

BUILD THIS

Radio- Electronics Surround Sound Decoder

AS STARFLEET COMMANDER, YOUR STARFIGHTER HAS the latest in weaponry. From above and behind you hear the dull *thwup-thwup* of the laser pom-poms as the ball-turret tracks the incoming enemy spacefighters, whose energy bolts *zing* past your ship into the void behind. From your ship's right and left energy pods the phasor cannons fire a staccato stream whose roar fades off into a darkness that can be seen only by your ship's time-transporter.

But turn off the sound effects and once more the indefatigable starfleet commander is just another viewer in a movie theater. Without the imagery created by multi-directional sound—what we call *surround-sound*—even the most thrilling sci-fi adventure flick is not much better than an “olde-tyme” silent movie.

Just try to imagine *Star Wars* or *Top Gun* without surround-sound: They would be deadly dull. In fact, the lack of video-movie surround-sound is what turns many of the great action movies into a dull night at home on TV.

Surround-sound brings scenes to life by wrapping you in a sound environment that's as good as being there. If the picture is a forest, you become surrounded by wind and wildlife. In auto chases, cars roar out of the back of the room and onto the screen. In crowd scenes, you actually sense yourself in the center of the crowd. Surround-sound creates such a sensation of being there, that once you hear it, you'll lose interest in video and movies without it.

This month, we'll show you how to build a low-cost surround decoder. Next time, we'll show you how to add even more excitement to your TV sound with a subwoofer simulator.

Concealed sounds

Every modern home video-movie now contains high-fidelity stereo tracks, which are output on the back panel of a modern VCR as left and right channels. When connected to a stereo system, they provide a *wide-screen* (semi-stereo) sound rather than the mono heard from a conventional TV or video monitor.

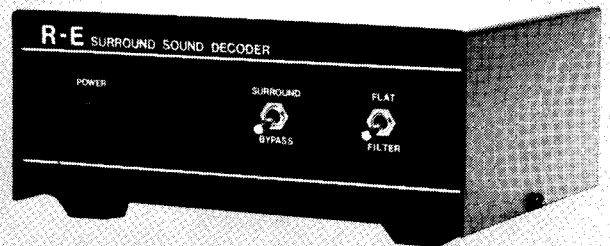
But *wide screen*, even genuine stereo, isn't surround-sound because it's still two-dimensional. The three-dimensional effect of surround-sound requires, at the very least, a rear channel, which might be provided by one or

*Add some excitement
to your TV viewing!*

*Our easy-to-build
surround-sound decoder*

*brings movie-theatre sound
to your living room.*

NORMAN M. HILL



more additional sound tracks in the original theatrical release print; or, the rear sounds can be encoded within the stereo tracks. As far as home videos are concerned, there is only the stereo tracks, so the rear channel that creates the illusion of surround-sound is concealed by a special encoding within the left and right sound tracks. The encoded signals either blend into the front stereo channels or cancel each other; either way, they are not heard as distinct sounds when the sound you hear is played through a conventional stereo system.

It takes a special kind of decoder, such as our surround-sound decoder, to extract the rear sounds from the stereo signal, and it is the decoded rear sounds that cause the home viewer to be enveloped by a surround-sound that is very similar to what is heard in a movie theater.

Broadcast movies

What happens if the movie is broadcast by a TV station? The same thing, but only if the station is broadcasting MTS stereo. If you decode the MTS stereo signal you will again derive the rear audio channel. If you record the TV signal on a VCR, you can either decode the station's MTS stereo, or have the VCR do the stereo decoding (if it is so equipped).

Dolby

Surround-sound is brought to you by Dolby Laboratories, the same people that developed Dolby tape-noise reduction. A form of Dolby noise reduction is part of their surround-sound record/play system, and Dolby owns the rights to the surround-sound technique. Our decoder however does not include Dolby noise reduction yet it still produces good results.

