen in most home-video systems is relatively small, especially when compared to the screen in a movie theater, dialogue which should be confined to the screen, tends to appear off screen in the left and right speakers—particularly for viewers seated off center.

The AFG uses frequency-selective circuitry to cancel some of the dialogue from the left and right channels, but that creates a phantom "hole" in the center of the soundstage. So, the AFG also creates a center dialogue channel to fill that hole by summing the left and right channels and passing them through a bandpass filter with a response curve which favors the range of frequencies covered by the human voice. Feeding the voice-only "dialogue" signal directly to the speakers in the video monitor locates the dialogue firmly on the screen without destroying the spatial effects of the front soundstage.

Finally, the AFG includes a 75-Hz active low-pass filter for driving a subwoofer setup. If you are not currently using a subwoofer as part of your system, you are missing out on the dynamic impact and heightened level of excitement which is imparted by the extreme low-frequency sounds used in motion pictures, primarily as a special audio effect. The subwoofer output of the AFG has that sonic information isolated and ready to feed to a power amplifier and speaker of your choice. You may wish to consult with a local audio dealer for advice on selecting a proper subwoofer and power amplifier. Suffice it to say, that a relatively high-power amplifier and large subwoofer will be required if you intend to fill your room with earth-shaking bass that goes far beyond the capabilities of most "full-range" speakers. It is preferable to place the subwoofer toward the front of the soundstage, although the exact position is not critical, due to the ear's inability to accurately locate very low-frequency sound. Thus, many subwoofers are designed to physically resemble an end table or other piece of furniture, so that they can aesthetically blend into the other room decor.

The AFG was designed to be connected into the pre-amp/power-amp loop of your regular home entertainment system. Consequently, all the functions of the AFG may be switched to bypass and unity gain to effectively remove it from the system, if required. We believe, however, that once you experience the added sonic dimension that the AFG adds to music as well as movies, you'll never want to switch it off.

PARTS LIST

All resistors ¼-watt, 5%, except as noted.
R1—1500 ohms
R2, R3, R54—22,000 ohms
R4, R5, R32, R33—1000 ohms
R6, R7, R61, R62, R74—20,000 ohms
R8, R9—1 ohm, ½-watt, 5%
R10–R13, R19, R34, R35—47,000 ohms
R14–R17, R20–R25, R47–R49, R55, R56—100,000 ohms
R18, R57—330,000 ohms
R26–R31, R66, R70—150 ohms
R36–R43, R67—8060 ohms, 1%
R44–R46—16,000 ohms
R50, R51—5600 ohms
R52—2400 ohms
R53—8200 ohms
R58–R60, R63–R65, R71–R73—10,000 ohms
R68—9530 ohms, ¼-watt, 1%
R69—102,000 ohms, ¼-watt, 1%
R75, R80—100,000 ohms, potentiometer
R76—10,000 ohms, potentiometer
R77—50,000 ohms, PC-mount potentiometer
R78, R79—1000 ohms, PC-mount potentiometer

Capacitors
C1–C4—2200 µF, 25 volts, electrolytic
C5, C6—10 µF, 35 volts, radial electrolytic
C7–C12, C19–C22, C27, C28, C30, C31, C45, C49, C58—0.1 µF, 50 volts, metal film
C13, C14, C23, C24, C43—2.2 µF, 50 volts, bi-polar radial electrolytic
C15, C16—22 µF, 16 volts, bi-polar radial electrolytic
C17, C18—0.22 µF, metal film
C25, C26—0.047 µF, metal film
C32–C34—3300 pF, polyester
C36, C37—2700 pF, polyester
C38–C41—270 pF, 5% ceramic disc
C42, C47—0.47 µF, metal film
C44—120 pF, 5% ceramic disc
C46—0.56 µF, metal film
C48—0.039 µF, metal film
C50—0.012 µF, metal film
C51, C56—0.01 µF, metal film
C52—1000 pF, 5% polyester
C53–C55—0.027 µF, metal film
C57—5600 pF, 5% polyester
C58—4700 pF, 5% polyester
C59—470 pF, 5% ceramic disc

