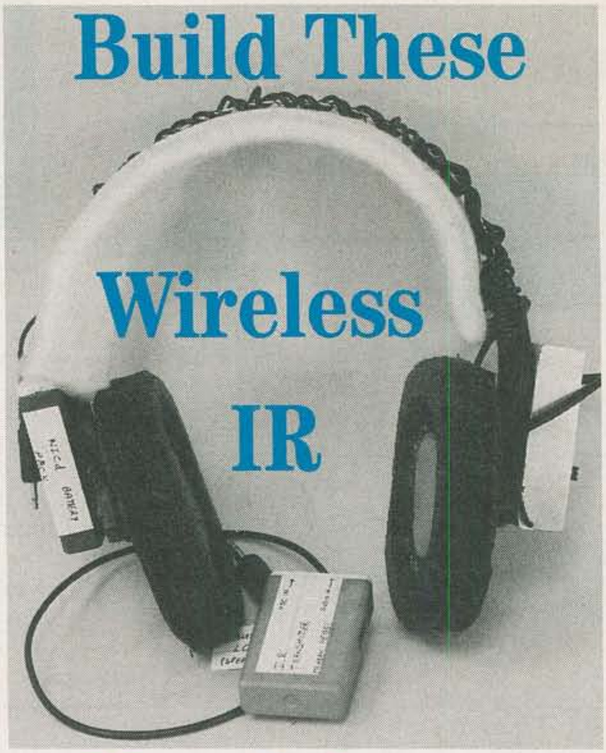
Build These Wireless IR Headphones



BY BRIAN MCKEAN

Listen to your favorite music unencumbered from a headphone cord with this easy-to-build transmitter/receiver combination

The age of wireless is here. Although the term "wireless" has until recently implied radio, that is by no means the only wireless media. The *Wireless Headphone* project described in this article uses a different form of wireless link—infrared. Using a 100-kHz frequency-modulated (FM) carrier, the Wireless Headphone has A 4-kHz bandwidth, making it suitable for general-purpose listening. Its high carrier frequency provides interference-free operation, even around most consumer IR remote controls, which operate with a carrier frequency of 40 kHz. And it requires no special connections to the radio or TV.

The power requirements for the system are modest: The transmitter requires a 7- to 14-volt, 200-mA DC supply, while the receiver draws about 10 mA (at minimum volume) from a 9-volt battery. The receiver has a volume control for convenience, although the audio source's volume control may also be used to that end.

The Transmitter Circuit. The transmitter for the Wireless Headphone (see Fig. 1) consists of a pair of infrared LED's and a CD4046 CMOS phase-locked loop (or PLL, which is comprised of two phase comparators, a voltage-controlled oscillator or VCO, a source follower, and a Zener reference)—coupled with a driver transistor. Note that in this application, only the PLL's VCO is used.

The VCO's supply voltage is stabilized by the internal Zener reference. The VCO input at pin 9 is biased near the midpoint of the VCO's linear region. The VCO's programmable sensitivity and high input impedance eliminates the need for signal preconditioning.

Components C1 and R2 provide impedance matching for low-impedance speakers; those components should be eliminated if the audio source has a high impedance (600 ohms). The VCO frequency is set by R4, R5, and C4 for a minimum frequency of 85 kHz, a maximum frequency of 115 kHz, and a nominal center frequency of 100 kHz, which yields a VCO sensitivity of 7.5 kHz/volt.

The VCO output at pin 5 of U1 drives a saturated common-emitter circuit, built around Q1 (a 2N2222A general-purpose NPN silicon transistor). Although U1's Zener reference decouples the VCO from supply variations, the IR-emitter current is not regulated. Components shown in the schematic should be suitable for most applications. The number of IR emitters (on our circuit, LED1 and LED2) connected to the collector of Q1 can be increased to provide increased room coverage, as long as the supply voltage is sufficient to drive the LED string. Allow 1.8 volt per LED, and select R7 so that the peak current through the LED's does not exceed the part specification (typically 100 mA).

The IR transmitter's supply voltage may be an unregulated DC source greater than 7 volts. An internal Zener reference at pin 15 of U1 regulates the supply to 5–6 volts for the VCO. The current through the IR LED's may be adjusted by changing the value of R7 to suit the diode ratings.

