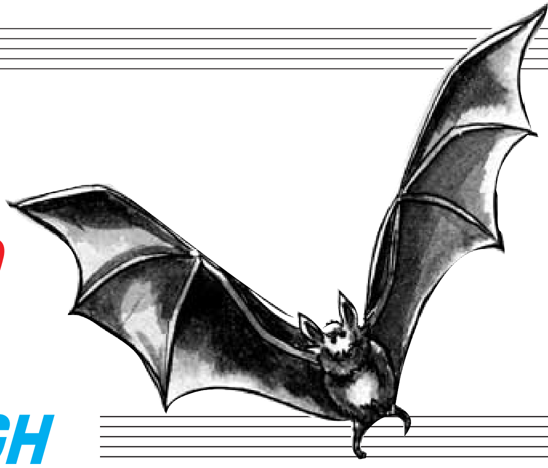
Constructional Project

BAT-BAND CONVERTOR



THOMAS SCARBOROUGH

Listen-in to the world of bats with this low-cost b.f.o. detector

THE author's original purpose was to design a simple Bat-Band Convertor that would "really work". The resulting Bat-Band Convertor uses just a single i.c. and a handful of components to deliver surprisingly good performance.

The circuit has been named a Bat-Band Convertor, since it not only *detects* bats, but *converts* their sounds to frequencies that fall within the range of human hearing. In so doing, it gives a reasonably faithful representation of a bat's sound.

It is well known that bats use ultrasound for navigation and the location of prey. A bat will emit rapid bursts of ultrasound – typically 10 to 200 times a second, increasing in rapidity as a bat closes on its prey. These bursts are in the region of 12kHz to 150kHz, with wide variations in frequency, depending on the species.

They are high amplitude sounds, and the first time the author used a bat detector, he was surprised at the volume that a bat emits. A typical bat will "scream its little lungs out"!

HEAR-HEAR

The Bat-Band Convertor is a highly sensitive circuit that "hears" over the range of 13·6kHz to 180kHz. The only limiting factor will be the transducer that you use.

The author settled on a standard 40kHz ultrasonic receiver transducer, and this gave good performance up to about 50kHz, with sensitivity dropping off around 60kHz. However, it was able to "hear" well above 100kHz, and the first test of the unit will be performed at 180kHz.

Constructors might wish to experiment with the transducer, and virtually any piezo device may be tried. A standard piezo sounder might well "hear" up to 50kHz, at minimal cost, and may even hear (faintly) beyond 100kHz. A crystal earpiece, too, was tried with some success.

A piezo horn tweeter was found to perform particularly well, offering better reception than a 40kHz ultrasonic transducer, and reasonable reception even up to 180kHz. It is, of course, far bulkier, and it admitted more ultrasonic noise than a 40kHz transducer – but this may in some cases be desired. The author suggests that constructors might like to try such a tweeter, and contrast its performance with a 40kHz ultrasonic transducer.

IN CONCEPT

There are two common approaches to bat detectors. The first is to compress a range of frequencies (e.g. 20kHz to 100kHz) into the range of human hearing (e.g. 2kHz to 10kHz). That is, the sounds which a bat emits are divided into lower frequencies.

The author has also used this principle to obtain a *visual* representation of a bat's sound, and this has the advantage of eliminating low frequency sounds in particular, which can be the bane of budget bat detectors.

A second approach, which is the one used here, is to use a beat frequency oscillator (b.f.o.) to obtain a beat note. As the sound of the bat is mixed with the oscillator frequency, a beat note or heterodyne is created, which represents the *difference* between the two frequencies. Hence it is sometimes called a *difference frequency*.

This means that one needs to tune the circuit to within about 10kHz of a bat's sound to obtain the beat note. If the difference is greater than this, the beat note will be too high to be heard – unless one should be hearing harmonics.

This approach has the advantage of obtaining a "deeper" representation of a bat's sound (rather than a compressed one), it greatly reduces the problem of loud low frequency sounds, and it may be used to hunt for particular bats whose frequency is known. For example, Horseshoe bats use fixed frequencies of around 80kHz to 100kHz, and this easily distinguishes them from more common bats such as the Pipistrelle, which use variable frequencies of around 40kHz to 50kHz.

