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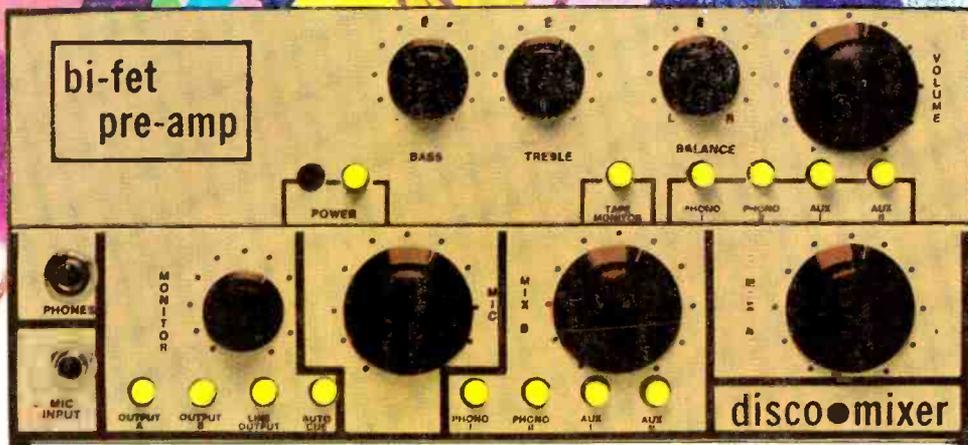
WORLD'S LARGEST-SELLING ELECTRONICS MAGAZINE

SEPTEMBER 1978/\$1

Analog-to-Digital with Two IC's Converting Schematics to PC Patterns

Special Focus On Audio

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Build a Disco Preamp/Mixer

BY JOHN ROBERTS

Provides multi-source inputs and mixing/fading for your home disco.

A TYPICAL audio system is not suitable for disco applications. It lacks the mixing, monitoring, and microphone preamps normally found in such facilities. The Disco Mixer presented here is a special-purpose audio preamplifier/mixer with a number of attractive and unusual features. It has two independent phono preamplifiers employing the new IEC equalization characteristic, two IC-buffered auxiliary inputs, a low-noise microphone preamplifier, switching and mixing capability for multiple inputs, and the traditional preamp's bass, treble, balance, and volume controls. The Disco Mixer also contains a monitor circuit that allows the user to cue records or listen to one program source while another is driving the system's power amplifier.

You can build either a preamp/mixer or a preamplifier only. A kit for the preamp/mixer is \$110, while one for the preamp alone is just \$70.

The Disco Mixer is designed around six integrated circuits. Thanks to the advent of specialized IC's, signal processing functions previously performed by dozens of discrete components can now be accomplished by single chips. In many cases, both stereo channels can be handled by one IC.

High-level signals in this project are processed by members of a new family of high-performance op amps that are fabricated by "BIFET" technology. This is a process which allows diffusion of

both junction-field-effect and bipolar-junction transistors on the same chip. These op amps exhibit the excellent input characteristics of JFET's and the highly desirable output characteristics of BJT's—literally, the best of both worlds. BIFET op amps have higher slew rates and cause less TH and IM distortion than common bipolar IC's (see Fig. 1).

About the Circuit. A block diagram of the complete mixer/preamplifier is shown in Fig. 2. Functionally, the Disco Mixer can be considered to be made up of three types of circuits: input conditioning, high-level processing, and output conditioning. Let's examine each.

Input conditioning for the line-level auxiliary inputs, which would typically be driven by a tuner or tape deck, consists of simple unity-gain inverting buffers. One of the four buffers included in the preamp is shown in Fig. 3. An RC network at the buffer input acts as a high-pass filter to prevent the passage of a dc level or infrasonic ac signals. One section of a quad BIFET operational amplifier, IC3, presents an inverted version of the input signal to the switching matrix composed of S2 and S4. This buffer displays a relatively high impedance (about 50,000 ohms) to the program source and a very low output impedance to the switching matrix. This avoids loading down the signal source and prevents interaction in the mixing process.

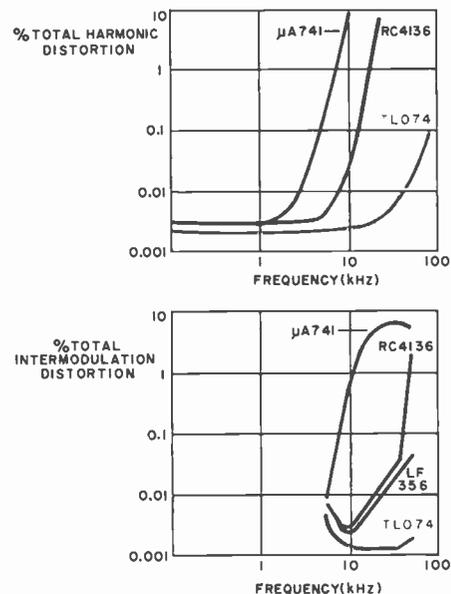
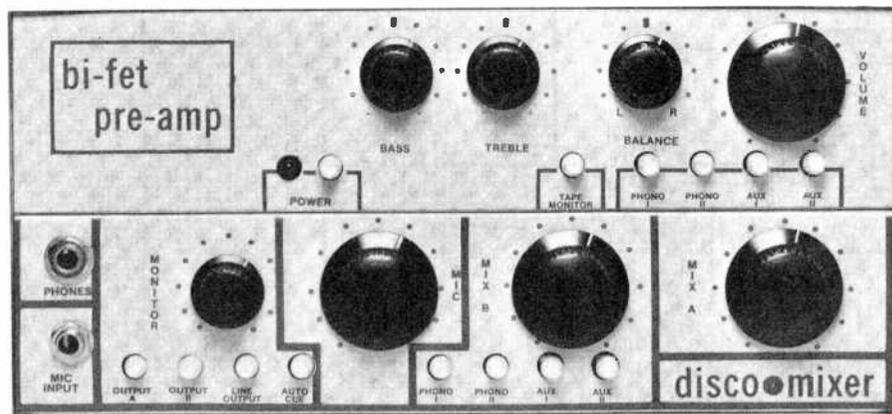


Fig. 1. TI's TL074 BIFET op amp generates less distortion than common bipolar linear IC's.

