

Build It! A Portable Headphone Amplifier

By Mark Amundson

Ever wanted to monitor a line level signal? Or want to provide another headphone output to share the multi-track mix? Well, this Do-It-Yourself (DIY) project is for you. With the modern Musical Instrument (MI) grade of equipment, many situations arise where the need to individually monitor mixer channel inputs for adjustment of signal levels is not available. Also there are times when a portable signal sniffer is just the ticket to troubleshoot sound system interconnects.

A Little Design Philosophy

I chose this project to teach a little circuit design as well as arrive with a headphone amplifier. One could have grabbed a couple of LM386 Audio Amplifier Integrated Circuits (ICs), added a few passive parts, and completed the project. But I chose a discrete version instead. The rationale to avoid the purpose built ICs is thin but does have its merits. One is to break out the heat generating output transistors to avoid the thermal changes from affecting the other transistors. Another is to prove to our younger generation that before integrated circuits, simple good sounding audio amplifiers were possible in small sizes.

This project also has the goal of using commonly available parts so that first time DIY project builders would feel comfortable finding the parts and use assembly techniques like perforated board or etch your own circuit board. The transistors are garden variety 2N2222 and 2N2907 types and either plastic or metal case types can be used. The diodes are 1N4001 rectifier and 1N4148 switching types that can be easily found. All the resistors are 5% carbon film, quarter watt values and the capacitors should 16 volt or higher voltage ratings.

Circuit Description

This portable headphone amplifier project consists of two audio amplifier circuits for stereo operation powered by a switched 9 volt alkaline battery. Each audio amplifier circuit contains a 100 kilo-ohm, audio taper potentiometer on a common shaft for volume control. A common stereo headphone jack (ring-tip-sleeve) is used along with four phone jacks (tip-sleeve) for input signals. Stereo/mono switching is easily possible as well. Figure 1 shows the top level schematic.

Each audio amplifier circuit consists of six transistors, three diodes, nine capacitors, and fourteen resistors. Figure 2 shows the circuit schematic. This circuit is best described in backwards fashion; from output towards the input. Transistors Q1 and Q4 form the push-pull output stage and are configured for rail to rail operation. This permits the output voltage swing to approach the battery supply voltage for best peak-to-peak capability. Diode D3 is placed in series with the battery's positive lead to prevent accidental reverse battery connections from destroying the circuit. Capacitor C2 is a 470 microfarad electrolytic device for decoupling the DC offset voltage from the push-pull output to the ground referenced headphone load.

Resistor R3 and Capacitor C1 form a high frequency load to keep the amplifier stable in the presence of inductive loading of the headphone voice coils. Resistors R15 and R16 are 4.7 ohm resistors that cover a couple functions. Their prime purpose is to provide some degeneration of drive signals on heavier headphone loads. Most professional studio headphones and personal "Walkman" stereo headphones have voice coil impedances of 30 ohms or higher. However, classic home stereo headphones have an impedance of 8 ohms or more. These lower impedances draw more current from the amplifier. The 4.7 ohm resistors drop more voltage and limit the output dissipation to about 350 milliwatts. These resistors also prevent accidental short circuits from destroying the output transistors.

Transistors Q2 and Q3 plus resistors R1 and R2 form the driver stage of the audio amplifier circuit. By sharing the 4.7 ohm resistor's voltage drop on the driver transistor's emitters, the above mentioned drive degeneration occurs. Resistors R1 and R2 are not strictly necessary but are added to achieve better fidelity of sound by helping drain capacitive charges accumulated on the base-emitter junctions of the output transistors.

Resistor R5 through R8, along with diodes D1 and D2, capacitors C3 and C8, and Transistor Q5 form the pre-driver stage of the audio amplifier circuit. One kilo-ohm resistors R6 and R7 with capacitor C6 tapped in between, form a collector load for transistor Q5 plus a "poor man's" or bootstrap constant current source for the driver stage biasing. By selecting C3 at 100 microfarads, the capacitor attempts to retain a constant voltage across R7 which forms the current source. The reason to desire a constant current source is that diodes D1 and D2 plus R5 will maintain a constant voltage drop for optimum driver transistor biasing. Resistor R8 keeps transistor Q5's gain under control via emitter degenerative feedback. Capacitor C8 forms a miller capacitance to minimize circuit oscillation and keep the amplifier stable.