Receiver. The schematic diagram of the receiver for the Wireless Headphone—essentially a reverse-biased photodiode detector/amplifier—is shown in Fig. 2. That circuit consists of a CA3237 high-gain IR remote-control preamp (U1), a 4046 phase-locked loop (U2), and an LM386 low-voltage audio amplifier (U3).

Integrated circuit U1—which is designed for 40-kHz carrier systems but can provide limiting action to up to 1 MHz—contains two amplifiers whose gain is set by C6/R4, and C7/R5. Together those components provide DC and low-frequency blocking, while setting the combined gain of the amplifiers to about 85 dB at 100 kHz. The Schmitt-trigger section (pins 4 and 6) of U1 is not used.

The IR remote-control preamp's output at pin 7 is AC coupled to the phase-locked loop, which operates with a 100-kHz center frequency. The PLL's 15-kHz capture range allows for considerable center-frequency mismatch with the transmitter while providing proper demodulation bandwidth and noise rejection. The VCO of the PLL has a range of ±30 kHz around the center frequency, which also allows for transmitter/receiver mismatch without unduly sacrificing loop performance.

The loop lowpass filter output contains the demodulated audio signal and is internally buffered at pin 10. The audio is filtered and fed through amplitude control R12 to the non-inverting input of U3 (an LM386 low-voltage audio power amplifier), which pro-

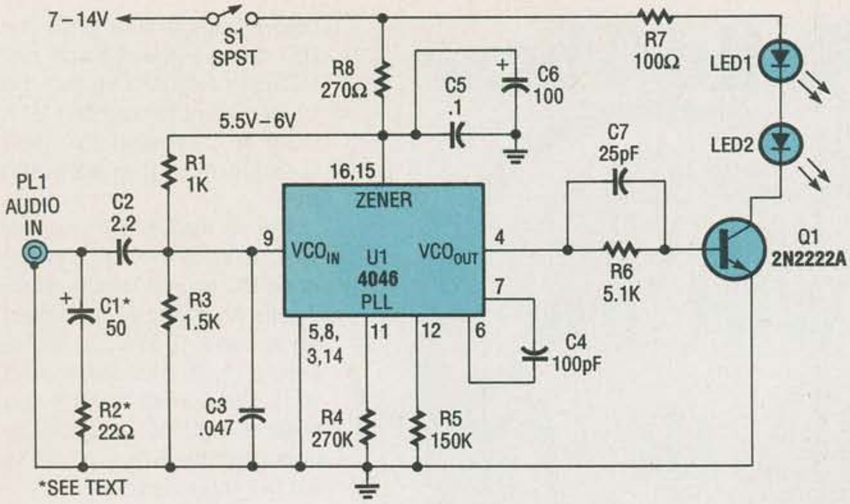


Fig. 1. The transmitter for the Wireless Headphone is built around a CD4046 CMOS phase-locked loop or PLL, coupled with a driver transistor, and a pair of infrared LED's. Although the CD4046 is comprised of two phase comparators, a voltage-controlled oscillator (or VCO), a source follower, and a Zener reference, only its VCO is used in this application.

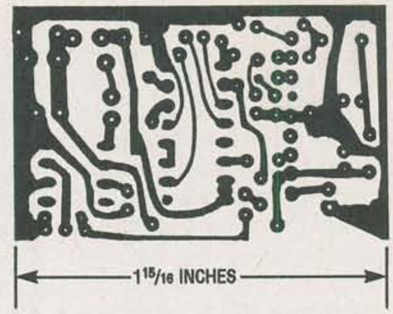


Fig. 4. The receiver's full-size printed-circuit layout is shown here.