Semiconductors
D1, D2—1N5400 50 PIV 3-amp diode
IC1–IC4—LF347 quad JFET
IC5—MN3008 2048-stage bucket brigade device
IC6—MN3101 2-phase clock
IC7—7812T +12-volt regulator
IC8—7912T −12-volt regulator
IC9, IC10—LM1875T audio amp
LED1—light emitting diode pilot lamp

Other components
T1—Power Transformer 25.2 Volt Center Tapped 2 Amp.
F1–F3—1-amp fuse
J1–J8—8-pin RCA-style jack panel
J9–J12—4-position pushbutton speaker-terminal panel
S1, S2, S5—SPDT switch
S3, S4—DPDT switch

Miscellaneous: speakers of your choice, 5 14-pin IC sockets, 1 8-pin IC socket, 1 heat sink (2×2×5¼-inch aluminum angle stock), 2 T0-220 mica insulators with mounting hardware, silicone grease, 3 in-line fuse holders, 3 knobs, chassis, linecord, solder, etc.

Note: The following items are available from T3 Research, Inc., 5329 N. Navajo Ave., Glendale, Wisconsin 53217-5036: An etched, drilled, and plated PC board, $15.00; a basic parts kit consisting of all semiconductors, resistors, and capacitors, $55.00; a piece of aluminum stock for the heat sink, $3.00. Please include $2.50 for postage and handling with your order. Wisconsin residents please include appropriate sales tax.

About the circuit

When viewed as a whole, the AFG circuitry is quite complex. However, referring to the simplified schematic in Fig. 1, you can see that the AFG is really made up of 10 relatively simple circuit elements. IC1-c and IC1-d are configured as unity-gain non-inverting buffer amplifiers. They transform the 47-kilohm input impedance, which is set by R10 and R11, to a low-impedance source which drives all of the AFG amplifiers, filters, and bypass outputs.

The summing (L+R) amplifier, IC2-c, combines equal amounts of the left and right signals, via R14 and R15, to develop a total composite signal. Left- and right-channel signals are applied equally through R13 and R12 to IC2-d, the difference (L−R) decoder. Any signal that's common to both channels is canceled by IC2-d, thus forming one signal which contains none of the common "mono" information present in the original stereo signal. Potentiometer R80 provides a means of exactly balancing the inverting and non-inverting gains of the amplifier for a perfect null.

The stereo width-enhancement circuit is made up from IC1-a and IC1-b. It works similarly to the (L−R) decoder, except that C25 and C26 have been added in the inverting inputs of each op-amp. Consider, for the moment, just the "right wide" circuit of IC1-a; C26 and R23 form a gently sloping high-pass filter for the left-channel signal only. Thus, the amount of signal cancellation is dependent on frequency and the relative amplitude between the two channels. In other words, the more a signal is the *same* in both channels, the more it is removed from the output of the circuit; the effect increases as the signal's frequency rises. If, however, the input signal appears only in the right channel, no matter what its frequency or amplitude, it does not cancel in the difference amplifier and appears at the output unaffected.

IC1-b functions in the same way to develop the "left wide" signal because its inverting and non-inverting inputs are connected to the left and right channels in a manner opposite that of IC1-a. The net effect of all that is to increase the apparent separation between the left and right channels by eliminating some of the material common between them. The output of the width-enhancement circuit is routed to S4, which selects either the "wide" or the bypass signal for feeding the front-channel amplifier.

The center-channel dialogue filter, or speech filter if you prefer (see Fig. 2), is built by cascading a 3-kHz low-pass filter with a 300-Hz high-pass filter to form a band-pass filter. The frequency characteristics of the human voice fall predominantly within that range. As with all of the other filters used in the AFG, those are of the 3rd order Butterworth design. That design was chosen because it offers minimum peaking within the passband. It has a sharp −18 dB/octave cutoff, a flat voltage and power frequency response, and minimum phase change within the passband. The output of the bandpass filter is routed to the high side of S3. That switch allows the center-channel output of the AFG to be switched between the dialogue filter and the bypass mode.

As shown in Fig. 3, IC3-a and IC3-b form an active crossover network for driving a subwoofer. IC3-a sums signals from the left- and right-channel buffer amps, it inverts the summed signal 180 degrees, and it provides a low driving impedance for the following filter stage. IC3-b and its associated RC network form a 75-Hz, 3rd-order low-pass filter. Because the filter inverts the signal another 180 degrees, the signal that appears across R79 (which is the output-level control) is back in phase with the original input signal.