The balance of the components in the audio amplifier circuit make up the amplifier's input stage. Resistors R4, R12, and R13 together with capacitors C5 and C9 provide stable bias voltage for input transistor Q6 to ensure that the whole amplifier circuit centers up about one-half of the supply voltage. Resistor R11 is sized at one kilo-ohm for almost a one volt (one milliampere) direct coupled bias for transistor Q5. Resistor R9 performs double duty as an emitter resistor and uses the 470 ohms in conjunction with the 22 ohms of resistor R10 as the gain setting part of the amplifier. Capacitors C4 and C7 set the low and high frequency response of the circuit respectively. Potentiometer R14 and capacitor C6 provide signal input to the base of transistor Q6 and provide decoupling for the incoming signal.

Project Construction

The portable headphone amplifier project construction can be done in many ways. As mentioned earlier, board type construction is the preferred method of circuit interconnection. Figures 3 and 4 show a prospective copper clad circuit board layout. Other proto-board types can also be used. If you try to layout your own board, use the schematic to help physically

place your components. Back in my school day's, my instructor would teach us to paste a paper schematic to a wood board, pound small brass nails into the circuit node points, and solder wire or components across the nail heads for interconnections. The term "Breadboarding" came from this early form of project construction since a kitchen's breadboard was an ideal flat piece of wood for usage. Figure 5 shows an inside view of the author's internal construction.

Project encasement can be done using a number of choices. Aluminum project boxes are my favorite by lending ruggedness in construction and providing an easy surface for drilling and painting. As with other projects, consider what conveniences your local hardware store offers for securing parts or dressing up your project. Adhesive backed foam weather stripping is one of my favorite items for securing batteries and circuit boards in project boxes; due to its insulating and light compression properties. In a rough and tumble world of gigs, rattles and loose hardware spell danger.

Project wiring can be done using non-critical types of insulated conductors. My favorite is PVC insulated solid conductor colored wires of small gauges for the stiffness of bending and for a clean lead dress in the project box. Assorted colors of wire wrap (Kynar) wire are also handy for interconnects. Shielded conductors for the input signal routing can be avoided if you use a conductive project case for shielding instead.

Circuit Performance

The next step after project construction is the dreaded "smoke test". Like the old, wise electrical technician said, "Every component has smoke inside it. You pass the smoke test if you do not let the smoke out." If possible use a DC ammeter between each amplifier circuit and the battery. Each amplifier circuit should draw close 8 to 10 milliamperes of battery current with no signal input. The junction of the 4.7 ohm resistors (or board jumper) should have about a 4 to 5 volt reading to ground using a DC voltmeter. If trouble is present, trace through your circuit connections, using a copy of the schematic and a hi-lighter pen to verify the construction.

Project Usage

The portable headphone amplifier as shown contains four phone jacks in which they are paired (bridged) to permit tapping into lines for monitoring a signal path. If you desire to troubleshoot signals or just use mixer insert jacks, then only a single jack per stereo side will be needed. With the optional mono/stereo switch, a single line connection can be made. Figure 6 shows a typical application.