The signal conditioning stage for the microphone input must be able to amplify signals generated by the microphone by 60 dB (1000 V/V) or more. An NE5534N integrated circuit was selected for this task (Fig. 4) because it has a high open-loop voltage gain and a very low input noise voltage. The open-loop gain—the gain of the device in the absence of feedback—must sufficiently exceed the closed-loop gain selected by the proper choice of feedback components if the amplifier is to exhibit gain accuracy and low distortion. (An amplifier's closed-loop distortion is its open-loop distortion divided by the ratio of open-loop to closed-loop gain.) The microphone preamp's input noise voltage is of critical importance because this noise signal will be amplified along with the millivolt-level microphone output signal.

With an open-loop gain of 6000 V/V at 10,000 Hz and less than one microvolt of input noise, the NE5534 (IC7) meets the foregoing requirements easily. The noninverting microphone preamp fea-



tures a pc-mounted trimmer potentiometer (*R43*) which allows the user to adjust the stage's gain to suit the sensitivity of a particular microphone. As is the case with the auxiliary input buffers, signals are capacitively coupled to the op amp. The microphone preamplifier has a high input impedance that will not load down the microphone, and presents a low output impedance to the mixing stage.

Similar gain and noise requirements must be satisfied by the phono preamplifiers. In addition, these stages must contain an equalization network which properly compensates for the pre-emphasis introduced in the recording process to increase dynamic range and suit the constant-velocity characteristic of the playback transducer (phono cartridge). At present, there is some debate as to the ideal de-emphasis (playback) curve. The existing RIAA does not clearly specify exactly how a phono preamplifier's gain should roll off at low frequencies.

This has resulted in many phono preamps with very high gain at infrasonic frequencies, a situation which can cause serious problems when warped records are played or acoustic feedback combines with turntable rumble. The phono cartridge, preamplifier, power amplifier and speakers try to reproduce the warp or rumble as if it were a valid audio signal. However, many speakers are not designed and lack the ability to generate such strong, very low frequency output and can be damaged while attempting to do so.

Therefore, a feedback network comprising *R3* through *R7* and *C7*, *C9* and *C10* has been incorporated into the phono preamplifiers (Fig. 5) so that these stages exhibit a frequency response which agrees with the International Electrochemical Commission's proposed amendment to the RIAA characteristic. The deviation from the RIAA curve is slight and only at the lowest audible frequencies, and the improvement in infrasonic signal attenuation considerably outweighs the almost imperceptible (-3 dB at 20 Hz) low-frequency rolloff.

The LM387AN dual low-noise preamplifier has been chosen for *IC1* and *IC2* because of its excellent (high) open-loop gain and (low) noise characteristics. That there are two independent, identical amplifiers in one 8-pin DIP helps simplify the pc layout. The phono car-

tridge drives the noninverting input and is loaded by *R2*, a 47,000-ohm resistor and *C6*, a small disc ceramic, glass, polystyrene or silver mica capacitor. The user should consult the manufacturer for the recommended capacitance for his particular cartridge. In most cases, the value will lie between 10 and 300 pF.

Now that all input signals have been amplified to reasonable levels and impedances normalized, mixing can be performed in a straightforward manner. Two four-station interlocked switch arrays (*S2* and *S4*) assign any one of four input signals to two mixer potentiometers, *R46* and *R47*, as shown in Fig. 6. The wipers of these potentiometers are connected to one quarter of *IC6*, a quad BIFET operational amplifier, which is used as a unity gain inverting summer. This allows the user to mix any two of the four inputs or pan back and forth between the two as a disc jockey at a discotheque would. A third potentiometer, *R51*, mixes in a portion of the microphone preamp output so that the disc jockey can voice over his mix.

The inverting summer drives both the output conditioning circuitry of the preamplifier and a special monitor circuit which has been designed into the mixer section. This circuit allows the user to listen to other program sources without affecting the main preamplifier output, an especially convenient feature when

