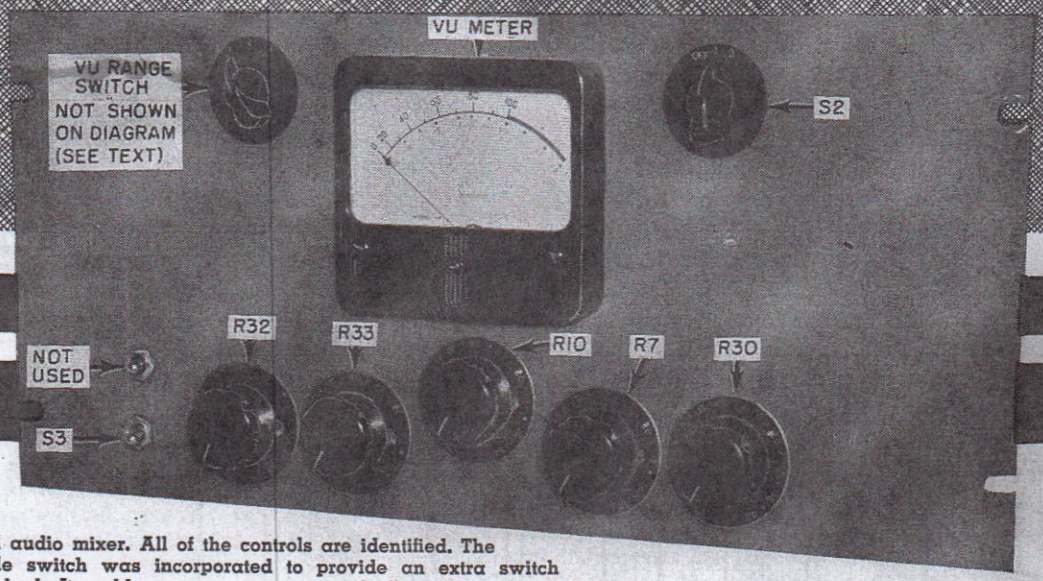
A FOUR-CHANNEL AUDIO MIXER



The four-channel audio mixer. All of the controls are identified. The "not-used" toggle switch was incorporated to provide an extra switch should it be required. It could serve as a power supply "on-off" control, if desired.

By **JOHN S. CARROLL**

Construction details on a professional-type unit which uses only four audio transformers instead of the usual eleven.

EVERY recording studio except the very smallest has, on occasion, need for audio mixing facilities. Unfortunately, most of the inexpensive mixing equipment that is commercially available is, at best, of amateur quality while professional-type equipment is usually priced in direct proportion to its quality.

The problem faced by the author in building the unit to be described was one of small budget and the fact that the mixer was to be used with professional-type recording equipment. The mixer could not be permitted to add materially to either the noise level or distortion of the system. Thus, such shortcuts as had to be made to keep the cost to a minimum, had to be taken keeping this performance requirement firmly in mind.

The particular studio for which this unit was intended was that of a producer of documentary motion pictures and the facilities were designed for recording sound tracks by the "live-mix" method. That is, the narrator's (or at times, two narrators') voice would be recorded on, at most, two microphones while simultaneously the musical score would be dubbed from discs or tape. A total of four channels were therefore required, two for microphones and two for phonographs.

Under normal circumstances a professional-type, four-channel mixer would have a total of nine transformers up to the mixer stage, four input transformers to the preamplifiers, four output transformers from the preamplifiers to the line-mixer potentiometers, and a line-to-grid transformer to the mixer stage. Two additional transformers would be required, between the mixer stage and the output of the "line" amplifier and an output transformer to line, making a total of eleven audio transformers required in the whole unit.

In the mixer unit to be described the total number of audio transformers was reduced to four by resorting to the following expedients. It was decided at the beginning that the phonograph channels would be fed by a pair of the new, high-fidelity crystal pickups, eliminating the need for preamplification for the two phono stages. Thus, only two input transformers were required.

With the preamplifiers and mixing amplifier on a single chassis, there appeared to be little objection to high-independence mixing, especially since the associated power supply would be remotely placed. Using molded carbon-element potentiometers (*Ohmite* or *Allen-Bradley* types) cut down on the slider noise and "frying" until it was virtually inaudible as compared to ordinary broadcast radio-type volume controls. In any case, the mixing is done at a point in the circuit where the signal levels are high and not too much amplification follows the mixer potentiometers.