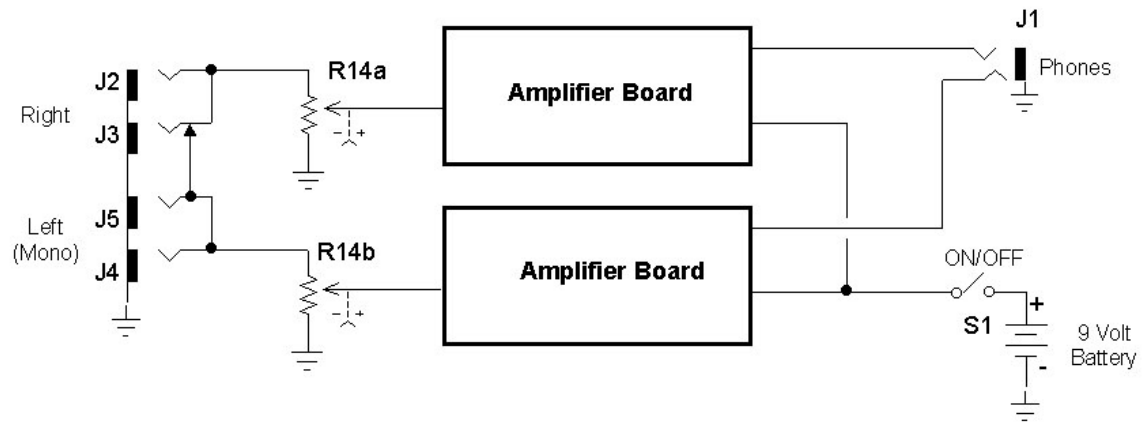
ABOUT THE AUTHOR

Mark Amundson's interest in music and electronics started in 1972 and 1974, respectively. He is an Analog and RF Development Engineer and has been building and modifying audio projects for years, since his first one-tube radio kit. His favorite instruments are guitars, electric and acoustic, and keyboards. Mark plays regularly with a local band, and has spent over two decades as a musician and soundman.