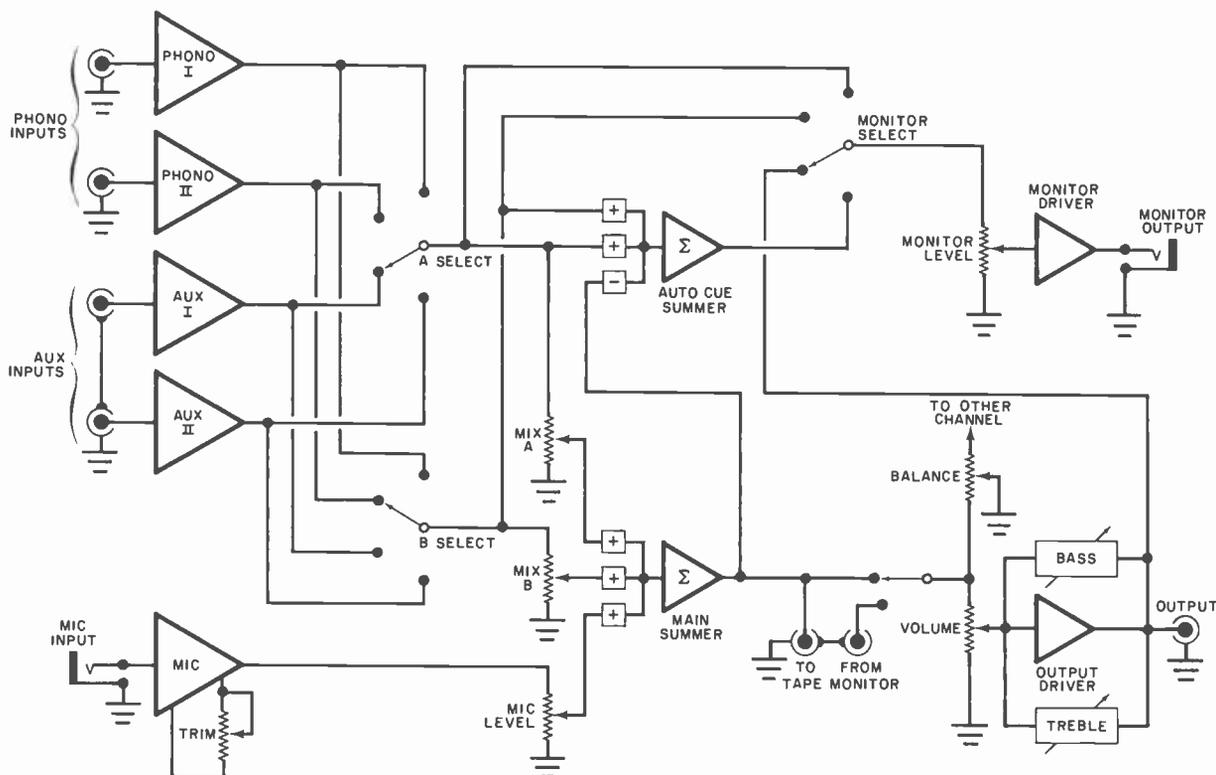


Fig. 2. Block diagram of combined preamplifier and mixer showing inputs, outputs, and controls.

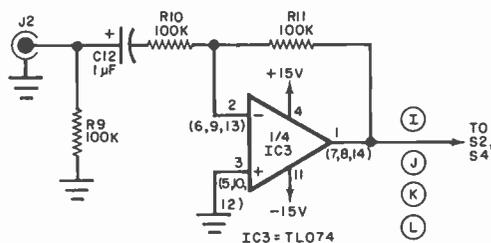


Fig. 3. Schematic of one of four auxiliary input buffers which employ the new BIFET IC.

Fig. 4. Microphone preamp features high gain and sensitivity control.

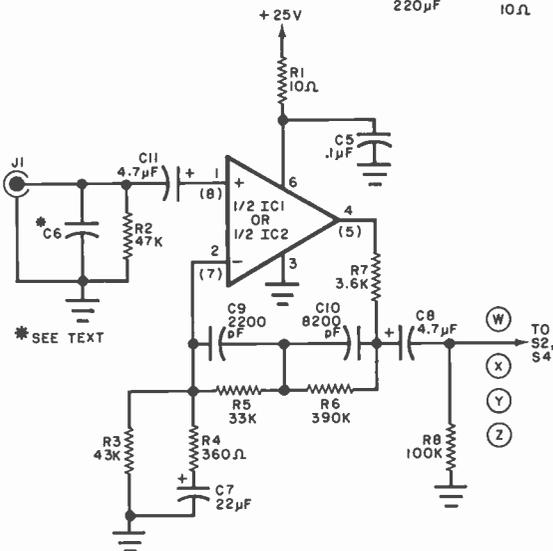


Fig. 5. One of four phono preamps with IEC equalization. Capacitive coupling is used in all other inputs.

C1, C2, C3, C20*, C25—1000- μ F, 16-volt electrolytic
 C4, C14—220- μ F, 35-volt electrolytic
 C5*, C21, C22, C26—0.1- μ F, 50-volt disc ceramic
 C6**—10-to-300-pF (see text)
 C7**—22- μ F, 16-volt electrolytic
 C8**, C11**—4.7- μ F, 16-volt electrolytic
 C9**—2200-pF, 5% tolerance polystyrene
 C10**—8200-pF, 5% tolerance polystyrene
 C12**, C13, C17*, C18—1- μ F, 16-volt electrolytic
 C15*—0.1- μ F, 10% tolerance Mylar
 C16*—0.01- μ F, 10% tolerance Mylar
 C19*—100-pF disc ceramic
 C23, C24—0.01- μ F disc ceramic
 C27*—10-pF disc ceramic
 D1 through D6—1N4001 rectifier
 F1— $\frac{1}{2}$ -ampere fast-blow fuse
 IC1, IC2—LM387AN dual low-noise pre-amplifier (National Semiconductor)
 IC3, IC4, IC6—TL074CN BIFET quad operational amplifier (Texas Instruments)
 IC5—LM377N dual 2-watt audio amplifier (National Semiconductor)
 IC7—NE5534N low-noise preamplifier (Signetics)
 J1**—insulated phono jack
 J2**, J5*, J6*, J7*, J8*—phono jack
 J3— $\frac{1}{4}$ -inch phone jack
 J4— $\frac{1}{4}$ -inch stereo phone jack
 LED1—20-mA light emitting diode
 The following are $\frac{1}{4}$ -watt, 5% tolerance carbon-film resistors.

PARTS LIST

R1*, R13, R40—10 ohms
 R2**—47,000 ohms
 R3**—43,000 ohms
 R4**—360 ohms
 R5**—33,000 ohms
 R6**—390,000 ohms
 R7**—3600 ohms
 R8**, R9**, R10**, R11**, R12**, R15, R17*, R20*, R27*, R28*, R29*, R30*, R31*, R32*, R33*, R34*, R35*, R36*, R37*, R38, R41*, R42—100,000 ohms
 R16*, R26*—100 ohms
 R19*—24,000 ohms
 R21*, R22*, R23*—5600 ohms
 R14, R24*, R25*—1800 ohms
 R43—10,000-ohm linear-taper printed circuit trimmer potentiometer
 R44—100,000-ohm linear-taper potentiometer
 R45 through R48—50,000-ohm dual audio-taper potentiometer
 R49, R50—50,000-ohm dual linear-taper potentiometer
 R51—50,000-ohm audio-taper potentiometer
 S1, S3—Dpdt pushbutton switch
 S2, S4, S5—four-station dpdt interlocked pushbutton switch
 T1—24-volt, 100-mA center-tapped transformer (Signal Transformer Co. #241-4-20)
 Misc.—Printed circuit boards and standoffs, IC sockets or Molex Soldercons (if desired), shielded cable, LED holder, hookup wire,

cueing up special record cuts or verifying the desired operation of a program source before routing it to the output.