How it began

The early 1970's saw the development of a patented technique of encoding four channels into two stereo tracks. When decoded, the stereo signal produced four distinct outputs. By adjusting the phasing and relative levels of the signals blended into the stereo tracks, it was possible, by using the speaker placement shown in Fig. 1, to create the illusion of sound coming from the front, the sides, or the rear. Effectively, the sound could be located anywhere within a 360° field.

The technique was later modified so that a conventional stereo-front/

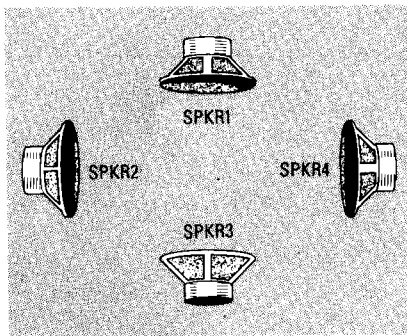


FIG. 1—THE EARLIEST OF MULTI-DIRECTIONAL sound systems used this unusual speaker arrangement, which foreclosed true stereo listening.

stereo-rear speaker placement could be used; that is, left and right speakers in front of the listener and left and right speakers behind the listener. Unfortunately, the stereo-type technique eliminated wide stereo separation. In fact, left-to-right and front-to-rear separation was often reduced to as little as 3 dB. Since 3 dB is the *minimum* change in *program material* that can be sensed by the human ear, electronic enhancement of 4-channel sound was necessary in order to create the spectacular effects expected by the listener. Basically, it was done by electronic gain-riding. A monitor circuit determined which sound position (location) was dominant and adjusted the gain of the various channels so that the listener would perceive a stronger signal at that position. As a general rule, the electronic enhancement added 3 dB to the already existing 3-dB separation. The total of 6-dB separation was sufficient to trick the brain into believing it was sensing a precise sound location.

For various reasons, among them being the extra cost of the rear amplifiers and speakers, and the eventual deployment of several kinds of encode/decode circuits, 4-channel sound, usually referred to as *quadraphonic* or *quadriphonic* sound, met with little success in the marketplace. But it did establish that a multi-directional sound could be encoded within conventional stereo tracks.

About that time, the movie industry was searching for a blockbuster technology that would bring in more patrons; something more attractive than just another form of wide-screen projection. The blockbuster was to be Dolby Stereo.

Dolby Stereo

The Dolby Stereo system was intro-

duced for movie theaters in 1975. Under that system, 35-mm film carries two stereo tracks, and uses quadraphonic weighting to encode/decode the stereo signal into four outputs.

However, the need in a theater is not for 360° quadraphonic coverage. A theater needs only a single rear track to generate spectacular effects. There is no need for side sound because the primary sound placement is almost always on the screen, which is in front of the viewer. The needed speaker arrangement is shown in Fig. 2.

Unfortunately, that's far from a complete solution because the limited 3-dB channel separation of movie surround-sound is a real problem for all but the good seats at the center. Seats close to the rear will be swamped by the 3-dB leakage from front left and front right. Up front, better separation

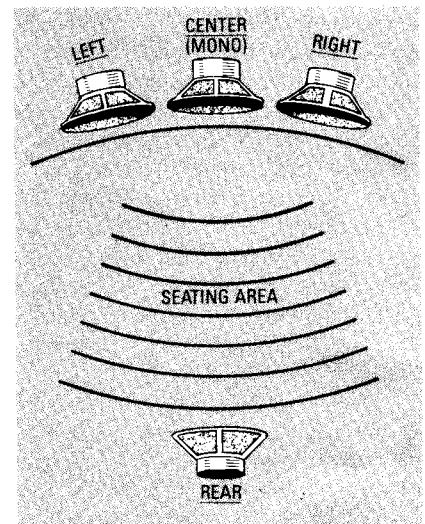


FIG. 2—THIS IS THE SPEAKER ARRANGEMENT for movie-theater surround-sound. Notice that a center speaker provides direct mono, rather than a mono image that's derived from left and right speakers.

is also desired so that audio sources track with the image on screen.

For those reasons, the quadraphonic concept of gain-control positioning of the dominant audio direction was incorporated into Dolby Stereo, and the smashing 1977 success of the Dolby-Stereo encoded *Star Wars* entrenched the system as the industry standard.

