A Home Theater Preamp

With this six-channel preamp, you'll be able to accommodate the latest audio formats.

Is it worthwhile for an audio hobbyist to try and build a multi-channel preamp in the age of multi-format digital audio? The answer is "yes," especially for those who relish separate amplifiers and active frequency dividing networks. Inexpensive home theater receivers do not likely contain multi-channel analog outputs to support a multi-amplifier system.

Obtaining an expensive home theater preamp limits you to the digital audio formats embedded therein at the time of purchase. The chipset used for decoding is often touted as an advantage for audio quality. However, if you wish to take advantage of newer formats such as multi-channel PCM, Dolby True-HD, or DTS-HD available on Blu-Ray and HD-DVD discs, the unit may not be able to decode these. Instead, you will need to resort to using a set of analog multi-channel inputs along with an audio decoder internal to the player or other source.

PREAMP OVERVIEW

The preamp contains inputs for four sources, three of which are six-channel inputs and one stereo input. In my system (**Photo 1**), these are connected to a Dolby Pro-logic decoder (for TV sound), a Blu-ray disc player, a DVD audio/video player, and a CD changer. The disc players decode multiple audio formats internally and deliver them via multi-channel RCA outputs.

The preamp contains five outputs (more on that later). The main channels are sent to a three-way active crossover network and then subsequently through separate MOSFET power amplifiers. The center channel and surround right/left channels are connected directly to respective amplifier channels.

The reason for including only five outputs is that the "subwoofer" input channel is summed with the main channels. This "subwoofer" signal is a combination of the Low Frequency Effects channel (Dolby 5.1 soundtracks) and low-frequency information that has been re-directed from the center and surround channels. This is a matter of personal preference because my system does not contain typical subwoofers, but rather a set of robust three-way main speakers. Should you choose to build your own preamp, you could modify the design to include a dedicated subwoofer output.

The front panel of the rack cabinet (**Photo 2**) contains a rocker power switch, three function push buttons, and a red bezel window. Mounted behind the bezel are an infrared detector and the seven-segment LED displays. The rear panel (**Photo 3**) contains 25 RCA connectors necessary for the audio component connections.

The LED display indicates which of the four sources is currently selected. When the attenuation up or down command is given, the attenuation level is displayed (0 to –60dB in 2dB steps). For my application, a gain > 1 is not necessary given that digital audio players have sufficient output levels to drive the power amplifiers into clipping (overloaded). However, you may choose to modify the design for additional gain to suit your application.

The preamp is programmed to respond to NEC type IR commands that are generated by a "universal" TV remote. The attenuation level is controlled with arrow keys on the remote. Numbered buttons 1-4 set the input source selection. I also added a mute function ("0" key) that sets the attenuation level

PHOTO 1: Author's audio/video system.

PHOTO 2: Front panel.

PHOTO 3: Rear panel.

to >-100dB, which is great for dealing with annoying commercials. This mute feature is only available from the remote control.

Another added capability of the preamp is that relative levels of the individual channels may be set from within the software. This is useful when the internal decoding of your equipment does not allow for proper balancing of the surround system.

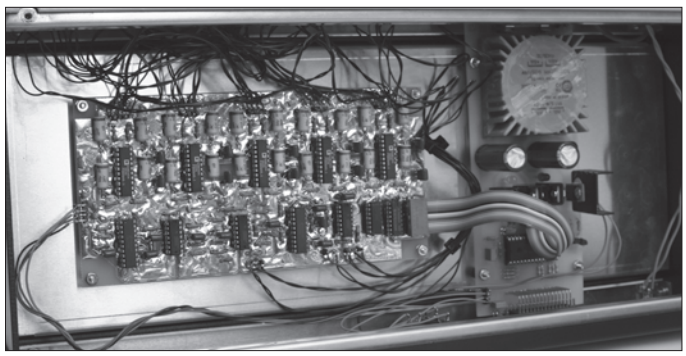

PHOTO 4: Preamp PC and power supply (right) boards.

THE POWER SUPPLY/ MICROCONTROLLER BOARD

The power supply board (**Photo 4** far right) is a single-sided PCB that contains the power supply, the microcontroller IC with associated components, and the IR detector and seven-segment LED displays. The power supply is made up of a toroidal transformer T1, rectifier bridge D1, filter capacitors C1/C2, and four fixed-voltage regulators. Regulator output stability is ensured with the use of tantalum output caps. The ±15V levels are used to supply the op amps on the audio board. All other ICs use the ±5V levels. Note: The four TO-220 package regulators use small heatsinks; however, I used a slightly larger 5W rated heatsink for the +5V regulator due to the heavier current demand.