A four-station interlocked switch array, S5, selects the monitoring mode. The user can monitor the A mixer input only, the B input only, the main preamplifier output (highly desirable if he is in a booth away or acoustically isolated from the sound system), or monitor in the "Auto-Cue" mode. Auto-Cue monitoring means that the user is listening to the exact opposite of his mix settings. For example, if MIX A potentiometer R46 is at its maximum setting and MIX B potentiometer R47 is at its minimum setting, he will hear the MIX B signal through the monitor if S5 is in the Auto-Cue position. Then, if the MIX A potentiometer is rotated fully counterclockwise and MIX B fully clockwise, MIX A will be heard. This mode is very useful in two-turntable systems because it allows the deejay to always listen to the one being cued.

The level of the monitor signal is controlled by MONITOR LEVEL potentiometer R48. A dual 2-watt audio amplifier, IC5, amplifies the monitor signal and delivers it to J4, a stereo phone jack. Either a pair of headphones or small monitor speakers can be plugged into J4. The audio IC, an LM377N, has internal current limiting and thermal protection so that, if overloaded, it will shut itself off until it

suitable enclosure, machine hardware, line cord and strain relief or grommet, solder, etc.

Note—The following are available from Phoenix Systems, 375 Springhill Road, Monroe, CT 06468, (203) 261-4904: Complete kit of parts including enclosure for preamp/mixer, No. P-1130-DM, for \$110.00; complete kit of parts including enclosure for preamp only, No. P-1130-PA, for \$70.00; etched and drilled preamplifier pc board, No. P-1130-BPA, for \$7.50; etched and drilled mixer pc board, No. P-1130-BDM, for \$7.50; power transformer T1, No. P-1130-T, for \$6.00; dpdt pushbutton switch, No. P-1130-SW1 \$1.00; four-station dpdt interlocked switch, No. P-1130-SW2, for \$4.00; BIFET quad op amp, No. P-1130-C-TL074CN, for \$3.50; dual low-noise amplifier, No. P-1130-C-LM387AM, for \$3.50; dual 2-watt audio amplifier, No. P-1130-C-LM377N, for \$3.00; and low-noise, high-gain op amp, No. P-1130-C-NE5534, for \$3.00. All integrated circuits are fully tested. Please allow six weeks for delivery. Connecticut residents add 7% sales tax; COD charge \$0.85. Handling charge is \$1.00 for orders of less than \$10.00. No shipping charges within continental U.S.

*—two of each component required for full stereo preamp/mixer.

**—four of each component required for full stereo preamp/mixer.

cools down, thus avoiding thermal self-destruction.

The output of the mixer is applied to

the output conditioning section of the preamplifier (Fig. 7). Switch S3 provides tape monitor facilities. Potentiometers R44 and R45 are balance and volume controls, respectively. A BIFET buffer amplifies the signal and presents it to the output stage in which the tone controls are found. Drive signals for the system's power amplifier(s) are available at jacks J7 and J8.

The excellent power supply rejection of the integrated circuits employed in

this project eliminates the need for a regulated supply. As shown in Fig. 8, two full-wave rectifiers and filter capacitors furnish the ± 15 volts required by the BIFET operational amplifiers and the microphone preamp. The +15-volt line is tapped to power the monitor audio driver. A voltage doubler composed of C3, C4, D5 and D6 develops the +25 volts required by the phono preamps.