The block diagram in Fig.1 shows the simplicity of the concept. An amplifier, based on two j.f.e.t. op.amps, amplifies the bat's sound. A third j.f.e.t. op.amp is wired as a beat frequency oscillator. These two frequencies are mixed by a fourth j.f.e.t. op.amp, creating a beat note at the output.

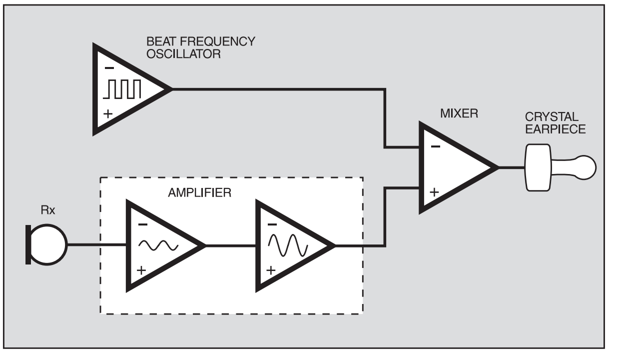


Fig.1. Block diagram for the Bat-Band Convertor.

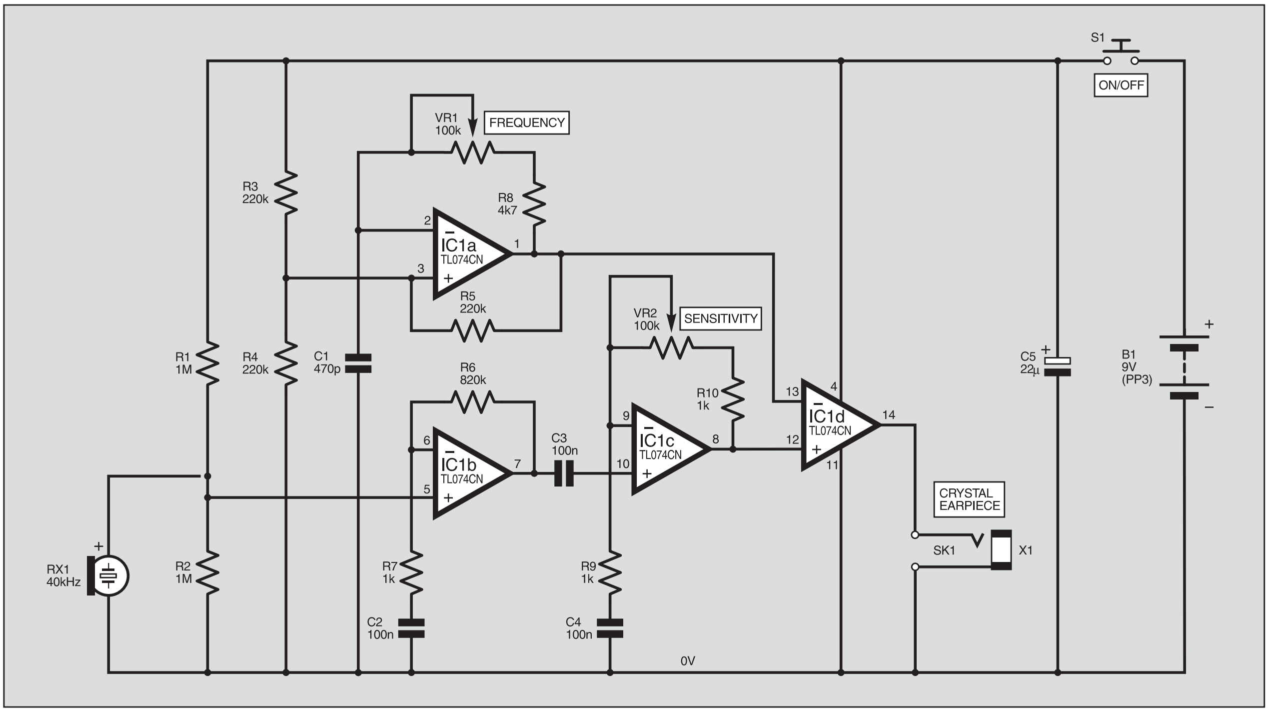


Fig.2. Complete circuit diagram for the Bat-Band Convertor. The crystal earpiece is plugged into the jack socket SK1.