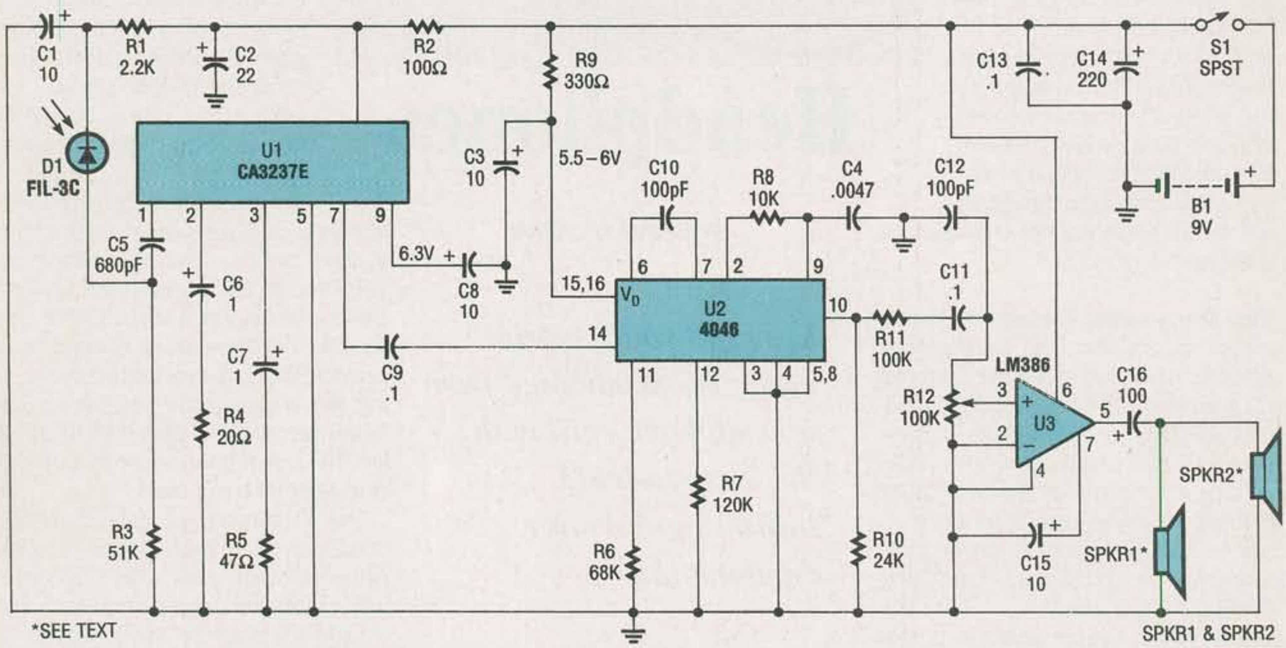


Fig. 2. The receiver for the Wireless Headphone consists of a CA3237 high-gain IR remote-control preamp (U1, which is designed for 40-kHz carrier systems,), a 4046 phase-locked loop (U2), and an LM386 low-voltage audio amplifier (U3).

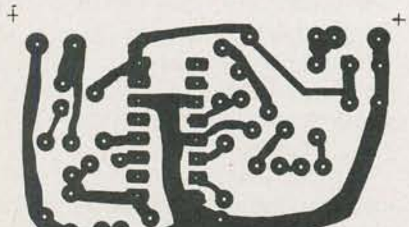


Fig. 3. The transmitter's printed-circuit layout is shown here at full size.

vides a 26-dB gain and will easily drive a paralleled pair of AC-coupled, low-impedance earphones.

Voltage regulation in the receiver is provided by U1 and U2, with the assistance of R2 and R9. The receiver will operate from supply voltages as low as 7 volts, making battery operation (from a rechargeable 9-volt battery) highly practical.

A final note regarding the high-gain receiver: Normal practice would require such a circuit to be enclosed in a metal case to provide electrostatic shielding. That may not be necessary, but is recommended for best range.

Assembly. Most parts are quite noncritical. Many parts can be replaced with near value(s) without affecting the circuit. The exceptions are noted on the schematic diagrams by asterisks—those parts should not be replaced with any other value. If you can not find the specified photodiode, one salvaged from a commercial IR receiver should work well. It should have a capacitance of 30 pF or less at –5 volts, and be 0.1-inch diameter or less. The capacitor should be miniature radial-lead unit.