Construction. Printed circuit assembly

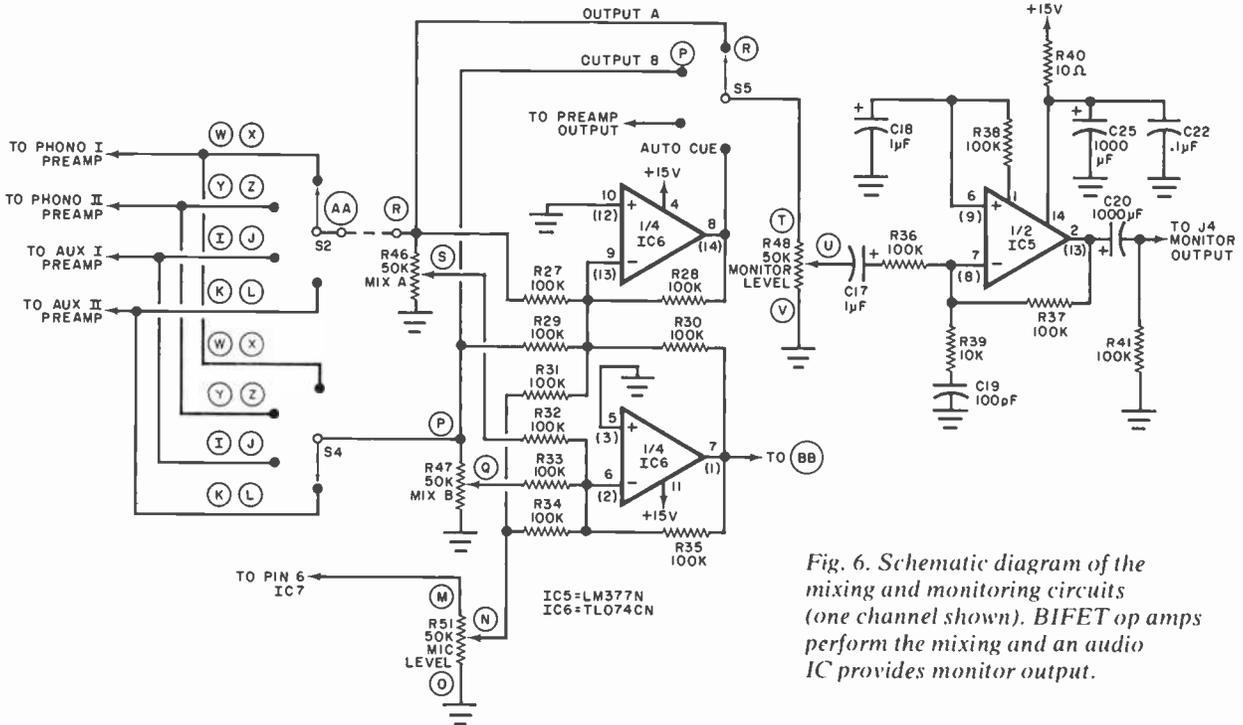


Fig. 6. Schematic diagram of the mixing and monitoring circuits (one channel shown). BIFET op amps perform the mixing and an audio IC provides monitor output.

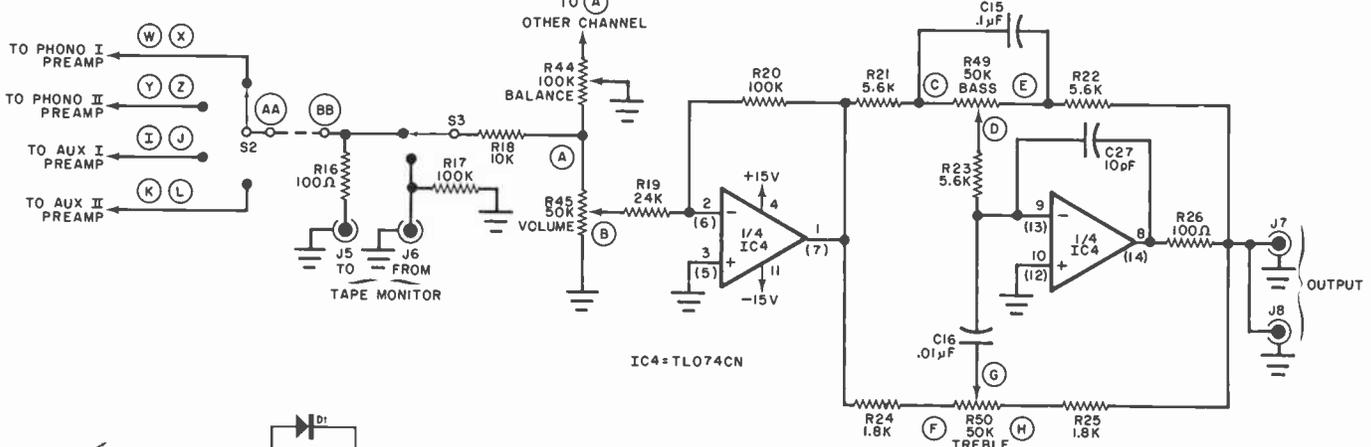


Fig. 7. Output stages of the preamplifier for one channel. Conventional bass and treble tone controls are included, as well as a tape monitor loop.

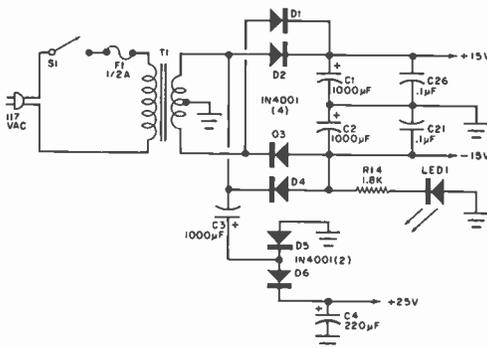


Fig. 8. Schematic of power supply, which delivers three voltages required by the disco mixer stages (+15, -15 and +25 V).