The delay section of the AFG, shown in Fig. 4, is built around the MN3008 *B*ucket *B*rigade *D*evice (BBD), made by Matsushita (Panasonic), and the MN3101 two-phase variable-frequency clock generator. The BBD is a P-channel silicon-gate MOS LSI circuit comprised of 2048 bucket-brigade stages fabricated on a single chip. Each stage consists of a small capacitor that stores an electric charge and a tetrode transistor for switching purposes. Electrical charges corresponding to analog signals are transferred from one stage to the next by a two-phase clock drive, in the same manner that a fireman's bucket brigade transfers a pail of water from one man to the next. A signal presented at the input is transferred down the line of buckets toward the output at a speed controlled by the clock frequency. The more slowly the clock runs, the longer it takes for the signal to travel through the circuit. (See discussion of BBD theory in the October 1986 **Radio-Electronics**.)

The amount of delay required in our system varies between approximately 5 and 35 milliseconds, so our first consideration must be to select the proper range of clock frequency. The delay time of a BBD is equal to the number of stages divided by twice the clock frequency. So, based on manufacturer's data for the MN3101 clock-generator IC, values were chosen for R53, R54, R77, and C44, to produce a clock frequency, adjustable via R77, which varies from about 30 kHz to 130 kHz.

Our next consideration deals with the property of delay lines known as aliasing. If the frequency of the signal applied to the input of a delay line becomes higher than one half of the clock frequency, the time available to store the sample of that signal in the capacitor becomes too short. The amplitude of that signal's frequency has a value which changes during the time of the sample, so the charge stored in the capacitor is not an accurate representation of that instant of time. To avoid the problem and the resulting distortion, a filter is placed ahead of the BBD which limits the input frequency to one half of the lowest clock frequency used. Given that we'd like to run the clock at speeds as slow as 30 kHz, we must limit the maximum fre-

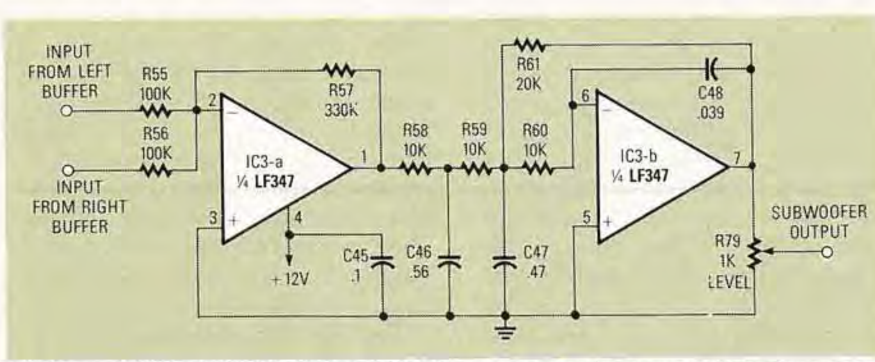

FIG. 3—AN ACTIVE CROSSOVER NETWORK for driving a high-power subwoofer system is made from IC3-a and IC3-b.