The gain-control circuitry is a serious complication, necessary to make all the seats in the house good ones. Home decoders loaded with such circuitry, such as the Shure HTS5000 are available for around \$750. Units that incorporate gain

control are identified by the *Dolby Surround Pro Logic* logo.

The Dolby home decoder

In 1981, Dolby Labs acknowledged a need for a low-cost, no-gain-control decoder for home video and recommended an appropriate circuit. Decoders without gain-control carry the *Dolby Surround* logo.

Those lower-cost units are available from various licensed manufacturers for \$200-\$400, and to carry the *Dolby Surround* logo they must process audio according to the block diagram shown in Fig. 3.

Dolby's decoder.

All processing is performed on the (L-R) difference signal, which is concealed within the left and right stereo tracks. While only a single rear-channel is decoded, it is intended that two speakers will be positioned at the rear of the room, hence, the rear output is shown as REAR LEFT and REAR RIGHT, even though they both carry the same signal. Two traditional stereo speakers provide the front sound.

As shown in Fig. 3, Dolby restricts the rear channel's high-end frequency response to 7 kHz. When the standard was being developed, the high-frequency coherence between the two channels of home-video equipment wasn't consistent. Directional placement could become random if high-frequency phase-coherence were to be lost on a wide-band signal; for example, an actor's voice might be reproduced with the lower frequencies from the front and the sibilants from the rear. However, the likelihood of that happening depends on the equipment used for recording and playback. While some tapes sound better

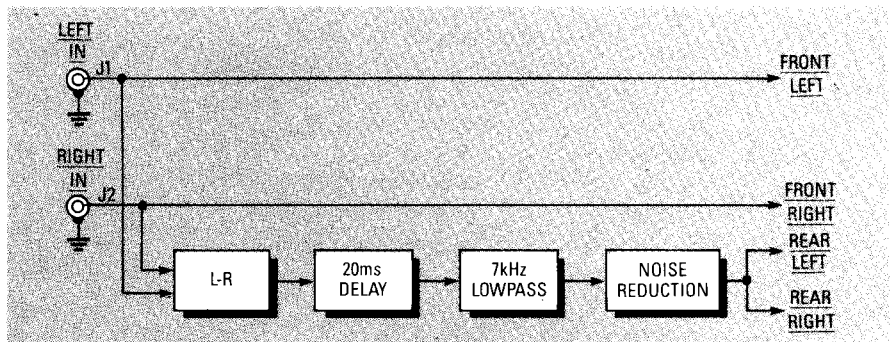


FIG. 3—DOLBY'S RECOMMENDED HOME DECODER includes a 20-ms delay and a noise-reduction system.

with a rear filter, many tapes and the equipment they are played on have cohered high-frequency phase performance, and they sound better—at least more natural—without the filter. If you're finicky about sound quality, the 7-kHz cut-off should be switch selectable so that you can enjoy the best in sound when the tape and equipment make it possible.

Notice that Fig. 3 indicates a 20-ms time delay. The delay serves two purposes. First, since 20 ms represents the time it takes the sound to travel about 20 feet, it allows the rear speakers to be positioned close to the seating, yet the sound appears to originate from farther back, more closely simulating theater sound, where the rear speakers are located considerably behind the viewer. The time delay also proves useful when there is accidental leakage of the front-left or front-right sound to the rear. Since the 20-ms delay causes the sound to arrive after the front sound, it reinforces the perception that the sound is up front.

Fortunately, the positioning of home rear speakers can usually be juggled so that the delay isn't really necessary, which simplifies con-

struction of a home decoder, reduces its cost, and also eliminates the noise and distortion that might be caused by a delay unit.

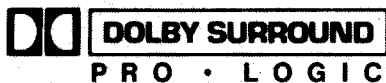
Noise reduction

In the Dolby system shown in Fig. 3, the rear-channel information is supposed to be encoded with a noise-reduction that is similar to the *Dolby B* processor used for cassette recorders. Listening tests and inspection of a frequency/gain table indicate that we could probably do without it as far as surround-sound is concerned, so we left it out of the prototype.