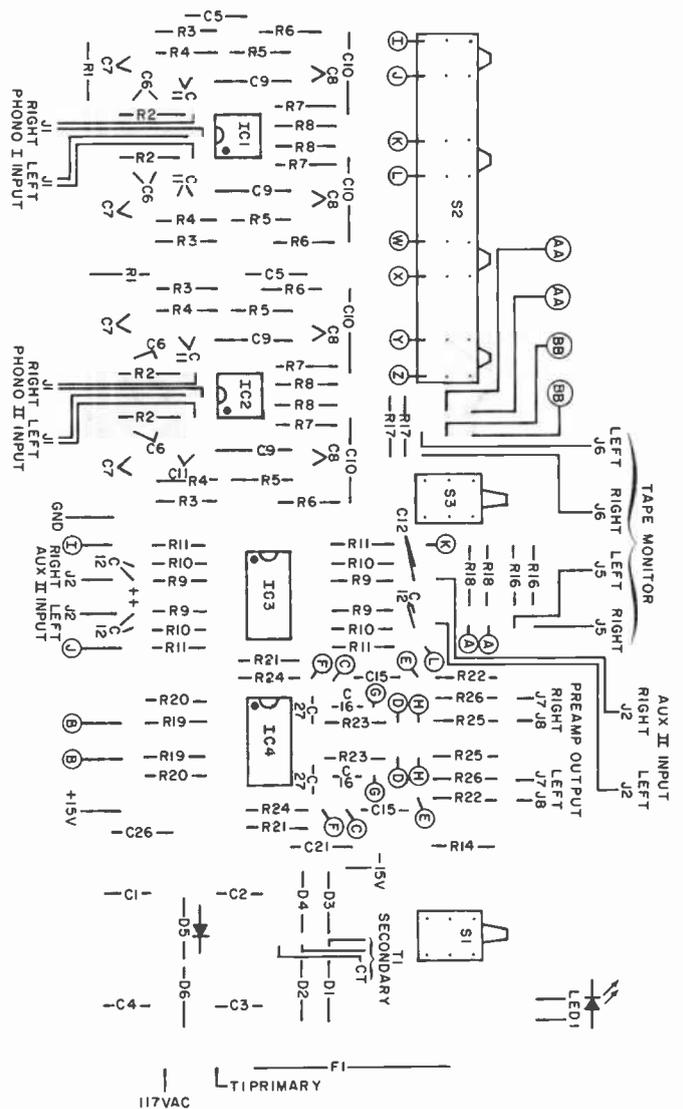
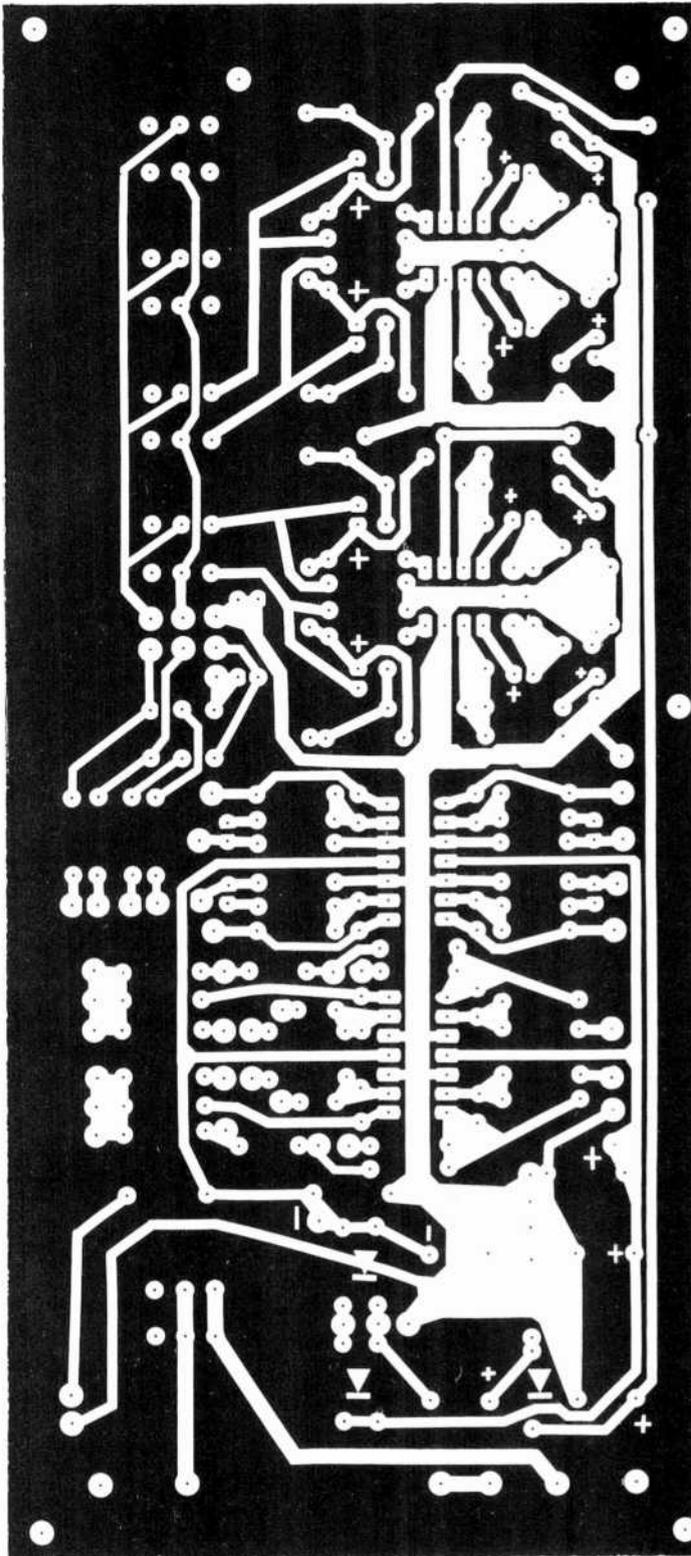


Fig. 9. Actual-size etching and drilling guide for the pc board for the preamplifier is shown at left. A diagram for components placement is above.

bly techniques are strongly recommended. Although it is possible to employ perforated board and point-to-point wiring, the layout of the high-gain stages (phono and microphone preamplifiers) is critical. These circuits are very sensitive to ground loops, hum fields and stray feedback paths. Extensive power supply decoupling is called for because the IC's

employed in this project have very high gain-bandwidth products and can break into oscillation very easily.

Suitable etching and drilling and parts placement guides for the preamp and mixer boards are shown in Figs. 9 and 10, respectively. If mixing facilities are not desired, the preamp board can be used on its own as a high-quality stereo

preamplifier. You will notice that both the schematic diagrams and the pc guides contain numerous points labeled with letters of the alphabet. These have been included to ease interconnections between the boards, and the boards and the jacks, switches and potentiometers. Most of these connections can be made

(Continued on page 71)

Phono Equalization — Time For a Change ?

Due to the nature of cutting heads, playback cartridges, and the recording medium itself, a precise amount of pre-emphasis and de-emphasis is introduced in the record/playback process. The pre-emphasis characteristic attenuates low frequencies so that "cutover" (the excursion of the cutting stylus through the wall of one groove into the wall of the preceding one) is avoided and boosts high frequencies to improve the signal-to-noise ratio. During playback, a mirror image de-emphasis characteristic must be introduced so that a flat overall frequency response is achieved.