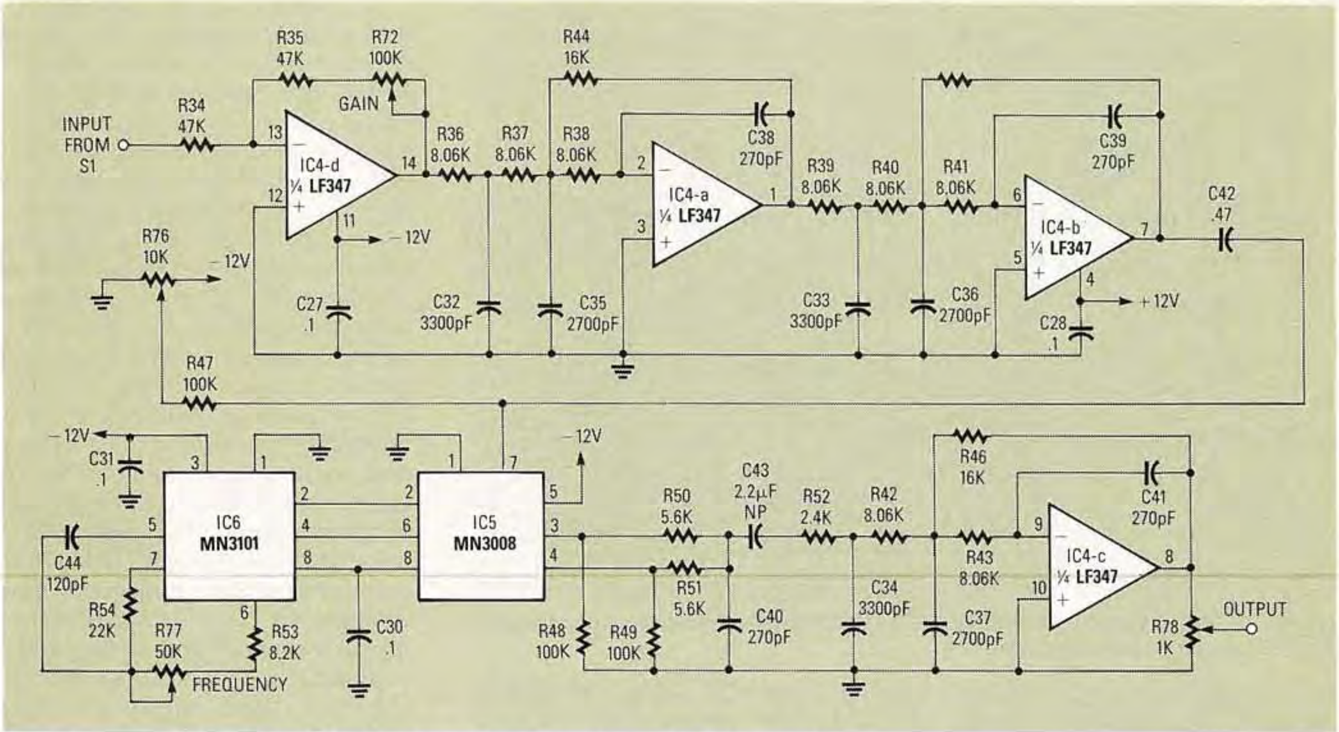

FIG. 4—THE DELAY SECTION OF THE AFG is built around the MN3008 bucket-brigade device and the MN3101 two-phase variable-frequency clock generator.

quency that we apply to the BBD to 15 kHz.

If you refer back to Fig. 1, S1 selects the signal to be delayed; either the difference signal (L − R) from IC2-d in the matrix mode or the sum signal (L + R) from IC2-c in the concert mode. The selected signal is fed from S1 to the delay section (Fig. 4) where IC4-d is configured as an inverting amplifier; R75 adjusts the gain between unity and × 3. Integrated circuits IC4-a and IC4-b, along with their associated RC networks, are identical 3rd-order 15-kHz low-pass filters. Cascading two filters produces a very sharp cut off (− 36 dB per octave), which is convenient, as it eliminates any problems that may arise with aliasing, while maintaining a respectable 15-kHz bandwidth for the section. Potentiometer R76 is used to adjust the bias voltage required by the BBD to exactly one half the supply voltage; a requirement of the device. Notice that both the BBD and the clock IC run off of the negative power-supply rail.

Another property of a BBD is that clock phase 1 drives all the odd-number stages of the device and clock phase 2 drives all the even stages. When the signal reaches the end of the line, the output of the last odd stage must be combined with the output of the last even stage to reconstruct an exact replica of the input signal. The purpose for doing that is to self-cancel any of the clock signal from the output of the device; R48 and R49 are the source-load resistors for the last two BBD stages and R50 and R51 sum the two outputs. The delayed signal is next applied to another 3rd-order 15-kHz low-pass filter comprising IC4-c and its associated RC network. That last filter is required to stop any remaining clock signal from reaching the output of the circuit. Potentiometer R78 is there to serve as the volume control for the surround channels by controlling the amount of delayed signal that is applied to the power amplifiers.

