The Plastic Tiger Audio Power Amplifier

A SIMPLE WAY TO ADD 2 MORE CHANNELS OF HIGH-QUALITY AUDIO

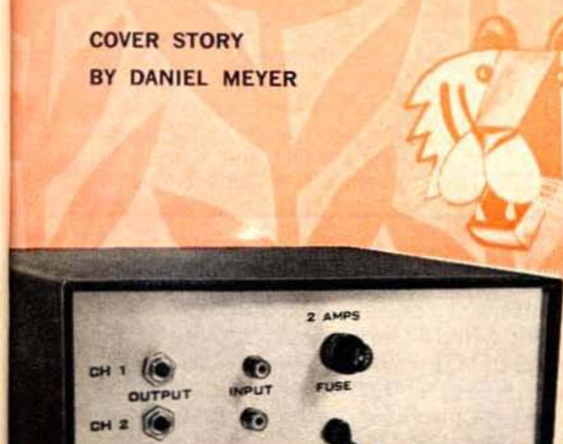
FOR THE HI-FI BUFF who demanded outstanding performance in a high-power amplifier, there was the Universal Tiger ("Assembling a Universal Tiger," October 1970). But if your power requirements are more conservative with no lessening in the demand for quality, now there is the "Plastic Tiger," second cousin to the Universal Tiger.

Except for a more conservative output power capability (30 watts as opposed to the Universal Tiger's 80 watts into 8 ohms), the Plastic Tiger has virtually the same outstanding performance of its bigger cousin. By using plastic complementary output transistors capable of more than enough power for the average listening room, the Plastic Tiger is simpler in design and more economical.

The circuit of the Plastic Tiger is completely stable with any type of input or output termination. The output stage is protected against excessive current drain by the same unique circuit used in the Universal Tiger. This circuit protects the amplifier against any loading condition from an open circuit to a dead short at any frequency in the audio range. The amplifier is also safe to use with a parallel capacitive load of up to 1-μF across an 8-ohm load at any frequency in the audio range.

The frequency response, distortion, noise, etc., characteristics are good enough to qualify the Plastic Tiger for use in