Many references in current audio literature point out that a mixer circuit of this type tends to have some interaction between the channel controls. Our experience with this unit indicates that this particular problem has perhaps been unduly exaggerated. If any interaction exists, it is so slight as to be completely negligible. Some variation in the noise level was found at a point about two-thirds of clockwise rotation of the master gain control. This was eliminated by a slight circuit change which will be explained in detail later in this article. Interaction between the channels is apparently completely eliminated by the isolation resistors connected in series with each of the potentiometers.

The basic circuit is the one recommended by *United Transformer Company* for a portable remote broadcast amplifier. The two phonograph channels were added by simply paralleling them with the original two mixer potentiometers. Construction is straightforward but due to the very high gain of the unit certain precautions must be taken. For the lowest possible hum level, the ground points are placed as near the two inputs as possible. These, then, are the only two places where the ground connects to the chassis. A ground bus is used between these two points and the "B—" terminal and is completely insulated from the chassis at all other points. All of the other grounds, including the condenser cans, are insulated from the chassis and connected to the ground bus.

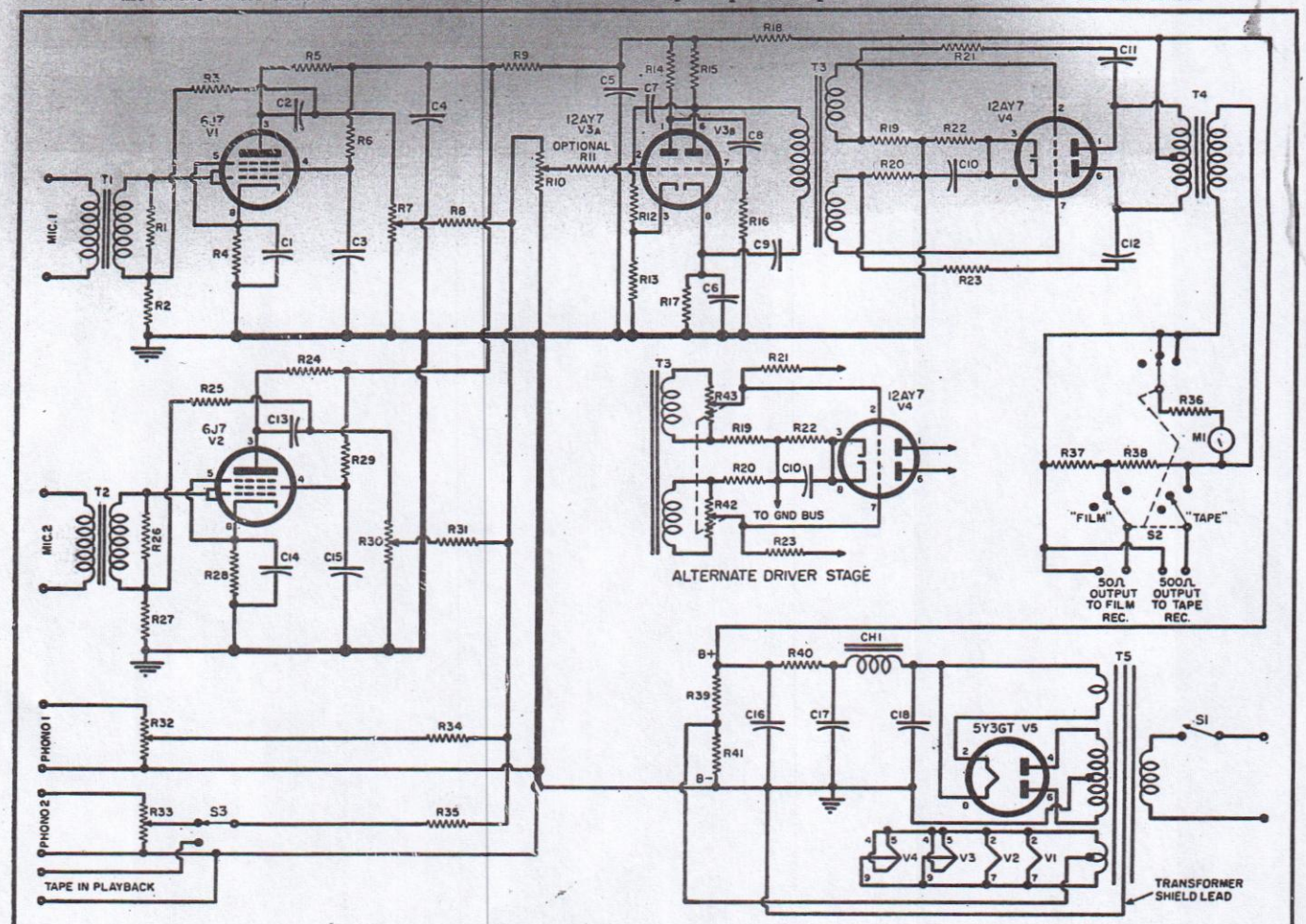
The heater circuit is not grounded at any point. The center tap of the 6.3 volt winding is returned to a tap on the voltage divider across the power supply. This places a fairly high positive bias on all heaters and prevents hum due to heater-cathode leakage or heater emission. With these precautions it proved unnecessary to use d.c. on the heaters of the preamplifier tubes. If any residual hum is present