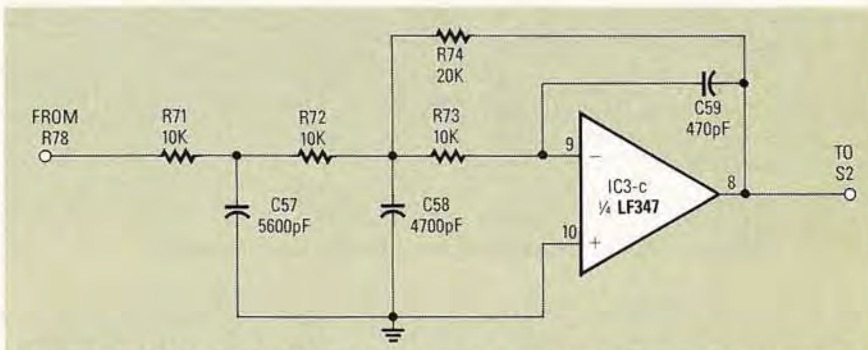

FIG. 5—A 3rd-ORDER 7-kHz LOW-PASS FILTER is made from IC3-c and its associated RC network.

To provide for increased high-frequency noise reduction in the surround channel and to more closely comply with the Dolby Laboratories standards for surround sound, a 3rd-order 7-kHz low-pass filter is included in the AFG design. As shown in Fig. 5, IC3-c and its associated RC network forms the filter; S2 then selects between the output of that filter and the bypass mode. If you refer back to Fig. 1, notice that the wiper of S2 is connected to two circuits; it goes directly to the left surround power amplifier via R31, and to IC3-d, a unity-gain inverting amplifier, via R32. The output of IC3-d drives the right surround power amplifier via R30. The reason for driving the power amplifiers out of phase will be explained shortly.

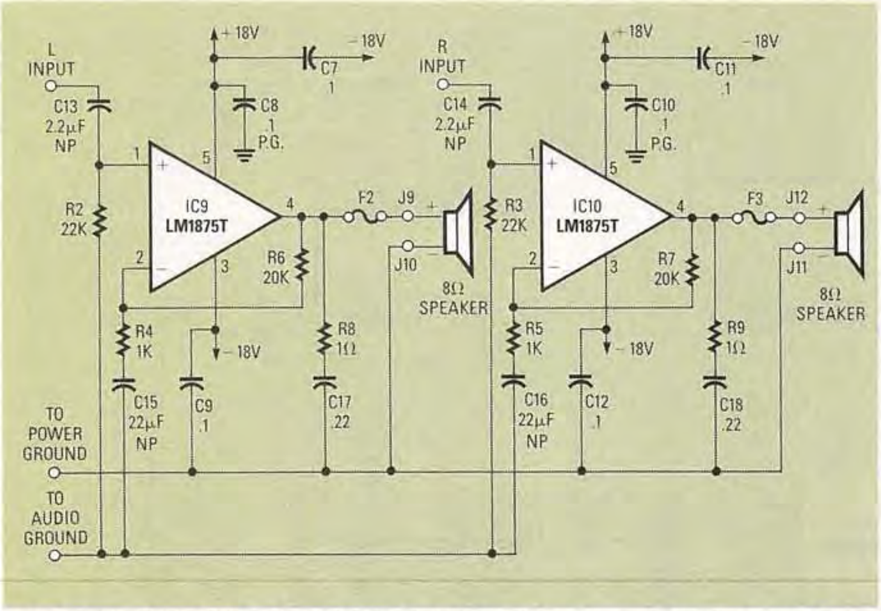

FIG. 6—THE SURROUND CHANNEL POWER AMPLIFIERS are designed around a pair of LM1875 monolithic power-amplifier IC's.

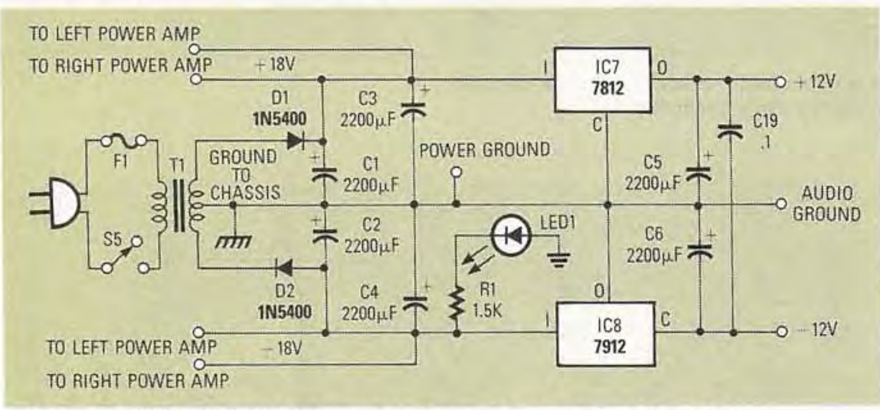

FIG. 7—THE POWER SUPPLY produces about ±18-volts unregulated DC.