COVER STORY
BY DANIEL MEYER



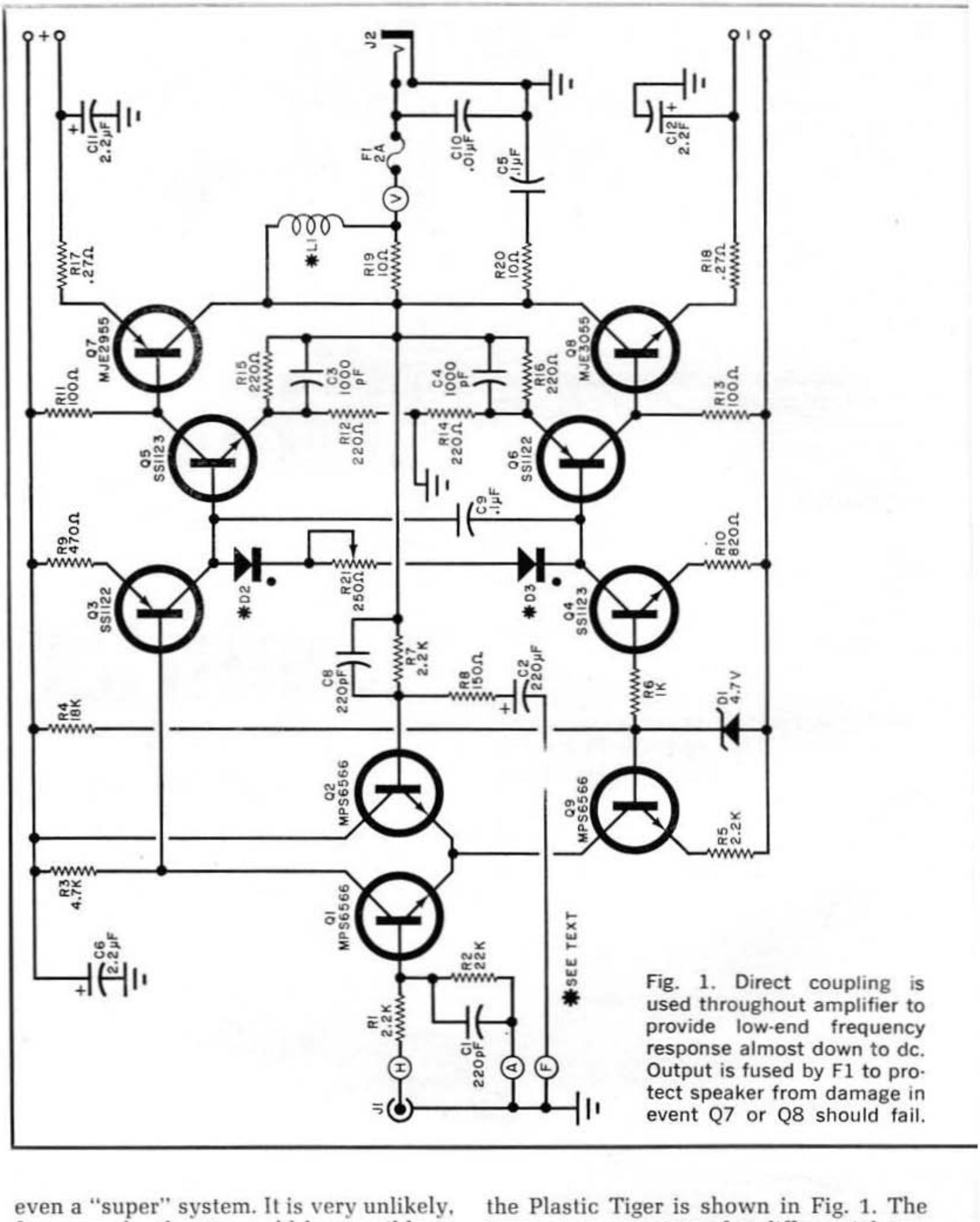


Fig. 1. Direct coupling is used throughout amplifier to provide low-end frequency response almost down to dc. Output is fused by F1 to protect speaker from damage in event Q7 or Q8 should fail.

even a "super" system. It is very unlikely, for example, that it would be possible to detect the difference between this amplifier and an amplifier with better performance with anything but a distortion analyzer. Further, the Plastic Tiger produces no detectable "coloration" to amplified sounds

Theory of Circuit Design. The circuit of the Plastic Tiger is shown in Fig. 1. The input stage consists of a differential amplifier with the input signal applied to the base of *Q1* and the feedback applied to the base of *Q2*. Current source transistor *Q9* provides controlled emitter current. The high impedance to the signal input point provided by the current source decouples the signal from any hum or noise existing on the -40-volt bus.

PARTS LIST

C1,C8—220-pF capacitor
C2—220-µF, 6-volt electrolytic capacitor
C3,C4—1000-pF capacitor
C5,C9—0.1-µF capacitor
C6,C11,C12—2.2-µF, 50-volt electrolytic capacitor
C7—Not used
C10—0.01-µF capacitor
D1—4.7-volt, 1-watt zener diode (1N4732 or similar)
D2, D3—Compensating diodes (see text)
F1—2-ampere standard fuse
J1—Phono jack
J2—Single-circuit phone jack
L1—Single layer of #26 wire close-wound on body of R19
Q1,Q2,Q9—MPS6566 transistor (Motorola)
Q3,Q6—SS1122 transistor (Motorola)
Q4,Q5—SS1123 transistor (Motorola)
Q7—MJE2955 transistor (Motorola)
Q8—MJE3055 transistor (Motorola)
R1,R5,R7—2200-ohm, ½-watt 10% resistor
R2—22,000-ohm " " "
R3—4700-ohm " " "
R6—1000-ohm " " "
R8—150-ohm " " "
R9—470-ohm " " "
R10—820-ohm " " "
R11,R13—100-ohm " " "
R12,R14-R16—220-ohm, ½-watt, 10% resistor
R4—18,000-ohm, 1-watt, 10% resistor
R19,R20—10-ohm, 1-watt, 10% resistor
R17,R18—0.27-ohm, 5-watt, 10% resistor
R21—250-ohm potentiometer
Misc.—Fuse holder; printed circuit board; chassis box; ¼" spacers; #18 or #20 hookup wire; mica insulators for Q7 and Q8; heat-transferring silicone paste; 4-40 machine hardware; solder; etc.
Note—The following items are available from Southwest Technical Products Corp., 219 W. Rhapsody, San Antonio, TX 78216: Circuit board No. 185b for $2.35; kit of parts for one channel, including circuit board but minus chassis and power supply, for $18.50 plus postage on 1 lb; complete kit of parts for two channels plus power supply and chassis for $55.00 plus postage on 10 lb.