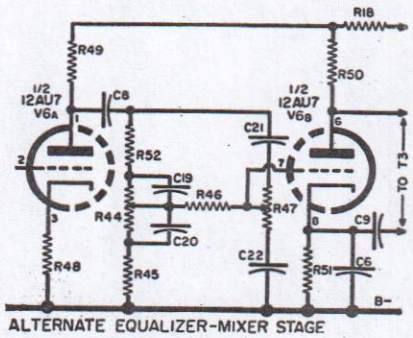
despite this precaution, it can be minimized by increasing the value of the cathode bypass condensers, C_1 and C_{14}, to 100 μfd. or higher.

In order to insure minimum distortion, feedback is used around the preamplifiers, around the mixer amplifier stage, and around the output stage. There is little or no danger of instability due to the loops around the preamplifiers and, in this case, the output stage also exhibits good stability. However, some resonance between the interstage transformer windings and capacitances in the mixer stage caused an ultrasonic oscillation which, while not audible, threw the vu meter completely off scale. This oscillation was suppressed by placing small phase-shifting condensers (50 to 100 μμfd.) across either R_{12} or R_{13}, or both.

If the builder wishes to add an equalizer to the unit, this may be placed between the two mixer amplifier stages and the feedback loop eliminated to provide sufficient gain for the equalizer. A 12AU7 was used in

Complete wiring diagram for the four-channel audio mixer. If only two inputs, Mic. 1 and Mic 2, are required, the schematic with its original driver stage will work without any difficulty. Should Phono 1 and Phono 2 inputs be required in addition, interaction may occur between the various controls. To eliminate this, it is suggested that the alternate driver stage shown below be used in place of the original circuit. When this is done, the master gain control R_{10}, is replaced by a standard 3-megohm, ½-watt resistor. The dual potentiometer, R_{42}-R_{43}, then becomes the new master gain control. Resistor R_{11} should be connected to the top of the newly-connected 3-megohm resistor to obtain maximum gain. Also shown below is an alternate equalizer-mixer stage. This has not been incorporated in the audio mixer unit. It should, however, work out advantageously and may be worth the installation effort involved.