Note, in particular, that Fig. 3 does not show signal processing to the front speakers: Differential signals driving the rear speakers pass to the front unchecked. If we add some of each front channel to the other, we attenuate to the leakage of the rear signals while reducing the front stereo separation. The reduction in separation is desirable because it helps viewers in off-center seats hear a stereo spread without resorting to a center channel. (Note the center mono speaker used in the movie system shown in Fig. 2.)

WHICH IS WHICH?

The type of circuits used in a home *Dolby Surround* decoder is identified by the kind of *Dolby* logo used. If the decoder contains both 20-ms time delay and noise reduction circuits it is called a *PRO LOGIC* model and has this logo shown.



If the decoder is the less expensive design that does not contain time delay and noise reduction circuits, it is identified by this *Dolby* logo.

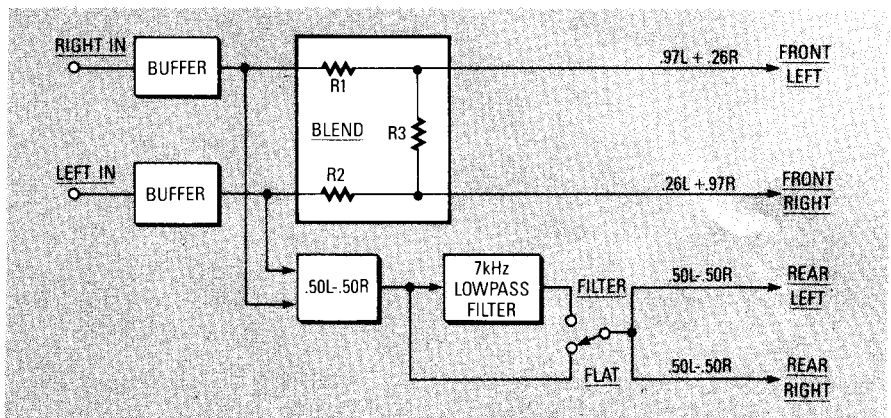


FIG. 4—OUR SURROUND-SOUND DECODER ELIMINATES both the time delay and the noise reduction, which doesn't seem to degrade how the three-dimensional effect sounds in the home.