The PIC microcontroller contains 2K bytes of flash program memory, which is easily programmed using a PICSTART Plus development programmer. This PC-based application allows changes to be made in minutes. The program listing, along with a flowchart explaining the IR remote portion of the code, is posted on the *aX* website (www.audioXpress.com). The program decodes NEC 6121 IR commands, which are 32 bits in length and are derived from Pulse-Position Modulation. I used the 6121 encoding because it was available from an existing TV remote and not used by any other equipment that I own.

The 22 I/O pins of the PIC16F57 are fully used in the preamp design. Port A is connected to the input switches SW1-SW3 and pullup resistors R15-R17. The Sharp IR receiver U7 is also connected to Port A. This three-terminal device contains the IR detector, amplifier, limiter, and 38kHz bandpass filter necessary to receive IR commands from across a room.

Port B I/O pins are connected to the multiplexed common-cathode LED displays (one overflow digit and a two-digit display). The LED displays are mounted on a 30-pin right-angle IC socket directly adjacent to the IR detector. Port C I/O pins control the function of the audio board via a 16-pin DIP header cable.

The schematic for the power supply

board is provided in **Figs. 1** and **2**. **Figure 3** is the component-placement diagram for the PCB. The single-sided etch pattern is also provided in **Fig. 4** (Note: The photo tool is negative in polarity due to the etch process used.) Construction of the PCB is fairly straightforward. I placed small circular pads in the pattern to locate the mounting holes.

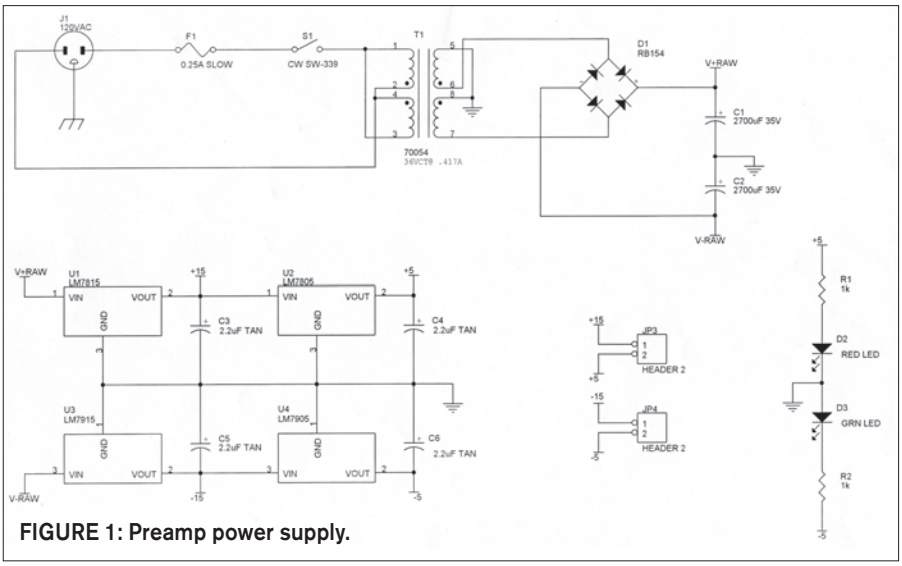

FIGURE 1: Preamp power supply.

THE AUDIO BOARD

The schematic diagram for the audio board (**Photo 4**) is shown in **Fig. 5**. The three sets of six-channel inputs (and single stereo input) are connected through DC blocking capacitors to quad analog switches. The SSM2404 is produced by Analog Devices and is designed especially for audio applications. Noise and distortion figures are negligible. Digital logic levels from the microcontroller select the input source.