ALTERNATE EQUALIZER-MIXER STAGE

R_1, R_{26}—68,000 ohm, ½ w. res.
R_2, R_{27}, R_{45}—10,000 ohm, ½ w. res.
R_3, R_6, R_{25}, R_{29}—1.5 megohm, ½ w. res.
R_4, R_{28}—1800 ohm, ½ w. res.
R_5, R_{24}—270,000 ohm, ½ w. res.
R_7, R_{30}, R_{32}, R_{33}—500,000 ohm audio taper pot
R_8, R_{31}, R_{34}, R_{35}—470,000 ohm, ½ w. res.
R_9—20,000 ohm, ½ w. res.
R_{10}—3 megohm pot
R_{11}—100,000 ohm, ½ w. res. (if required)
R_{12}—120,000 ohm, ½ w. res.
R_{13}, R_{17}—820 ohm, 1 w. res.
R_{14}, R_{15}—47,000 ohm, 1 w. res.
R_{16}—1 megohm, ½ w. res.
R_{18}—5600 ohm, 1 w. res.
R_{19}, R_{20}—18,000 ohm, ½ w. res.
R_{21}, R_{23}—82,000 ohm, ½ w. res.
R_{22}—290 ohm, 1 w. res.
R_{36}—3600 ohm, ½ w. res.
R_{37}—56 ohm, ½ w. res.
R_{38}—470 ohm, ½ w. res.
R_{39}—24,000 ohm, 2 w. res.
R_{40}—5000 ohm, 5 w. res.
R_{41}—6000 ohm, 2 w. res.
R_{42}, R_{43}—500,000 ohm dual pot
R_{44}, R_{47}—1 megohm linear taper pot
R_{46}, R_{49}, R_{52}—100,000 ohm, ½ w. res.
R_{48}—3300 ohm, ½ w. res.
R_{50}—22,000 ohm, ½ w. res.
R_{51}—2200 ohm, ½ w. res.
C_1, C_6, C_{10}, C_{14}—50 μfd., 25 v. elec. cond.
C_2, C_{13}—.1 μfd., 400 v. cond.
C_3, C_{15}—1 μfd., 200 v. metallized cond.
C_4-C_5—40/40 μfd., 350 v. elec. cond.
C_7, C_9—.5 μfd., 400 v. metallized cond.
C_8, C_{11}, C_{12}—.05 μfd., 400 v. cond.
C_{16}-C_{17}-C_{18}—20/20/20 μfd., 450 v. elec. cond.
C_{19}, C_{22}—.002 μfd. mica cond.
C_{20}—.02 μfd., 400 v. cond.
C_{21}—.0002 μfd. mica cond.
T_1, T_2—Input trans. 50 ohms to single grid (UTC A-10 or A-11)
T_3—Interstage trans. Single plate to push-pull grids, split secondary (UTC HA-106)
T_4—Output trans. push-pull plates to 500 ohm line (UTC HA-114)
T_5—Power trans. 240-0-240 v. @ 40 ma., 6.3 v.c.t. @ 2 amps; 5 v. @ 2 amps. (Thordarson TS-24R00 or equiv.)
CH_1—7 hy., 50 ma. choke
M_1—Vu meter (see text)
S_1—S.p.s.t. toggle switch
S_2—3 p. 3t. rotary switch
S_3—S.p.d.t. toggle switch
V_1, V_2—6J7 tube (1620 preferred)
V_3, V_4—12AY7 tube
V_5—5Y3GT tube V_6—12AU7 tube

preference to the 12AY7 for the equalizer. The circuit of this altered section is included in the diagram.

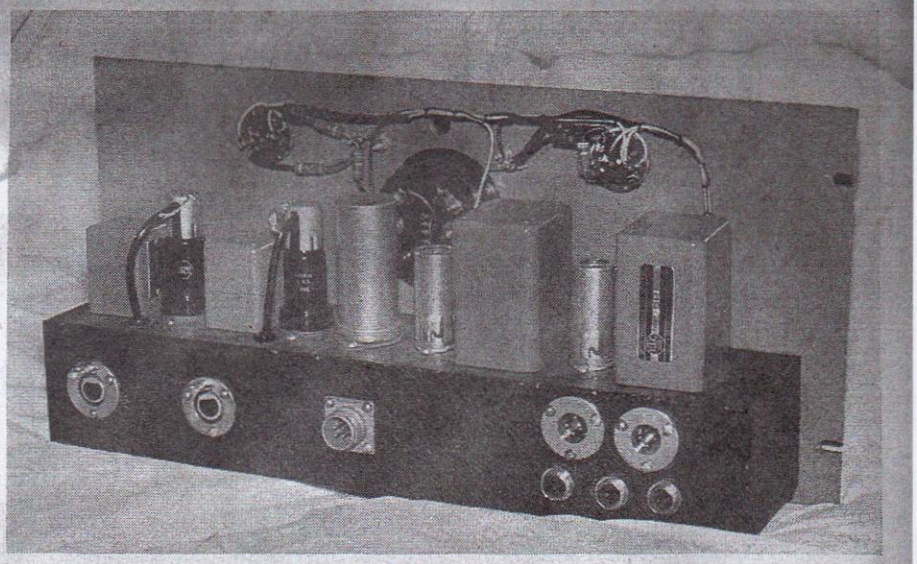
As previously mentioned, while there is no interaction between the four channels, there was some between the channel potentiometers and the master gain control. This was eliminated by feeding the combined output of the four mixer potentiometers directly to the grid of the mixer-equalizer stage and by placing the master gain control in the grid circuit of the output stage. A double potentiometer is used to control the push-pull grids simultaneously, as shown in the alternative schematic.