Exactly how much pre-emphasis and de-emphasis is used has for many years been determined by the RIAA (Recording Industry Association of America) standard. The standard has been universally accepted—even the state recording labels of Eastern European countries (Melodiya, USSR; Supraphon, Czechoslovakia; Hungaroton, Hungary; etc.) employ it. This world-wide acceptance of one recording standard has resulted in benefits to the recording industry and the consumer.

Recently, however, this unquestioned acceptance has been challenged by a proposal from the International Electrochemical Commission. This group has suggested an amendment to the existing RIAA standard which incorporates two modifications. The proposed changes are slight, as shown in the Figure, but a discussion of them is warranted.

The existing RIAA recording and playback curves have been around so long that they cover a frequency range of only 30 to 15,000 Hz. No one will take issue with the IEC proposal to extrapolate the existing curves to 20,000 Hz. In fact, phono preamp designers have been doing it for years. The amendment will merely give this practice official sanction.

The really controversial part of the IEC proposal deals with the lower end of the equalization characteristic. The Commission is suggesting a low frequency rolloff—down 3 dB at 20 Hz and having a -6-dB/octave slope below that frequency. Informally, circuit designers have extrapolated the curve to 20 Hz, but there has been no general consensus as to what should be done below that frequency. It is below 20 Hz that serious difficulties are encountered.

Record Warps. The gradual but continuing deterioration—on some labels, at least—of record quality has made warped discs the rule rather than the exception. Spectral analysis indicates that the waveforms caused by warps possess significant amounts of energy in the 5-to-10-Hz region even though their fundamentals lie octaves lower at about 0.03 Hz. Ten hertz is below the response of the human ear and that of most audio systems, and playback at moderate sound levels should not and usually does not present any difficulty. Problems can arise, however, when sound levels are increased or signal processing is introduced.

For example, a warp waveform superimposed on an audio signal can cause a tape recorder to saturate the tape, resulting in a very disturbing amplitude modulation and/or distortion. Furthermore, nonlinear signal processors such as noise reduction units can be tricked into interpreting the warp as a valid audio signal during encoding. This by itself is not a problem until an attempt is made to decode the signal and the infrasonic signal has been lost to the tape medium's limited low-frequency response. The resulting output signal is the audio signal modulated by the infrasonic warp which is no longer present even though it is really required for proper decoding. The infrasonic signal is long gone, but the modulation or distortion it has caused remains.

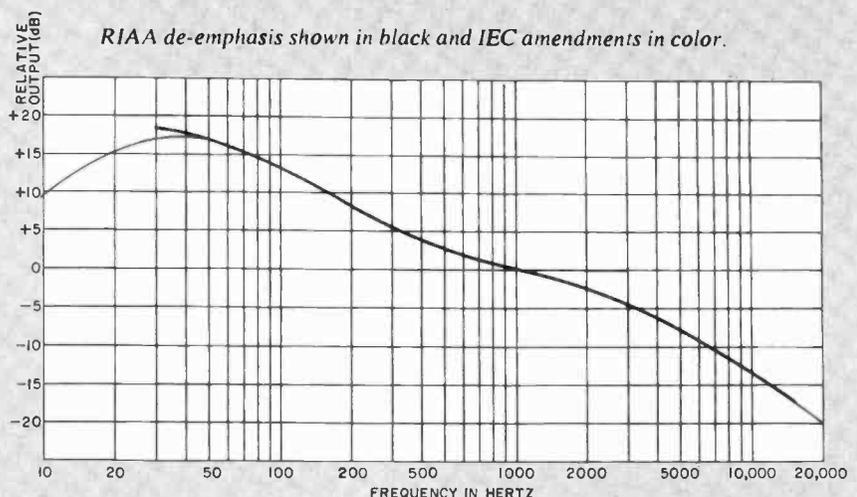
In straight playback situations, the effects of record warps on signal processors are not encountered but other serious problems can

crop up, especially at high listening levels. The power amplifier, if its frequency response extends sufficiently low, cannot discriminate between audible and infrasonic signals and will try to drive the speakers with an amplified version of whatever is applied to its input jacks. The possible deleterious effects of excessive speaker cone excursion and amplifier clipping are well-known and can result in permanent speaker damage and/or objectionable levels of distortion.

The ideal solution to the record warp problem would be an improvement in the manufacture and quality control procedures at the record plant. However, in the design of the Disco Mixer, a more realistic approach has been taken. RC networks have been included in the project's phono preamplifiers to give a de-emphasis characteristic coinciding with the IEC proposal. The difference in bass response between the existing and proposed standards is so slight (-1 dB at 40 Hz, -3 dB at 20 Hz) as to be barely audible, and will certainly not render obsolete existing record collections.

Probably the only people who will be upset by the IEC characteristic are those who put more faith in figures that they read rather than in the sounds that they hear. Of course, such people could be satisfied by a phono preamp with switchable equalization. But they should be warned to pay close attention to the setting of the equalization switch. It will be very difficult for them to tell the difference solely on the basis of what they hear—they are listening to a warped record!

RIAA de-emphasis shown in black and IEC amendments in color.