The outputs of the analog switches are loaded with 10kΩ resistors. The selected audio signals are then fed to two LM1973 three-channel log step attenuator ICs. These devices are also intended for professional audio applications. I chose stepped attenuator devices over any type of potentiometer attenuation control because even expensive ones wear and induce noise over time. The attenuation level is controlled by serial data sent from the microcontroller. Different offsets may be applied to any of

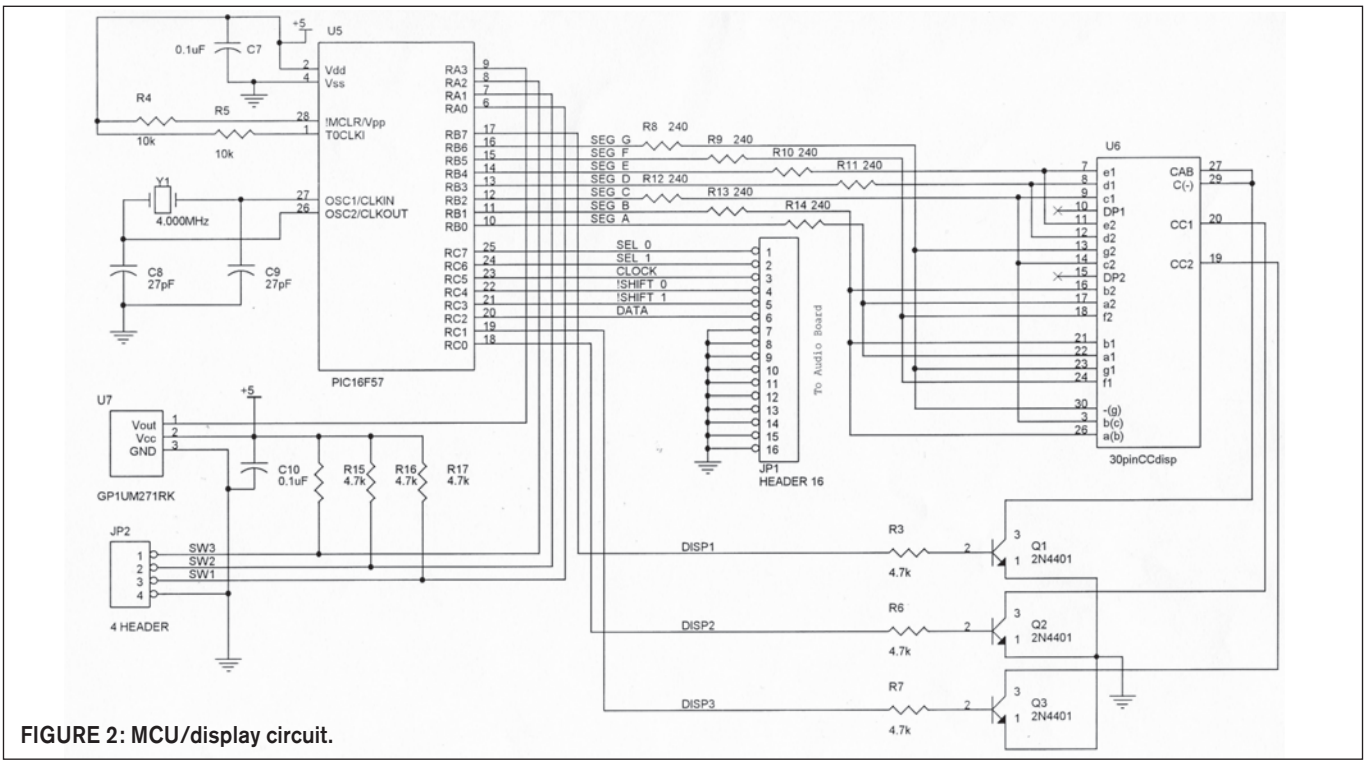

FIGURE 2: MCU/display circuit.

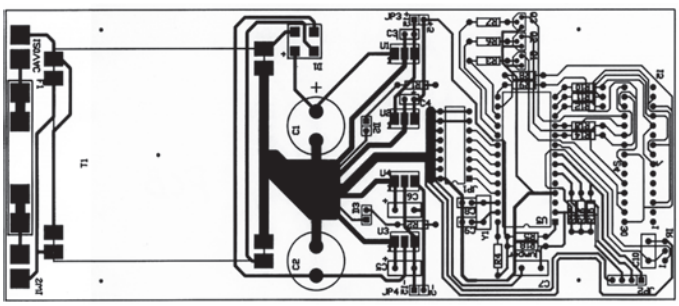

FIGURE 3: Component placement.