The output signal from *Q1* drives the base of Q3 which is the positive half of the bidirectional current driver. The negative half of the current driver is the *Q4* circuit. Transistors *Q3* and *Q4* provide the output driver transistors, *Q5* and *Q6*, with a high-impedance current source drive signal.

Diodes *D2* and *D3*, actually base-emitter junctions of silicon transistors, plus potentiometer *R21* provide enough bias voltage to just turn on the driver transistors. A gain of two is provided by Q5 and Q6 operating class AB. This gain is a function of the ratio between *R15/R12* and *R16/R14*.

Current source driver Q9 and a large amount of feedback eliminate any trace of crossover distortion. The load, or speaker system, is driven by the signal present at the collectors of output transistors Q7 and Q8. The lag network made up of *R20* and *C5* determines the high-frequency roll-off point in the feedback loop as is normally the case with this type of amplifier. Coil *L1* decouples the load at high frequencies to insure that the feedback loop cannot be shorted by an external capacitance and cause high-frequency oscillation. Capacitor *C10* simply provides r-f bypassing at the load terminals.

In Fig. 2 are shown amplitude and phase plots. The upper plot is for frequencies from 20 Hz on down, while the lower plot is for frequencies 20,000 Hz on up. The frequency and phase plots between 20 and 20,000 Hz form straight lines.

The low-frequency curves show that the amplifier is down 1 dB at 5 Hz with gain approaching unity at dc. The phase shift plot shows that a maximum low-frequency phase shift of about 60° occurs at approximately 0.7 Hz and then gradually approaches 0° again near the dc point.

The high-frequency curves show the amplifier to be down 1 dB at approximately 100,000 Hz, while the unity gain point occurs at 1.3 MHz. The phase plot shows that the amplifier has approximately a 40° phase margin, enough to insure stability under any operating conditions.

A plot of output impedance versus frequency is given in Fig. 3. The wiring resistance is on the order of 0.05 ohm and is included in this plot which was taken at the amplifier's output terminals. The output impedance is quite low over the majority of the audio range and begins a slow rise beyond 5000 Hz. It reaches a maximum of 0.2 ohm at 20,000 Hz. This is about what would normally be expected from the amount of feedback and the bandwidth of the circuit.

Oscilloscope waveform photos of the square-wave response of the amplifier at

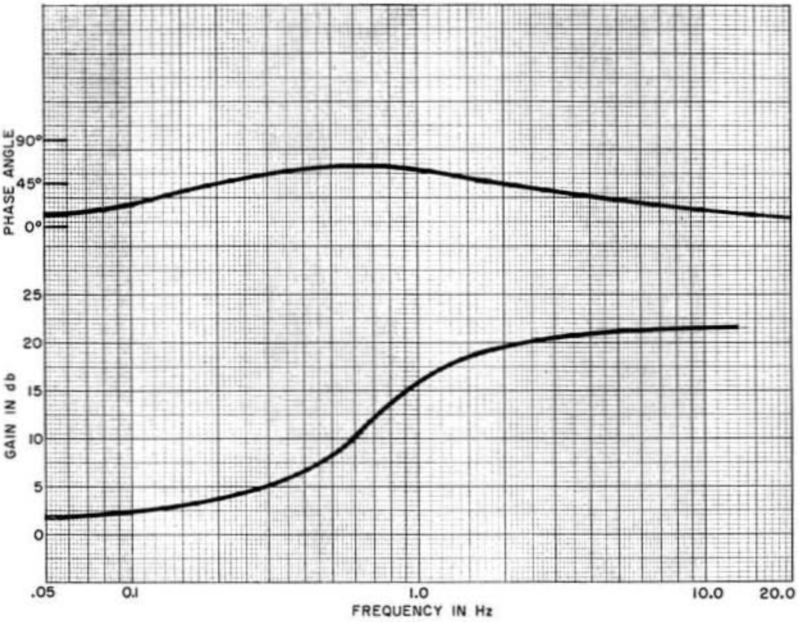
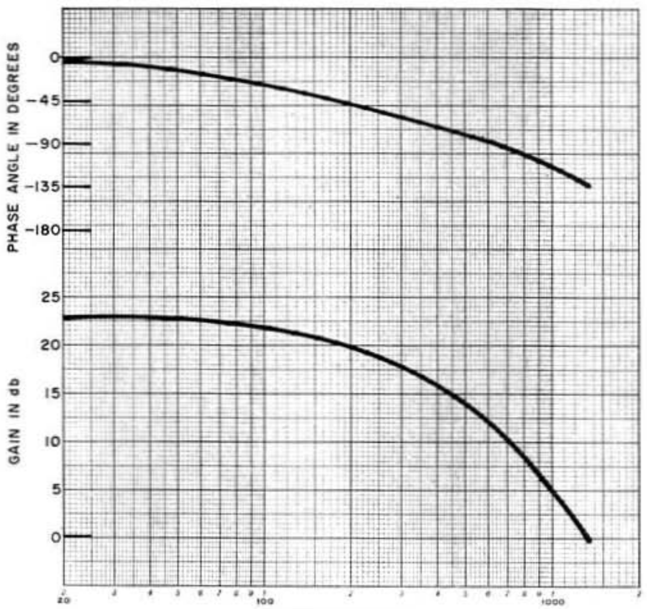