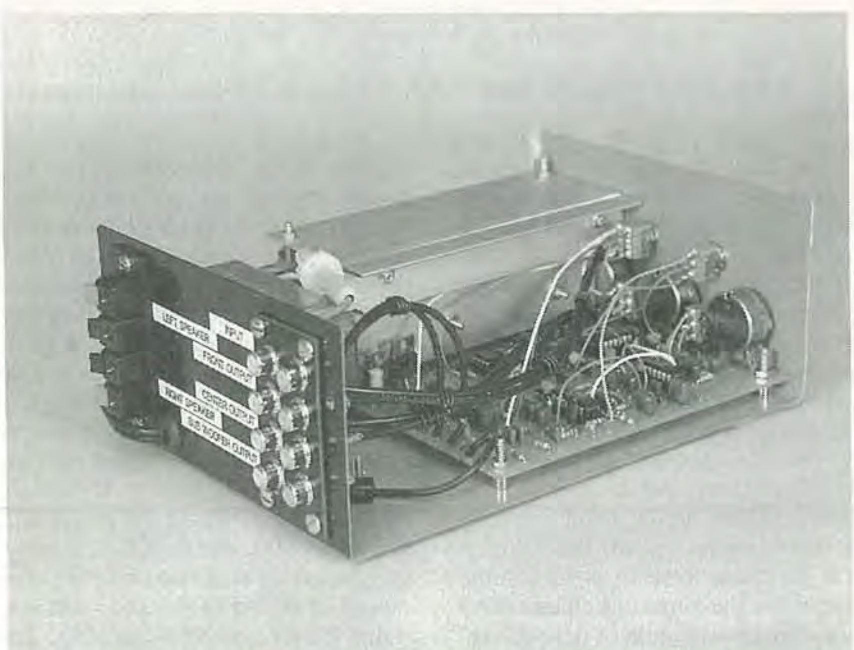

FIG. 8—THE PROTOTYPE ACOUSTIC FIELD GENERATOR. It's a tight fit in this cabinet, but it makes for a neater finished unit.

The surround channel power amplifiers of the AFG, shown in Fig. 6, are designed around a pair of LM1875 monolithic power-amplifier IC's. Chosen primarily because they require very few external parts to implement, and they also offer very low distortion, fast slew rate, wide power bandwidth, and the ability to deliver up to 20 watts into an 8-ohm load; all in a 5-pin TO-220 package. Because of limited heat-sink space in the AFG, we are running the LM1875 at about half of its power capability. The circuit configuration of the power amp is essentially the same as that of any ordinary op-amp operating in the inverting mode. Notice however, that there are two separate ground-return lines to the power supply. That is necessary because high currents flow through the output ground-return line. If a common ground-return line were used for both the input and output signal, those currents could develop enough voltage across the resistance of the return line itself to effectively act as an input signal to the amplifier, thus causing problems such as high-frequency oscillations or distortion.

The power supply of the AFG, shown in Fig. 7, is of conventional design. A 25-volt center-tapped transformer, along with diodes D1 and D2, produces about ±18-volts unregulated DC. Two 2200-μF filter capacitors are used in each leg of the supply to provide ample energy storage to meet the high-current demands of the audio output amplifier IC's during high-output peaks. Integrated circuits IC7 and IC8 regulate the positive and negative supply rails to plus and minus 12 volts for use in the low signal level circuits. The plus and minus 12- and 18-volt rails are bypassed to ground by 0.1-μF capacitors distributed throughout the entire AFG circuitry. That keeps the impedance of the supply rails at audio frequencies as low as possible, thus reducing the interaction between the various circuits.

That's all we have room for this time. We've given you the list of parts, so that you can at least gather all of them together. Next month we'll give you the foil pattern and parts-placement diagram so you'll be able to build your own AFG. You'll find that more fun than just looking at ours which, by the way, is shown in Fig. 8.

R-E