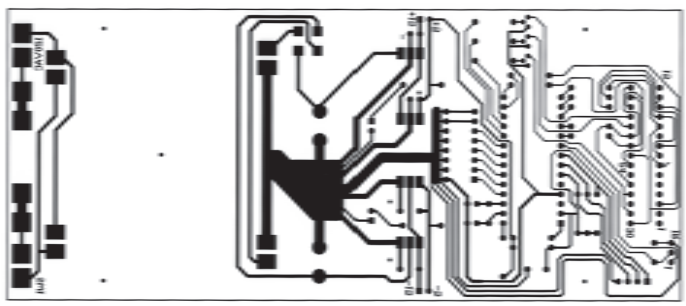

FIGURE 4: Printed circuit layout.

the six channels by the program, because each attenuator channel is individually addressable.

The outputs of the attenuators are buffered using LF347B bi-FET op amps. You may substitute more specialized devices; however, FET inputs are necessary to maintain clickless operation. The 100Ω series resistors prevent signal degradation when driving higher capacitance audio cables.

The purpose of op amp U5 is to sum the subwoofer channel with the main channels. Again, this has been done to suit a specific application (and admittedly a preference). You may modify the design to provide a dedicated subwoofer output if so desired.

The audio board is a double-sided PCB in which the top layer is designed primarily as ground plane. This feature, along

PARTS LIST

Power Supply/Microcontroller Board			
Ref.	**Value**	**Manufacturer**	**Digikey.com #**
C1, 2	2700µF 35V	Panasonic	P11247-ND
C3-6	2.2µF tan	Kemet	399-3550-ND
C7, 10	0.1µF	Panasonic	P4593-ND
C8, 9	27pF	BC Components	1430PH-ND
D1	RB154, 1.5A 400V	Bridge	RB154MS-ND
D2	Red LED	Generic	
D3	Green LED	Generic	
F1	0.25A slow	Generic	
JP1	Header 16	16-pin IC socket	ED3116-ND
JP2	4 header	Generic	
JP3, 4	Header 2	Generic	
J1	120V AC	Generic	
Q1-3	2N4401	Fairchild	2N4401-ND
R1, 2	1k	Yageo	1.00KXBK-ND
R3, 6, 7, 15-17	4.7k	Yageo	4.75KXBK-ND
R4, 5	10k	Yageo	10.0KXBK-ND
R8-14	240	Yageo	240XBK-ND
S1	SW-339	CW	SW339-ND
T1	70054	Talema	TE70054-ND
U1	LM7815	National Semi	LM340T-15-ND
U2	LM7805	National Semi	LM7805CTFS-ND
U3	LM7915	National Semi	LM7915CT-ND
U4	LM7905	National Semi	LM7905CTFS-ND
U5	PIC16F57	Microchip	PIC16F57-I/P-ND
U6	30 pin CC disp	Stanley	404-1131-ND, 404-1136-ND
U7	GP1UM271RK	Sharp	425-1139-ND
Y1	4.000MHz	Abracon	535-9057-ND
Preamp audio board			
Ref.	**Value**	**Manufacturer**	**Digikey.com #**
C1-3, 5, 11-14, 21, 22, 27-30, 35-38, 43, 44	0.1µF	Panasonic	P4593-ND
C4, 10, 15, 20	10pF	BC Components	1426PH-ND
C6-9,16-19, 23-26, 31-34, 39-42	10µF	BC Components	4211PHCT-ND
C45-48	2.2µF tan	Kemet	399-3550-ND
JP1	Header 16	16-pin DIP socket	ED3116-ND
JP2-15	4 header	Generic	
R1-3, 5, 6, 12-15, 17	100k	Yageo	100KXBK-ND
R4, 16, 28, 29, 35	100	Yageo	100XBK-ND
R7-11, 18-27, 30-34, 36-41	10k	Yageo	10.0KXBK-ND
U1	74LS00	TI	296-1626-5-ND
U2	74LS139	TI	DM74LS139-ND
U3-5	LF347B	TI	LF347B-ND
U6, 8-10, 12	SSM2404	Analog Devices	SSM2404P-ND
U7, 11	LM1973	National Semi	LM1973-ND
Miscellaneous			
Item	**Value**	**Manufacturer**	**Digikey.com #**
Rack chassis	RMC19038, RMP1908	Hammond	HM738-ND, RMP1908-ND
LED Bezel		PRD	PRD180R-ND, PRD180B-ND
Selector switches (3)		E-switch	EG2041-ND
RCA connectors (25)		Switchcraft	SC1134-ND, SC1146-ND, SC1147-ND
30-pin display socket		MILLMAX	ED58427-ND
16-pin DIP cable		CW	C6PPG-1606M-ND