Fig. 2. Shown here are amplitude and phase plots for 20 Hz on down (above) and 20 kHz to 2 MHz (right). Frequency and phase plots for 20-20,000 Hz form straight lines.



10,000 and 100,000 Hz are given in Fig. 4. The 10,000-Hz photo was taken only because this frequency is commonly used in amplifier testing. It is actually too low a frequency for testing an amplifier such as the Plastic Tiger. The 100,000-Hz response photo shows clearly the rise time of approximately 2.5 μs and the complete absence of "ringing" when driven with a step input. (Caution: Performing this test is *not* recommended for most amplifiers and should not be performed on the Plastic Tiger by the layman.)

Assembly. The majority of the components that make up the Plastic Tiger are to be mounted on a printed circuit board. If you plan to etch and drill your own board, an actual size etching and drilling guide and a components placement dia-

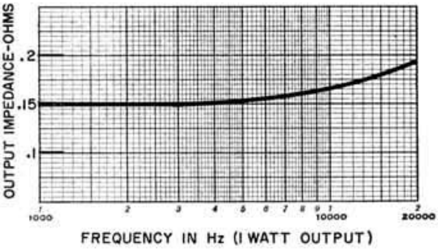


Fig. 3. Output impedance is quite low over audio range, rising to 0.2 ohm at 20 kHz.

gram are provided in Fig. 5. For those who prefer to purchase a ready-made board, refer to the Parts List for source information. Mount the components on the board and solder their leads to the foil pattern.

Power transistors *Q7* and *Q8* are to be mounted on the bottom of the board with their leads extending up through the holes drilled to accommodate them. To mount the transistors, first bend the outer leads up ¼" from the case and the center leads 7/16" from the case. When these leads are correctly bent, the metal side of the transistor cases will be facing down. Insert the transistor leads in the appropriate holes in the circuit board. Squarely position the transistors so that their bottom surfaces are parallel to and ¼" from the foil side of the board. Solder the leads to the foil pattern. If the mounting procedure is not done carefully, *Q7* and *Q8* will not lie flat on the chassis and heat sinking will not work properly.

Coil *L1* is made up of #26 insulated hookup wire close wound in a single layer along the body of *R19*. The exact value of this coil is not critical, and 8-10 turns will be the average number you can wind on the resistor. Strip away the insulation from both ends of the coil and solder the exposed wires to the leads of *R19*. Then mount the *L1/R19* assembly in the appropriate location on the circuit board.

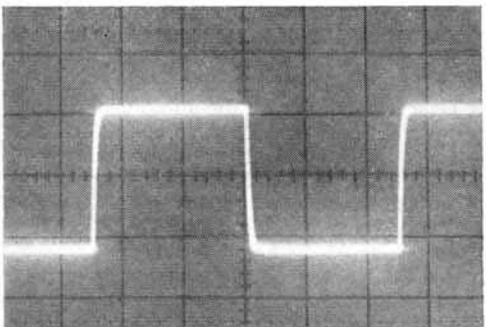
Bias diodes *D2* and *D3* are made from a pair of 2N4918 transistors after first cutting away the collector (center) leads. Use the emitter leads for the cathodes, soldering them to 3" lengths of hookup wire and the free ends of the hookup wire to the holes near the dots on the board. The base leads go to the unidentified anode holes via 3" wires.