Figure 3 shows a full-scale template

PARTS LIST FOR THE RECEIVER

SEMICONDUCTORS

U1—CA3237E IR preamplifier (NTE1682), integrated circuit
U2—CD4046B CMOS phase-locked loop, integrated circuit
U3—LM386 low-voltage, audio-power amplifier, integrated circuit
D1—FIL-3C, FIL-5C, PIN-3CD, PIN5D, or similar IR-detector diode

RESISTORS

(All fixed resistors are ⅛-watt, 5% units.)
R1—2200-ohm
R2—100-ohm
R3—51,000-ohm
R4—20-ohm
R5—47-ohm
R6—68,000-ohm
R7—120,000-ohm
R8—10,000-ohm
R9—330-ohm
R10—24,000-ohm
R11—100,000-ohm
R12—100,000-ohm PC-mount potentiometer

CAPACITORS

C1, C3, C8, C15—10-µF, 16-WVDC, radial lead electrolytic or tantalum
C2—22-µF, 16-WVDC, radial lead electrolytic or tantalum
C4—0.0047-µF, ceramic-disc
C5—680-pF, ceramic-disc
C6, C7—1-µF, 16-WVDC, electrolytic
C9, C11, C13—0.1-µF, ceramic-disc
C10, C12—100-pF, ceramic-disc
C14—220-µF, 16-WVDC, electrolytic
C16—100-µF, 16-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

SPKR1—8–32-ohm speaker
S1—SPST toggle switch
B1—9-volt alkaline, or rechargeable battery
Printed-circuit materials, enclosure, earphone jack, 9-volt battery connector, wire, solder, hardware, etc.

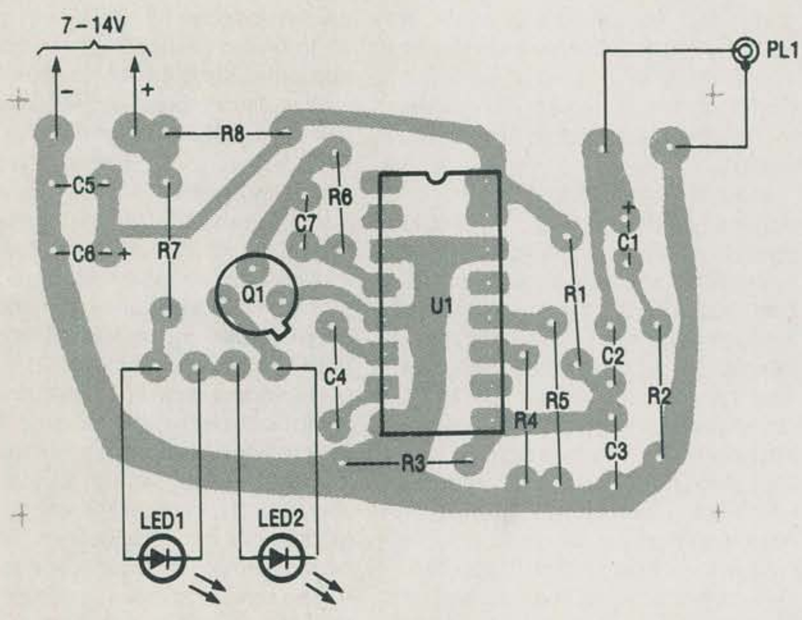


Fig. 5. The size of the parts used to build the transmitter are important due to space constraints, thus, ¼-watt or smaller resistors are a must and miniature (radial lead electrolytic or otherwise) capacitors are recommended.

of the transmitter printed-circuit artwork, and Fig. 4 shows a full-scale template of the receiver's printed-circuit artwork. Printed-circuit assembly is recommended, particularly for the receiver, which has a very high gain.

As can be seen from the size of those foil patterns, the most important factor governing the use of a particular component is its physical size. Due to that factor, the smallest sized components available should be used.