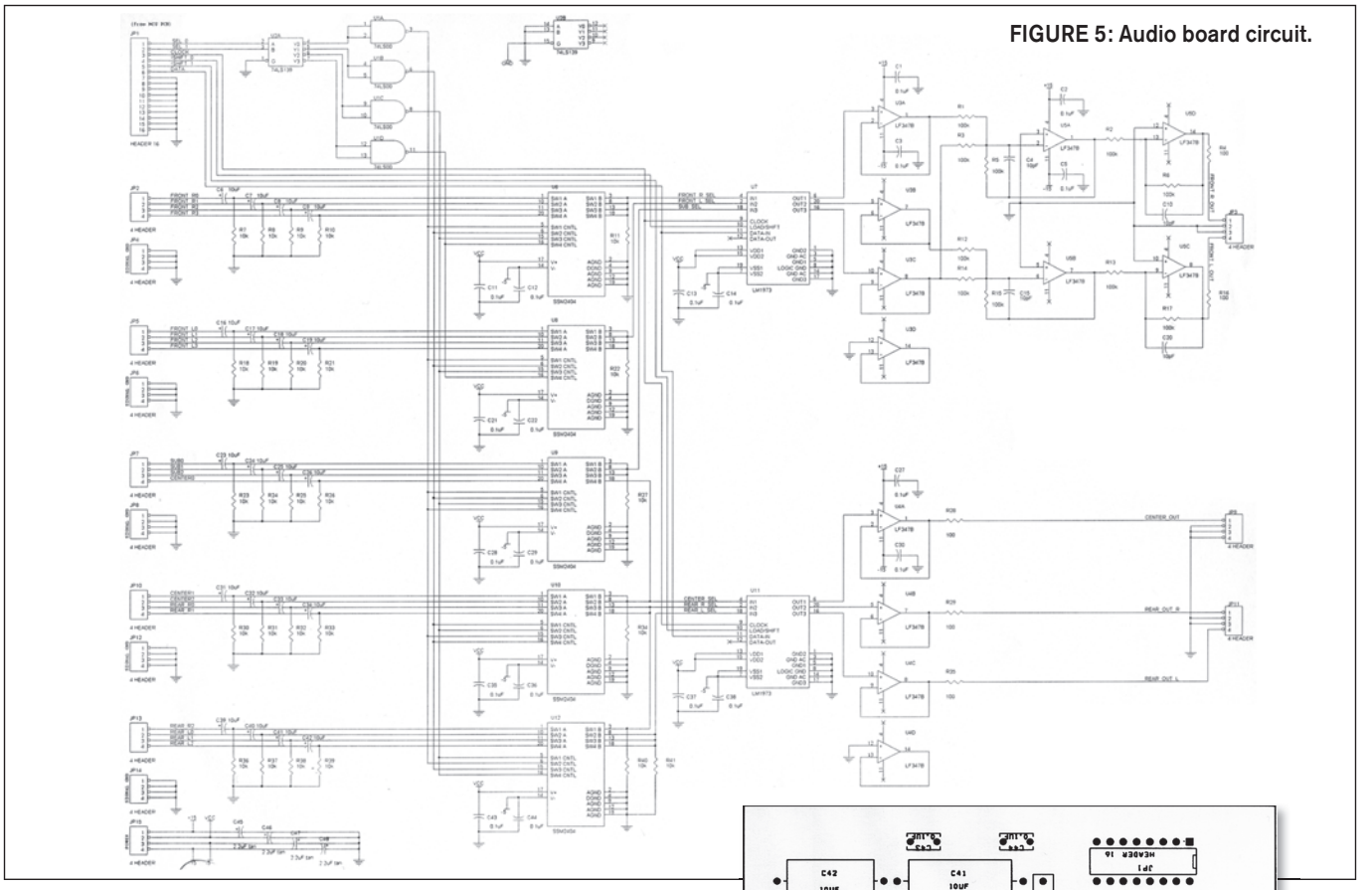

FIGURE 5: Audio board circuit.

with generous power supply bypass capacitors, helps ensure good electrical performance. The layout is available in **Figs. 6** and **7** (top and bottom side, respectively). The component layout is shown in **Fig. 8**.