Solder color-coded 10" lengths of hookup wire to the foil pattern at holes A, F, and H. Twist these wires together in a neat bundle. Solder one end of a 10" length of #18 or #20 wire to hole G, and 6" lengths of the same wire to both + and both − holes and hole V. Temporarily set the board aside.

Almost any power supply capable of delivering 2 amperes of current and with +40 and −40 volt sources will adequately power the Plastic Tiger. An example of such a power supply is given in Fig. 6.

The photos in Fig. 7 show an assembled stereo version of the Plastic Tiger. The same assembly procedures apply to both mono and stereo versions. Now, with the exception of the filter capacitors and their mounting clips, mount the power supply components on the chassis as shown. Power switch *S1*, if used, should be mounted on a 4-lug terminal strip with the center, or common ground, lug not used (the rectifier bridge assembly simply bolts directly to the chassis floor).

After mounting the input and output



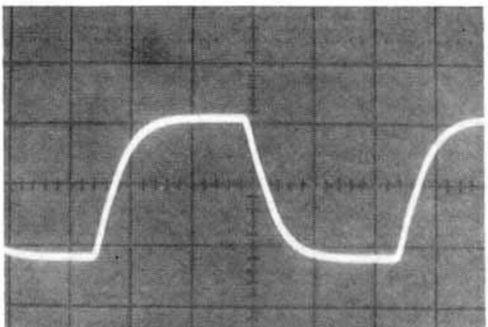


Fig. 4. Square wave output waveforms from amplifier show virtually zero distortion at 10,000 Hz (above left) and absence of ringing at 100,000 Hz (above) and beyond.

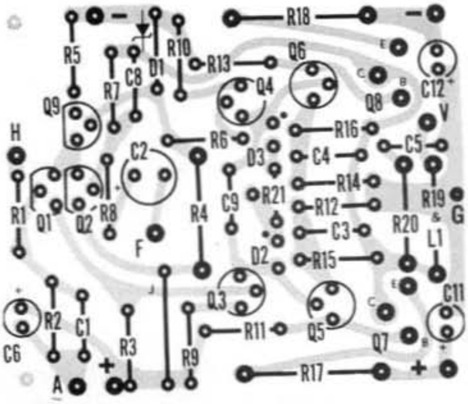


Fig. 5. Actual size etching and drilling guide at left is supplied for those who wish to make their own PC boards. Diagram above shows locations and orientations of components on PC board.

HIRSCH-HOUCK LABORATORIES
Project Evaluation

The 30-watt output power rating of the Plastic Tiger amplifier seems to be justified, although its power supply limitations keep it from realizing this power below 300 Hz. At 30 watts/channel, the distortion is only 0.084% at 300 Hz, but is 7% at 100 Hz and far greater with decreasing frequency. Otherwise, the distortion at any power level up to 30 watts/channel is typically well below 0.1% from 20 to 20,000 Hz. At normal listening levels, the distortion is less than 0.07% at any frequency, qualifying the Plastic Tiger as a first-rate high-fidelity amplifier.

The 1000-Hz harmonic distortion remains less than 0.09% from 0.1 watt to 30 watts, clipping rapidly at higher power levels. Intermodulation distortion follows a similar characteristic, but it is slightly greater—typically less than 0.3% up to 30 watts output.

At the point of visual waveform clipping, the output power into 8 ohms was 40.5 watts/channel; into 4 ohms, 33 watts/channel; and into 16 ohms, 25 watts/channel. The 8-ohm clipping level was also checked at low frequencies: at 50 Hz, it was 22 watts; at 20 Hz, it was 18.7 watts.

All of the preceding measurements were made with the Plastic Tiger's bias control set as received. The control was subsequently adjusted for minimum distortion at low power output levels (it is interesting to note that waveform notching could not be observed at any setting of the control). This produced a substantial reduction (two to five times) in both harmonic and IM distortion at power levels below 1 watt but had negligible effect at higer power levels. The optimum setting was with the control at one extreme. No measurements were made on idling currents under this condition, but it is possible that transistor dissipation would be undesirably high. If so, there is no point to the optimization of distortion since it is adequately low at almost any control setting.