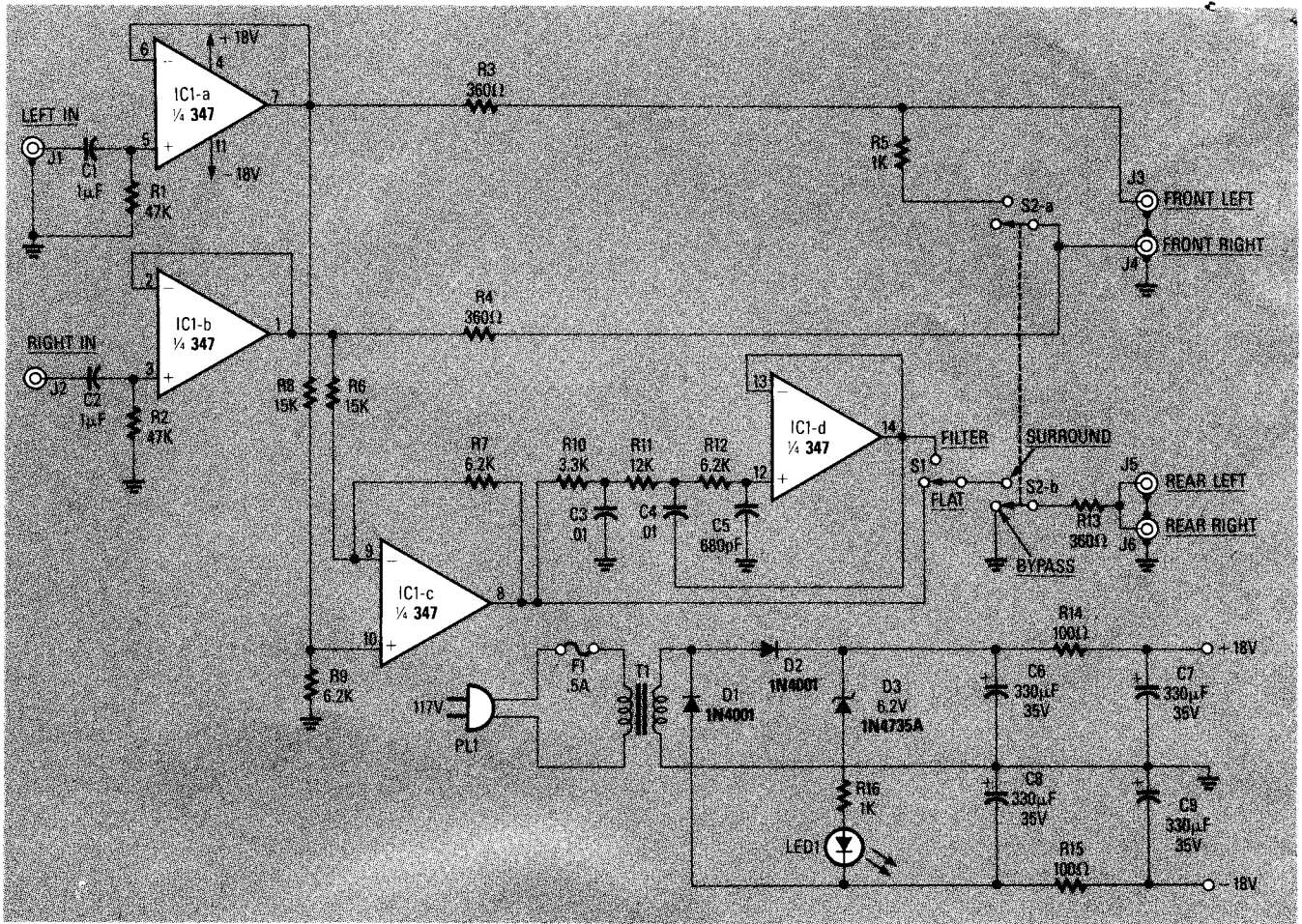


FIG. 5—THE DECODER'S CIRCUIT. Virtually nothing is critical because R3 and R4 isolate the buffer amplifiers from the capacitance of the shielded cables connected to J3 and J4.

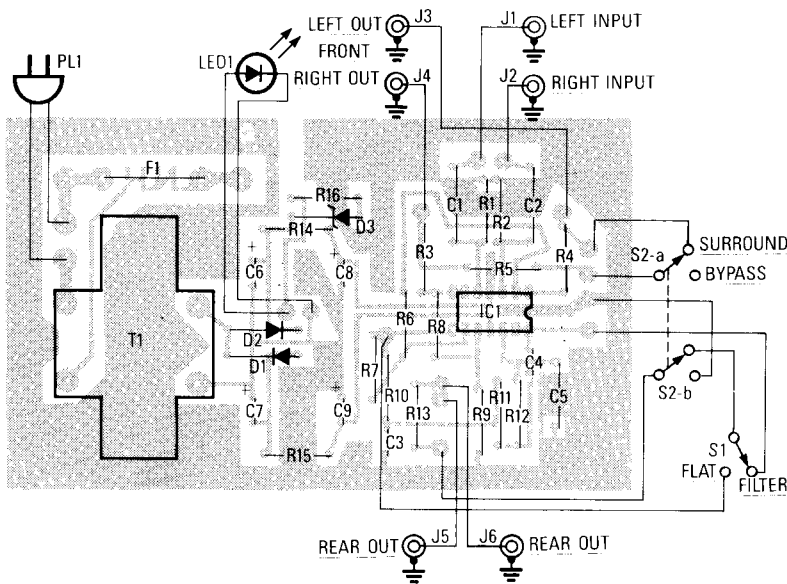


FIG. 6—THE COMPONENT LAYOUT for the printed circuit board. Double-check the polarity of all diodes and electrolytic capacitors.