The PCB has been designed without any vias, such that all front-back connections are made with only component leads. Hint: I achieve better results drilling from the bottom (main routing) side of the PCB. This reduces the chance of damaging a pad-trace connection due to drill bit deflec-

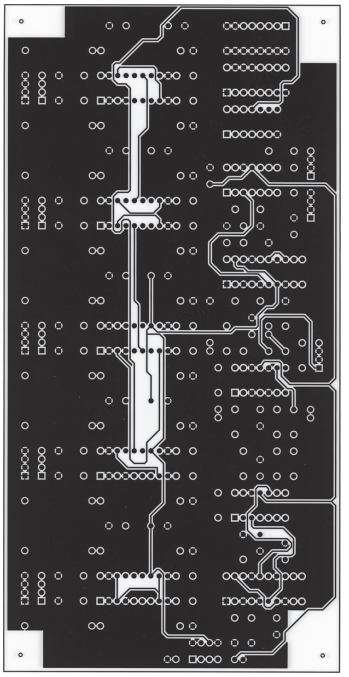

FIGURE 6: Audio board—top.

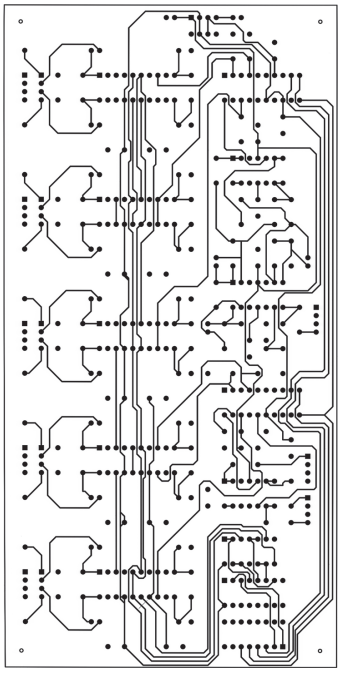

FIGURE 7: Audio board—bottom.

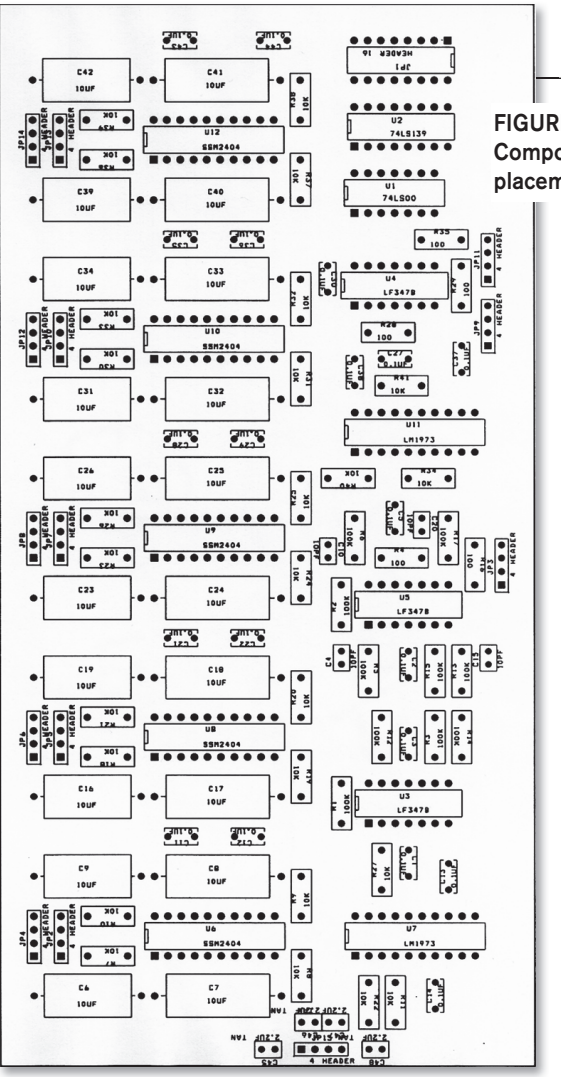

FIGURE 8: Component placement.