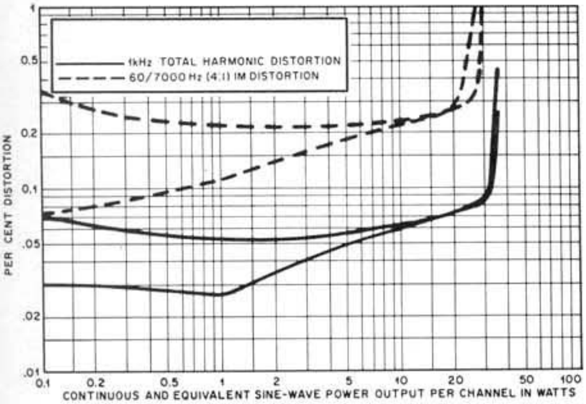
The frequency response of the Plastic Tiger was flat across the audio spectrum, down 0.2 dB at 15 Hz and 50,000 Hz, and down 1.7 dB at the lower measurement limit of 5 Hz. The high-frequency output was down 3 dB at 190,000 Hz. Square-wave rise time was 2 μs, while noise was 83 dB below 10 volts.

Although the entire amplifier became quite hot during our tests, this was not the case during normal listening usage. In all, the Plastic Tiger is certainly a compact, low-cost powerhouse.

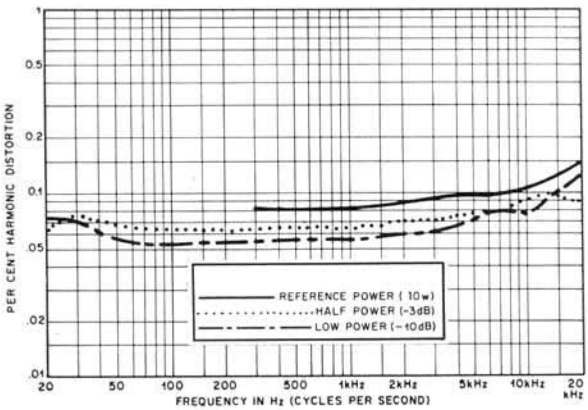
jacks on the front panel, mount the circuit board as follows. Spread a film of heat transferring silicone paste on both sides of four mica insulators; then place the insulators over the appropriate holes in the chassis. Lower the circuit board onto the chassis, aligning the mounting holes of the power transistors with the holes in the insulators and chassis. Press the transistors firmly into the paste. Place the metal sides of the diodes against the respective transistor cases—*D2* atop *Q7* and *D3* atop *Q8*—and orient them as shown. Fasten the diode/transistor pairs to the chassis with 4-40 machine hardware. Then, at the opposite end of the board, anchor the circuit assembly firmly in place with 4-40 hardware and ¼″ spacers.

Locate the twisted-together wires coming from the circuit board and route them to *J1* along the side of the chassis away from the power transformer. Connect and solder the wire coming from hole A to the signal, or center, contact of *J1*. Connect and solder the remaining two wires in the bundle to the ground lug on *J1*. Use two separate wires coming from holes A and F as directed, grounding them only at the input jack.

Bolt the speaker fuse holder to the floor of the chassis with 4-40 hardware. Also, mount the capacitor clips to the rear apron of the chassis and slip into them the filter capacitors. Wire together the power supply components, referrinig to Fig. 6. The common (COMM) line from the power supply connects to the circuit ground by running a length of #18 or #20 wire from the junction between *C1* and *C2* in the power supply to the ground lug on *J2*. If the stereo version of the amplifier is being built, run a separate wire from the capacitors to the respective jack ground lugs. (Note: Do not solder any connection to *J2* or the speaker fuse holder lugs until directed to do so.)



With R21 set as received upper broken and upper solid curves indicate measured distortion. Remaining curves were obtained when R21 was set for minimum distortion.



Curves show extremely low harmonic distortion over entire audio range at various power levels.