A surround decoder

Figure 4 shows the block diagram for our surround-sound decoder. It consists of input buffers, a front blender, a rear difference decoder,

and a switchable low-pass filter. The rear levels are such that, if all four speakers are identical, and the driving amps have identical gain, the system would be balanced for proper level

with no need for level adjustments. In practice, however, the rear speakers are different and the level is adjusted on the rear amplifier.

If any one speaker sounds at full volume, the other two sound half as loud (-6 dB), 1/4-power. A separation of 6 dB is a lot better than the 3-dB separation of a four-channel system, and such a decoder is easier to build than a "true" Dolby type, yet it sounds as good or better when it is fed from a Dolby surround-sound signal source.

Notice that the system actually puts out only three sound channels (the rear-right and rear-left are the same); it does not use a 20-ms delay, nor noise reduction, and although it lacks any form of gain control, the separation between channels is maximized.

In a typical home environment, the front speakers should just about flank the screen, because we want the sound to appear to originate up front, at the screen, just as it does in a theater. The rear speakers should be located behind and flanking the seating location of the viewer.

PARTS LIST

All resistors are 1/4-watt, 5%.

R1, R2—47,000 ohms
 R3, R4, R13—360 ohms
 R5, R16—1000 ohms
 R6, R8—15,000 ohms
 R7, R9, R12—6200 ohms
 R10—3300 ohms
 R11—12,000 ohms
 R14, R15—100 ohms

Capacitors

C1, C2—1 μ F, 100 volts, polyester
 C3, C4—.01 μ F, 50 volts, polyester
 C5—680 pF, polyester
 C6—C9—330 μ F, 35 volts, electrolytic

Semiconductors

IC1—LF347N, quad op-amp
 D1, D2—1N4001 silicon rectifier
 D3—1N4735A, Zener, 6.2 volts
 LED1—Light-emitting diode
Other components
 F1—Fuse, slo-blo, 0.5 ampere
 J1—J6—Phono jack
 PL1—Power plug
 S1—SPDT switch
 S2—DPDT switch
 T1—Power transformer: 120-volt primary; 12.6-volt, 300-mA secondary
Miscellaneous: Printed-circuit ma-

terials, fuse clips, enclosure, etc.

Note. The Kwik-Kal tape is available for \$16 VHS, \$19 BETA, plus \$2 shipping and handling from Zero Ohm Enterprises, 15214 NE 8th, Suite G-10, Bellevue, WA 98007. WA residents must add appropriate sales tax.

An etched and drilled circuit board is available for \$10.25 postpaid from Fen-Tek, P.O. Box 5012, Babylon, NY 11707-0012. NY residents must add appropriate sales tax.