The output of the unit was designed to feed either a tape recording setup with a 500-600-ohm line bridging input or a 16 mm film recorder with a 50-ohm line input. To avoid complicated switching of the output transformer secondary taps, a simple matching pad was placed on a switch on the output, so that switching from "tape" to "film" automatically adjusts the output impedance. It is evident that this pad causes a loss of output level of about 16 db; however, the film recorder in question had ample gain and the loss was not important. Using the pad permitted the vu meter to work across a 500-ohm line at all times. In addition, the pad has the effect of terminating the line, even when the output is disconnected. Thus, rehearsals can be run while feeding only a bridging monitor amplifier having a 20,000-ohm input.

The vu meter can be switched off during preliminary set-ups so that accidental jolts while moving the microphone will not damage the needle. The 3600-ohm resistor in series with the meter is the standard calibrating resistor usually used with vu meters. If variation in output level is required, or changes in meter range are desirable, this resistor can be replaced by a 7500/3900-ohm variable pad to extend the meter scale. Such pads are available from the manufacturer of such meters.

In this article great emphasis has been placed on instability and the causes and cures for it. This may come as a surprise to those audiophiles who are not accustomed to the extremely high-gain circuits used in recording work. The tube complement is based on the use of low-noise types throughout. If 6J7's are used instead of 1620's, it may be necessary to select the quietest from a number of tubes. The same thing applies to the 12AU7 if substituted for the 12AY7 in the mixer stage. The output stage should, in any case, be a 12AY7. The 12AX7 is not a good substitute due to its higher mu and plate resistance. The over-all gain of the unit is such that the thermal agitation noise of the first stage sets the limit on following amplification. If all recommendations are followed, this hiss should be stronger than any other noise, residual hum, etc.

The power supply, which is not shown in the photographs, should be built on a separate chassis and the same rule that applies to the mixer followed here. Ground the chassis at only one point and do not ground the center tap of the heater circuit. The power supply should be kept as far from the mixer unit as possible. If this is not feasible, it may be necessary to use triple-shielded input transformers.



Rear view of unit. Note particularly the type of jacks and plugs that were used in the construction of this unit. It is important that all of these components be of the shielded type to prevent hum pickup. The jacks and plugs are, from left to right; Mic. 1, Mic. 2, power cable connector, (far right, top) 50 and 500 ohm outputs, (far right, bottom) Phono 1, Phono 2, and tape playback inputs.

If the power supply can be isolated the power transformer lead shown as shielded and grounded can be omitted. Many transformers are made today without this shield. Should your unit not come so equipped, you can ignore this requirement—*if the power supply is isolated.*

Just a few final suggestions regarding the construction before you whip out your soldering iron and start to build this unit. In the interests of economy and to avoid purchasing unneeded components, decide at the start whether for your purpose the original circuit, shown in the schematic, is to be used or whether one or both of the alternate circuits are to be incorporated. Some of the parts specified in the original diagram will be omitted if one of the alternate circuits is used and *vice versa.*

Another point which cannot be emphasized too strongly is the matter of grounding discussed earlier. If you are seeking trouble-free performance from this unit, it is imperative that the author's suggestions be followed to the letter.

It goes without saying that in this application, at least, quality transformers will have to be used. The builder will find that compromises are too expensive in the long run to be afforded. Just keep in mind that this circuit incorporates only four audio transformers which are doing the duty of the eleven units normally encountered in commercial versions of four-channel audio mixers.

This is one instance when "bargain" transformers will prove to be no bargain and the prospective builder will do well to stick to quality components. The transformers specified in the parts list are recommended by the author as they have proved entirely satisfactory in this application. Use units of similar quality for best results.

While all of these precautions may sound like undue "fussing" to the novice builder of audio gear, they are being handed along as "gospel" by one who has been through the mill. Good luck in building this unit. It is well worth the effort. -30-

Under chassis view of mixer. Wiring is critical so check author's suggestions regarding grounding and the location of such ground points before construction.