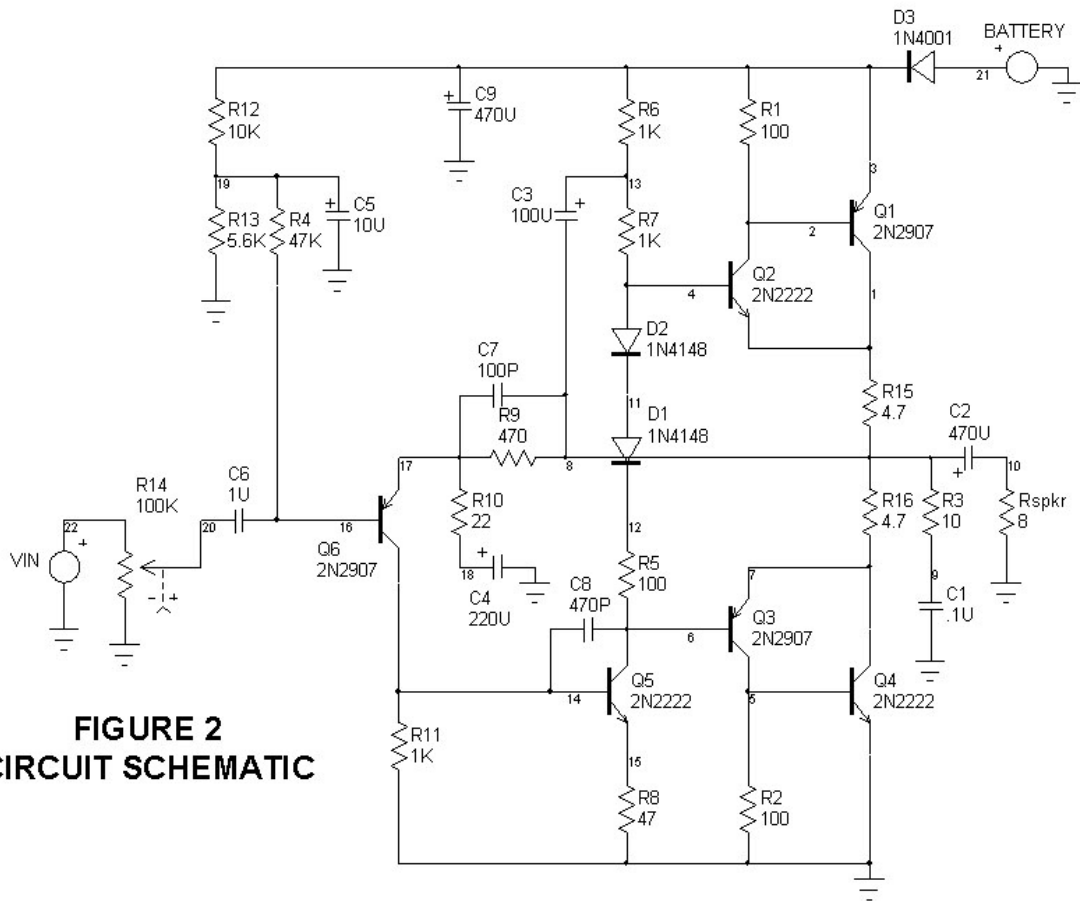
Table 1

PARTS LIST

REF. DES.	PART
BATTERY	9volt battery with battery clip and/or holder
C1	.1uf, 50volt or more ceramic capacitor
C2, C9	470uf, 16volt or more electrolytic capacitors
C3	100uf, 16volt or more electrolytic capacitor
C4	220uf, 16volt or more electrolytic capacitor
C5	10uf, 16volt or more electrolytic capacitor
C6	1uf, 16volt or more electrolytic capacitor
C7	100pf, 50volt or more ceramic capacitor
C8	470pf, 50volt or more ceramic capacitor
D1, D2	1N4148 or 1N914 Switching diodes
J1	3 conductor open circuit phone jack
J2, J3, J4	2 conductor open circuit phone jack
J5	2 conductor closed circuit phone jack
Q1, Q3, Q6	2N2907 or PN2907 PNP transistors
Q2, Q4, Q5	2N2222 or PN2222 NPN transistors
R1, R2, R5	100 ohm, ¼ watt resistors
R3	10 ohm, ¼ watt resistor
R4	47k ohm, ¼ watt resistor
R6, R7, R11	1k ohm, ¼ watt resistors
R8	47 ohm, ¼ watt resistor
R9	470 ohm, ¼ watt resistor
R10	22 ohm, ¼ watt resistor
R12	10k ohm, ¼ watt resistor
R13	5.6k ohm, ¼ watt resistor
R14	dual 100k ohm, audio taper potentiometer
S1	SPST switch
MISC	Case, Circuit board, Wire, Knob



**FIGURE 1
TOP LEVEL SCHEMATIC**



**FIGURE 2
CIRCUIT SCHEMATIC**

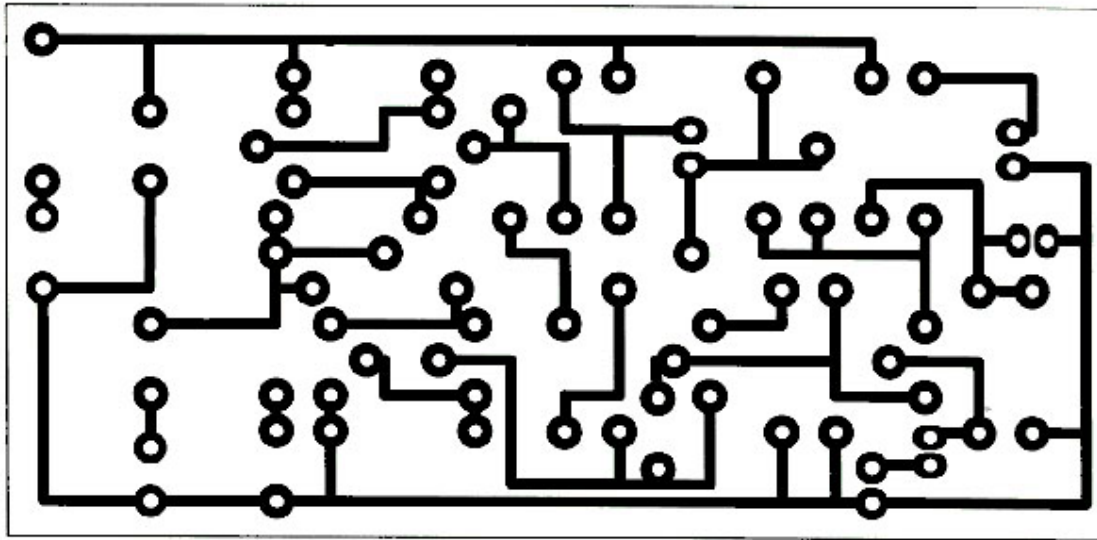


FIGURE 3
COPPER SIDE ARTWORK
 (3" by 1.5")