PARTS LIST FOR THE TRANSMITTER

SEMICONDUCTORS

U1—CD4046B phase-locked loop (do not use the 74C version)
Q1—2N2222A general-purpose NPN silicon transistor (use TO-18 if driving LED at high current)
LED1, LED2—RS276-143 infrared, light-emitting diode (Radio Shack)

RESISTORS

(All fixed resistors are ⅛-watt, 5% units, unless otherwise noted.)
R1—1000-ohm
R2—22-ohm
R3—1500-ohm
R4—270,000-ohm
R5—150,000-ohm
R6—5100-ohm
R7—100-ohm, ¼-watt
R8—270-ohm, ¼-watt

CAPACITORS

C1—50-µF, 1-WVDC, radial-lead electrolytic or tantalum
C2—2.2-µF, non-polarized multilayer ceramic
C3—0.047-µF, ceramic-disc
C4—100-pF, ceramic-disc
C5—0.1-µF, ceramic-disc
C6—100-µF, 10-WVDC, electrolytic
C7—25-pF, ceramic-disc

ADDITIONAL PARTS AND MATERIALS

S1—SPST switch
Printed-circuit board materials, enclosure, 7- to 14-volt DC, 200-mA source, wire, solder, hardware, etc.

Once you have etched your boards and obtained all the parts, assemble the board for the transmitter guided by Fig. 5 and the board for the receiver guided by Fig. 6. The audio and power connections to the receiver board are best handled by case-mounted connectors.

The circuits, once assembled, should operate immediately without adjustment or alignment. The Zener references can be checked at pins 15 and 16 of the CD4046's and at pin 9 of the CA3237. The transmitter and receiver VCO's can be checked at pin 4 of the two CD4046's. The free-running frequency of the transmitter should be 100 kHz ± 10 kHz; and the transmitter and receiver VCO frequencies should be identical when the two units are optically coupled and properly

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functioning. The VCO tests should be made without an audio input to ensure a stable frequency reading.

Implementation and Use. The receiver may be mounted in a number of ways, depending on the user and the availability of parts. Perhaps the most obvious, but most difficult, is in a headset. The small size of the receiver circuitry facilitates proportionally small packaging, but the added mass on a light-weight headset can result in an unstable mount. Use a large-size headset (full ear enclosure) and mount the receiver and battery as low as possible to maintain a low center of gravity.

Placing the receiver and battery on opposite sides of the two speaker elements is ideal or at least more balanced. Use shielded audio cable between the two headset speakers.

An alternative packaging idea is to use a lapel mount, in which the receiver and battery are combined in a single enclosure that is separate from the headphones. The photodiode may be oriented on the printed-circuit board to permit side or front illumination relative to the printed-circuit board.

No external lens is necessary at either the receiver or the transmitter—in fact I recommend against it in order to maintain a wide field of view at the receiver end. ■

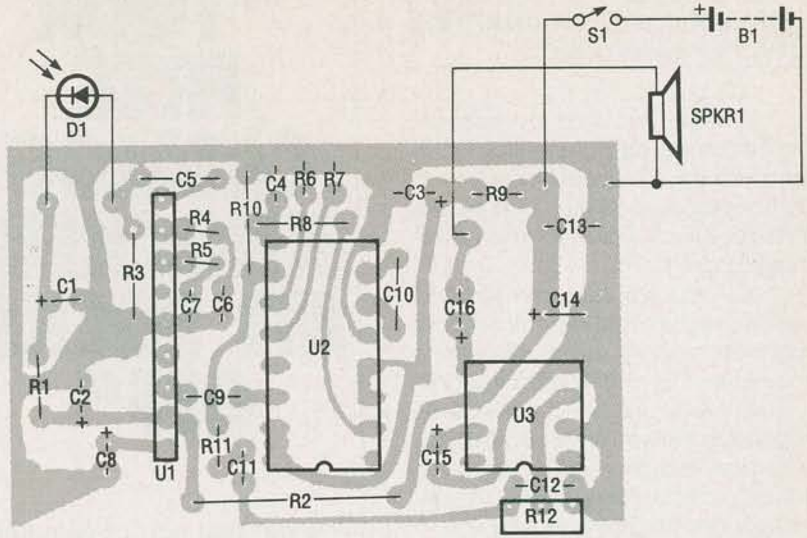

Fig. 6. The receiver's printed-circuit board should be assembled using ⅛-watt or smaller resistors and miniature (radial lead electrolytic and ceramic-disc) capacitors. The volume control (R12) can be a miniature PC-mounted potentiometer or conventional unit, which would have to be mounted off-board.