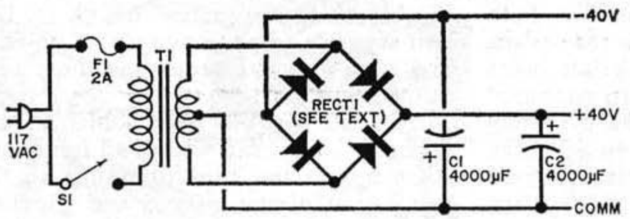


Fig. 6. In typical power supply for Plastic Tiger amplifier, RECT1 can be discrete diodes or rectifier assembly.

PARTS LIST
POWER SUPPLY

C1,C2—4000-µF, 50-volt electrolytic capacitor
F1—2-ampere fuse
RECT1—Four 200 PIV, 3-ampere silicon diodes or substitute Motorola MDA962-3 full-wave bridge rectifier assembly
S1—Spst switch (optional)
T1—42- to 45-volt, center-tapped, 2-ampere power transformer
Misc.—Fuse holder; 4-lug terminal strip; line cord with plug; hookup wire; solder; hardware; etc.

Locate the free end of the wire from hole G. Route this wire across the center of the chassis and connect and solder it to the lower hole in the ground lug on the terminal strip. Connect the free end of the wire from hole V to the near lug on the speaker fuse holder; then connect a length of #18 or #20 wire from the other fuse holder lug to the signal contact lug on *J2*. Lastly, connect *C10* to the lugs of J2 and solder all lug connections to the output jack and the speaker fuse holder. All that is left of the wiring is to connect and solder the two wires from the − holes on the board to the negative side of C2 and the two wires from the + holes to the positive side of *C1*.

Carefully check your wiring, especially in the power supply, against Fig. 1 and Fig. 6 for errors. When you are satisfied that your wiring is correct, use an ohmmeter to check the resistance from each lead of the biasing diodes and output transistors to chassis ground. Reverse the ohmmeter leads and perform the tests again. In all cases, the readings obtained should be several megohms to infinity. If you obtain a short-circuit indication or a very low resistance reading, the component in question is not properly insulated from the chassis and will have to be dismounted and reseated until insulation integrity is obtained.

(Continued on page 100)

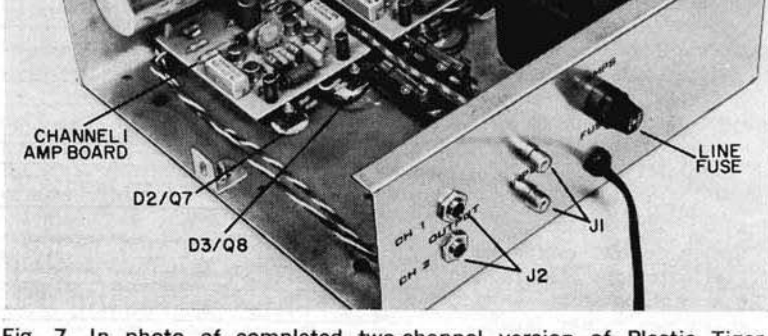


Fig. 7. In photo of completed two-channel version of Plastic Tiger, note the special mounting arrangement given to D2/Q7 and D3/Q8.

PLASTIC TIGER

(Continued from page 34)

Setup and Use. Plug the line cord into a convenient 117-volt ac outlet and close *S1*. Check the dc voltages with reference to chassis ground; they should be between 30 and 35 volts in both polarities. Now, check the voltages across *R11* and across *R13*. Typically, there should be little or no measurable voltage across *R11*. In no case is there to be more than 0.5 volt across *R13* if the amplifier is to operate properly. Make a final voltage check from point V to chassis ground; you should read 0.1 volt or less if everything is operating normally. If any of the transistors or other parts become warm or hot when there is no input signal or load on the amplifier, immediately shut down the power and find the source of the trouble before proceeding.

Now, if you have the appropriate instruments available, you can adjust bias control *R21* for optimum amplifier performance. First, connect an 8-ohm load to the Plastic Tiger via *J2* and drive the amplifier at *J1* with a 10,000-Hz sine wave signal of sufficient amplitude to provide a 1-watt output from the amplifier. Observing the wave-form of the output signal on an oscilloscope screen, rotate *R21* clockwise (viewed from the input end of the circuit board) until the small crossover notches disappear at the waveform's zero crossing points. If you do not have the appropriate instruments available, just set *R21* for a three-quarter clockwise rotation. ◈