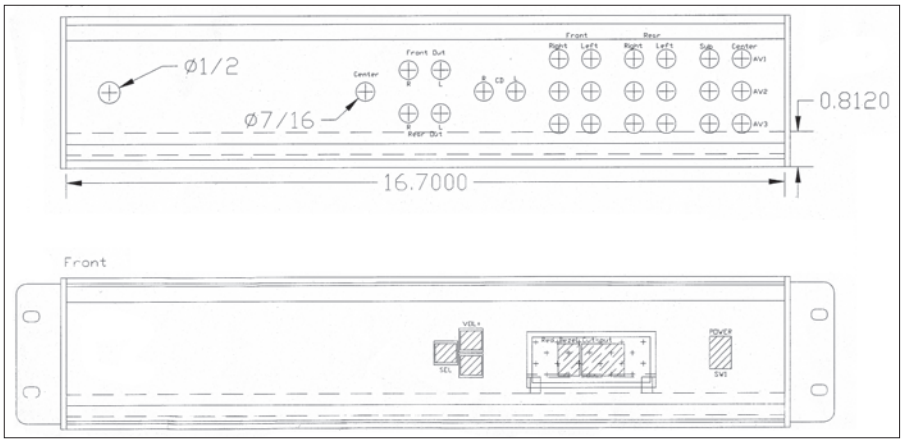

FIGURE 9: Template for front and back panels (45%).

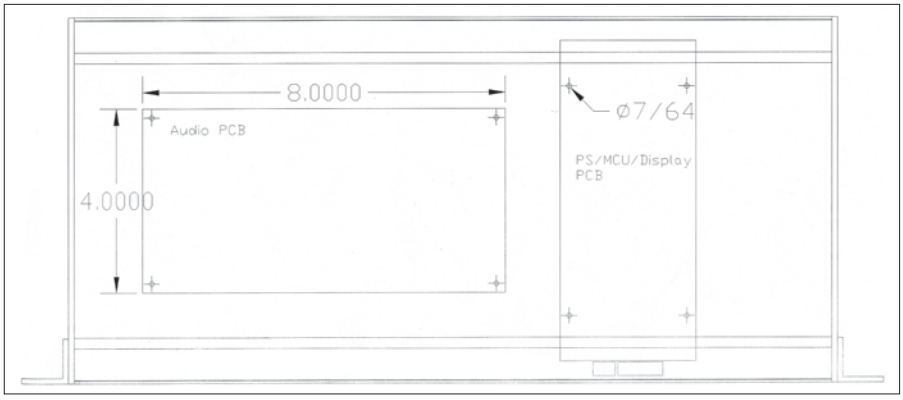

FIGURE 10: Top view template (43%).

tion or positioning error.

THE CHASSIS

The preamp was fabricated in a Hammond RMC19038 19″ × 8″ rack cabinet. I mounted the circuit boards on an optional RMC1908 chassis panel using ¼″ × ¼″ nylon spacers and 4-40 hardware.

I used an inkjet plotter to produce the [reduced as indicated] CAD drilling templates (**Figs. 9** and **10**). Once you cut these to size and affix them to the proper surface, you can use them to locate the drilled holes for the RCA connectors, PCB mounting holes, switch cutouts, and so on. Cut the display openings using a template along with a nibble tool and some patience. Use draw filing to clean the edges after using the nibble device.

FINAL WIRING AND TESTING

During assembly, I first verified the testing of the power supply, display, and remote functions by using a simpler version of the final program and then installed the audio board. After wiring the power supply, DIP ribbon cable, and RCA connectors, I applied power without any ICs inserted into the sockets. Voltage and logic levels were verified for each of the functions prior to installing all ICs.

The power supply and input/output connections were made using 26 GA twisted-pairs to reduce any crosstalk. You could also use shielded audio cable; however, it proved too difficult to manage so many I/Os in a limited space.

The ground plane of the PCB is connected to the power through redundant wires in the ribbon cable between the two boards. As best practice, I purposely made the ground connection much shorter than other power supply connections. Also note: Each RCA connector is connected separately to the ground plane of the PCB to minimize the production of ground loops. Finally, to complete the testing, inject a 1kHz, 2V peak sine wave with a waveform generator and verify the proper outputs and levels with an oscilloscope.

The preamp described here has worked flawlessly for many hours of use since I installed it into my system. It is the link that integrates a multi-amplifier, homegrown audio system with the latest sources without necessitating the purchase of an expensive home theater preamp. *aX*