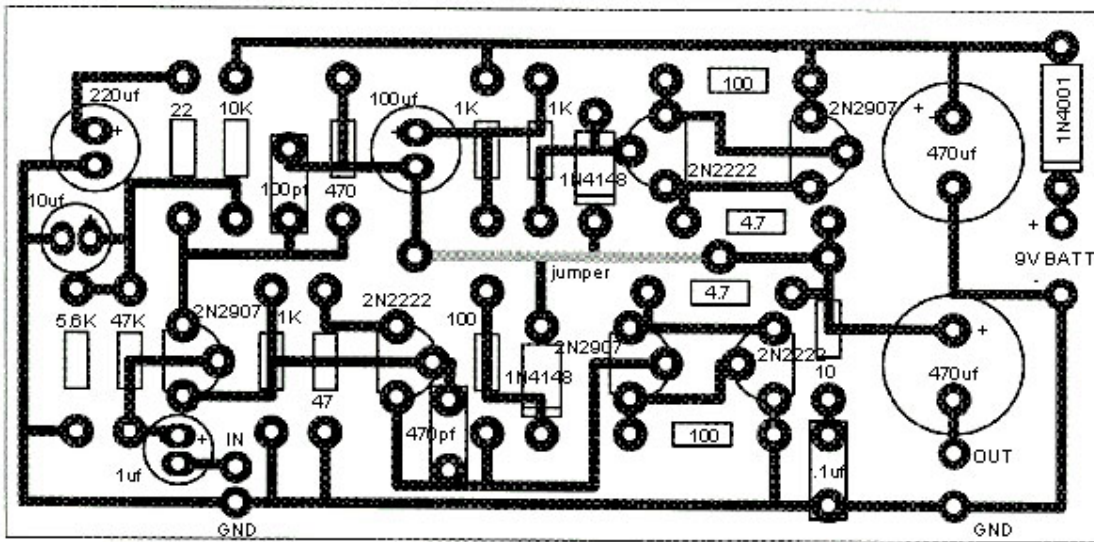


FIGURE 4
X-RAY VIEW

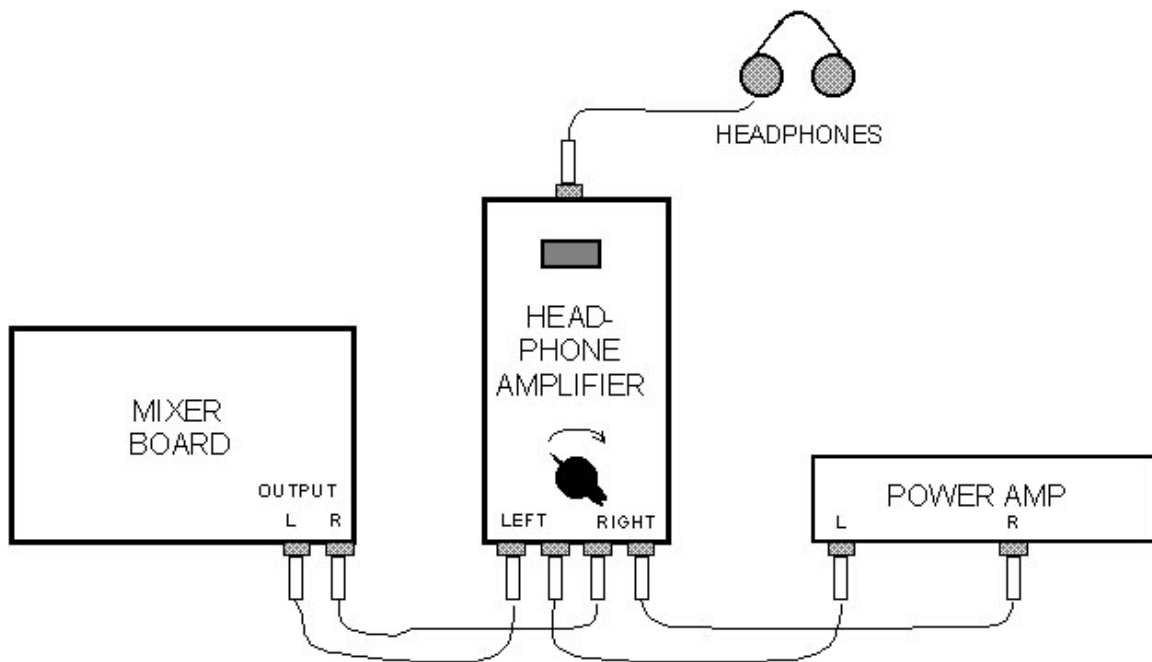


FIGURE 6
TYPICAL APPLICATION