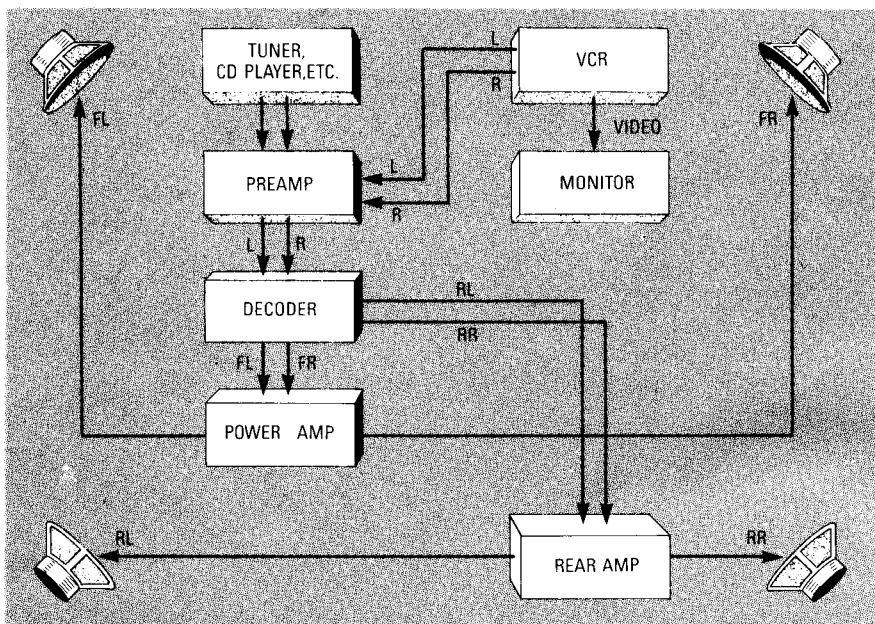


FIG. 7—THE MOST FLEXIBILITY IS ATTAINED if the decoder is used in a component system. This kind of arrangement also allows tuner and CD-player signals to be decoded.

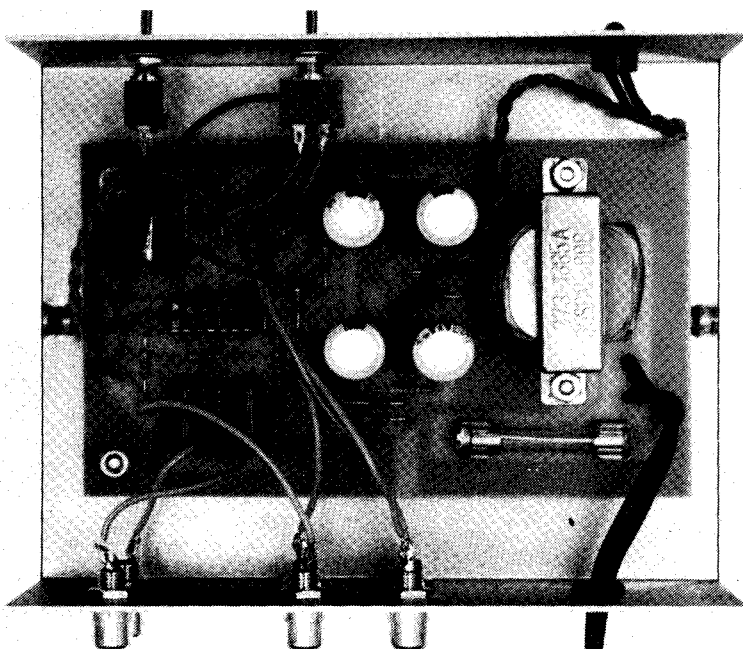


FIG. 8—THE PROTOTYPE USES PHONO JACKS for all input and output connections. Grouping them on the rear apron allows the decoder to be easily connected into any kind of component arrangement.

The circuit

The complete circuit is shown in Fig. 5. Components R1, R2, C1, C2, IC1-a, and IC1-b buffer the left and right channels at unity gain over the audio band. The front channel blending described earlier is attained when switch S2-a connects R5 across R3 and R4. When S2 is set to the BYPASS mode, R3 and R4 isolate IC1-a and IC1-b from the capacitance of the shielded cables that are connected to J3 and J4.

Resistors R6–R9, and integrated circuit IC1-c, make the L–R difference signal the correct level if all speaker/amplifiers are equal. Resistors R10–R12, along with capacitors C3–C5, and amplifier IC1-d, form a 3-pole Chebychev 7-kHz active filter. When the filter is selected, R13 isolates the capacitive cable loading from IC1-d.

The power supply is not regulated because precise voltage values are not critical. Diode D3 is used to slow the power-off loss of the positive-voltage output, reducing "turn-off" pops.

Our prototype decoder is assembled on a printed-circuit board; the template for the board is provided in PC service. There are no unusual assembly considerations other than insuring that there is isolation between T1's ground lead and C6–C8 (there should be only one power-supply ground, as shown). Also, ceramic capacitors should not be used because their tolerance varies with temperature and the applied voltage, thereby possibly creating distortion. Polyester capacitors are recommended.