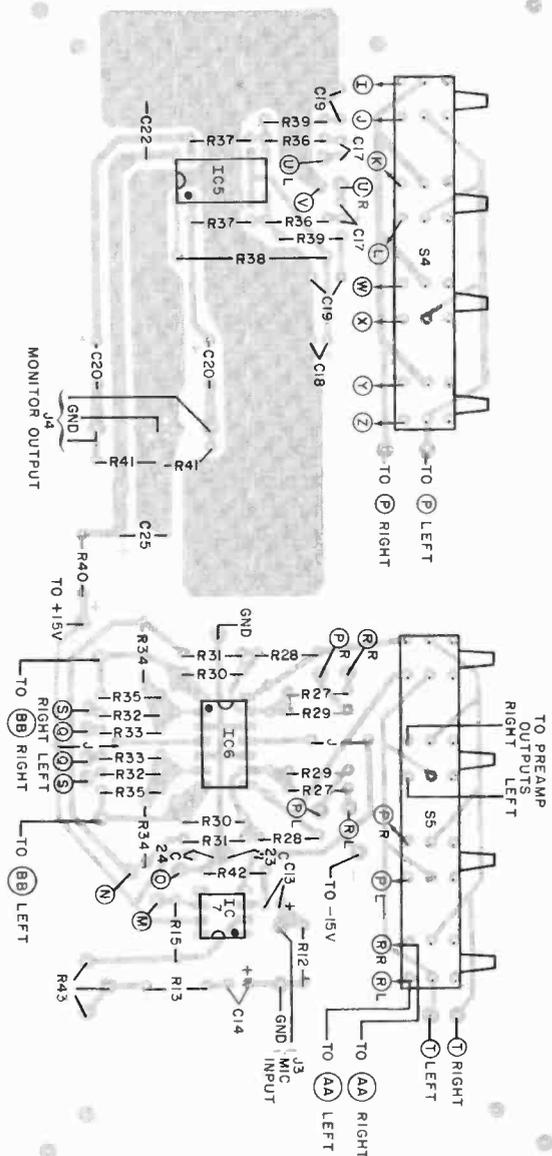
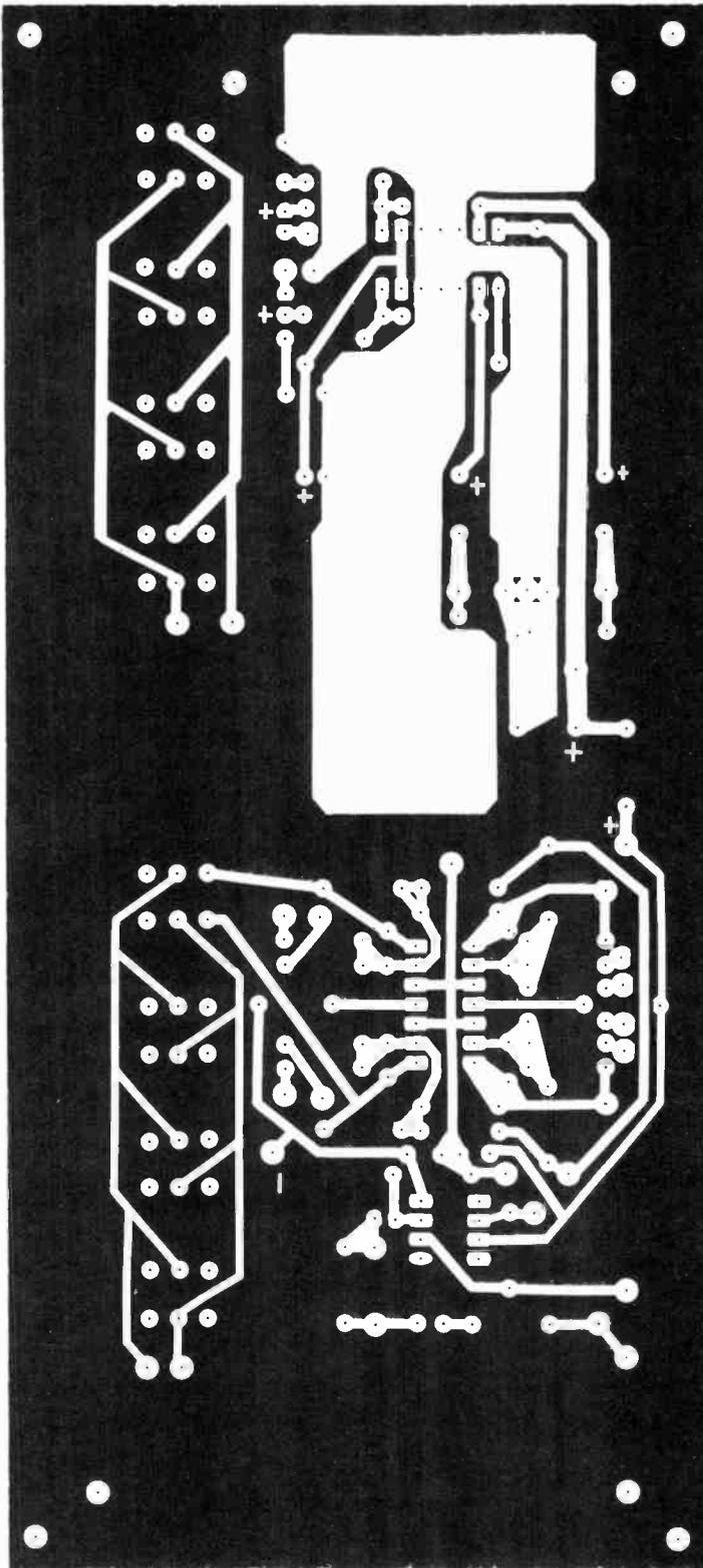


Fig. 10. Etching and drilling guide (left) and components place diagram (above) for the mixer pc board.

(Continued from page 69)

with hookup wire, but two-conductor shielded cable should be used between the phono input jacks and the preamp circuit board. If the preamp-only version of the project is built, install jumper wires between points AA and BB.

If desired, IC sockets or Molex Soldercons can be used when mounting the integrated circuits. Be sure to observe po-

larity and pin basing when installing electrolytics and semiconductors. Use good soldering practices.

When circuit board wiring has been completed, mount the boards in a metallic enclosure using machine hardware and spacers. The power transformer should be mounted directly in the enclosure. Those assembling the project using perforated board should take care to

keep the power supply away from the high-gain sections of the preamplifier.

Use. The Disco Mixer is straightforward in its use. Patch in the various program sources with suitable lengths of shielded cable and experiment with the different preamp and mixer controls and monitor modes. Then invite your friends over and have a disco party! ♦