The PC-board's component layout is shown in Fig. 6. Nothing is unusual or critical as long as the polarity of all diodes and electrolytic capacitors is

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SURROUND SOUND

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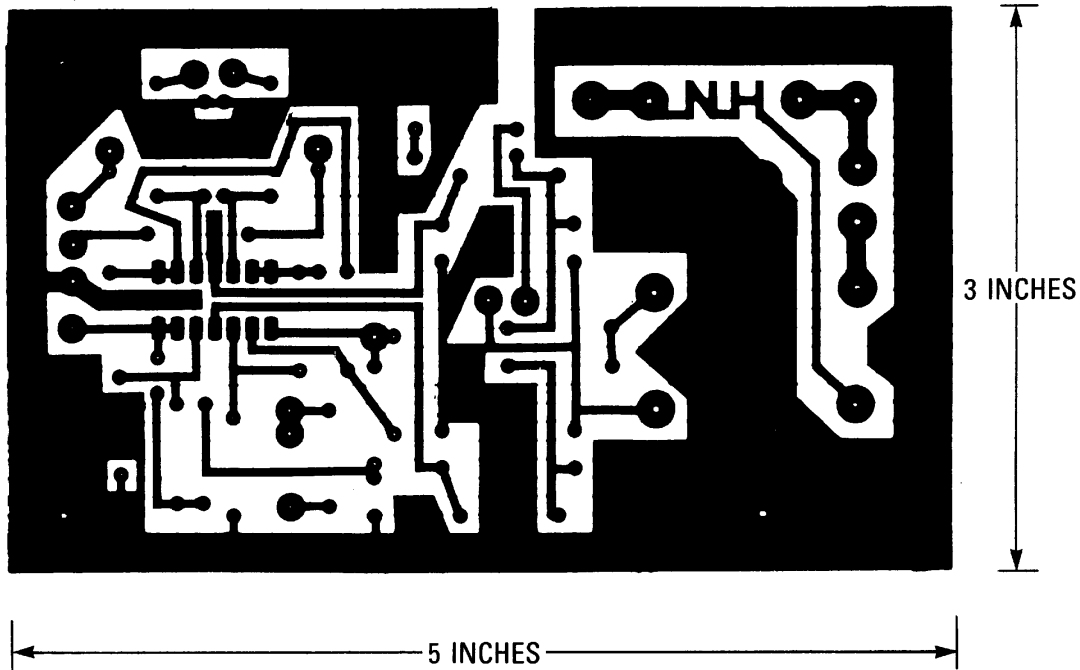
correct. Note that there is no power switch between power plug PL1 and T1's primary winding. That was done because the power to the prototype is switched with the rest of the system to avoid turn-on pops.

Setting up

Figure 7 shows how the surround-sound decoder can be set-up in a component video-sound system. Notice that by having the decoder connected between the preamplifier and the power amplifier it can also be used to decode signals that originate in a conventional tuner, a CD player, or whatever. Also note the use of left-rear and right-rear speaker signals even though the left and right decoder outputs, as previously discussed, are the same. Obviously, your particular video-audio system will be different, but Fig. 7 will give you a good idea of the various ways in which signal sources and amplifiers can be combined with the surround-sound decoder. As shown in Fig. 8, all of the decoder's inputs and outputs are made through phono jacks that match the conventional phono-plug patch cords that are used for all home video-sound connections.

If your system doesn't use components, and the stereo outputs of your VCR or TV normally drive an integrated amplifier or a receiver, simply connect the decoder between the VCR or TV and the amplifier's or receiver's AUX or VIDEO-SOUND inputs.

If all four speakers were identical, and if their driving amplifiers had identical gain, and if the front and rear speakers were equidistant from the viewer, no level balancing or adjustment would be necessary. But that's a lot of ifs. More than likely, you'll spend some time fiddling with the amplifier controls. A better way to calibrate Hi-Fi surround-sound system is to use a 7-minute video calibration tape called *Kwik-Kal: A Seven Minute Surround Test*, which features on-screen indication of speaker placement, the channel being encoded, and its weighting. The tape is available in the Beta and VHS formats and contains a Hi-Fi track. (See Parts List.) Once the system is optimized by using the tape, there's no need to fiddle with any adjustments. Simply sit back, relax, and enjoy the show. **R-E**



HERE'S THE PATTERN for the Surround-Sound decoder.