CIRCUIT DETAIL

The complete circuit diagram for the Bat-Band Convertor is shown in Fig.2. IC1a represents a standard *RC* op.amp oscillator. The timing elements are capacitor C1, potentiometer VR1 and resistor R8. Depending on the setting of potentiometer VR1, IC1a oscillates between 13·6kHz and 180kHz.

As capacitor C1 charges and discharges, so IC1a's non-inverting input flips "high" and "low", causing the output to continually change its state. This serves as a so-called reference oscillator.

A simple square wave oscillator is used here, since this is the easiest op.amp oscillator to implement, while it offers a very wide frequency range. A simple Wien Bridge op.amp oscillator would produce a finer result, but this would lack the necessary flexibility. Also, alternatives would require a good many more components.

Two simple non-inverting amplifiers are made up of IC1b and IC1c. Depending on the setting of potentiometer VR2, their combined gain will lie between 820 and 82,000 times. If gain needs to be increased, increase the value of resistor R6 – and vice versa. Or, if the output should prove to be too loud, a resistor may be wired in series with the crystal earpiece X1.

The final stage, IC1d, is a simple mixer, which is essentially switched on and off by oscillator IC1a, causing the difference frequency to appear at the ouput.

Supposing that a bat emits a fixed frequency of 80kHz, and that IC1d is switched at 75kHz, this would lead to rises and falls in amplitude at a rate of 5kHz, thereby rendering the bat's sound audible. The same would apply if the reference oscillator were running faster than the frequency of the bat. Waveform Fig.3a shows the circuit's output at 40kHz when no sound is heard, and Fig.3b when ultrasound (in this case ultrasonic noise) is detected.

Two further components deserve special mention, since these are critical to the correct operation of the circuit. They are resistors R1 and R2, which provide suitable d.c. bias at IC1b input pin 5. Without these resistors, performance would be erratic.

Current consumption is about 5mA, therefore the circuit will run for about one week continuously off a 9V alkaline PP3 "matchbox" battery. It may also be run off 12V. The circuit uses a pushbutton on-off switch, S1, which prevents it from being accidentally left on.

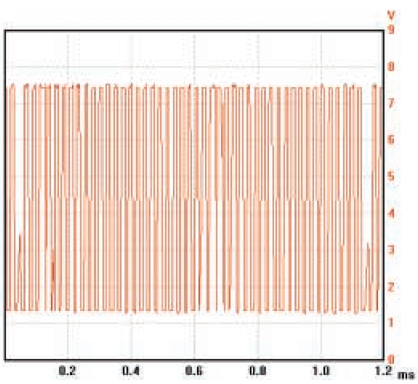


Fig.3a. Bat-Band Convertor tuned to 40kHz, no signal.

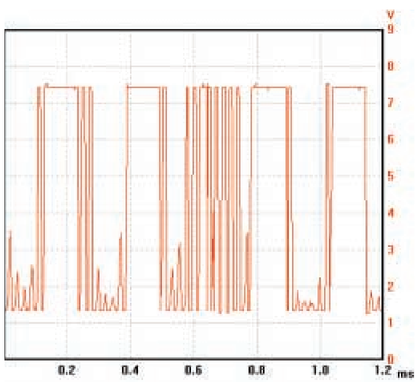


FIg.3b. Bat-Band Convertor tuned to 40kHz, ultrasonic noise.

COMPONENTS

See SHOP TALK page

Resistors

R1, R2	1M (2 off)
R3, R4, R5	220k (3 off)
R6	820k
R7, R9, R10	1k (3 off)

All 0·25W 5% carbon film

Potentiometers

VR1, VR2	100k rotary carbon, p.c.b. mounting – 5mm pin spacing, linear

Capacitors

C1	470p polyester
C2, C3, C4	100n polyester (3 off)
C5	22µ radial elect. 16V

Semiconductors

IC1	TL074CN quad low-noise j.f.e.t. op.amp

Miscellaneous

RX1	40kHz ultrasonic transducer (receiver)
X1	crystal earpiece
SK1	3·5mm p.c.b. mounting jack socket
B1	9V battery, PP3 type – see text
S1	pushbutton switch – push-to-make, release-to-break

Printed circuit board available from the *EPE PCB Service*, code 436; ABS plastic case, size 80mm x 60mm x 40mm (external); single-core link wire; multistrand connecting wire; battery clip (PP3 type); solder pins (4 off); solder etc.

Approx. Cost Guidance Only **£12** ***excl. case & batt.***

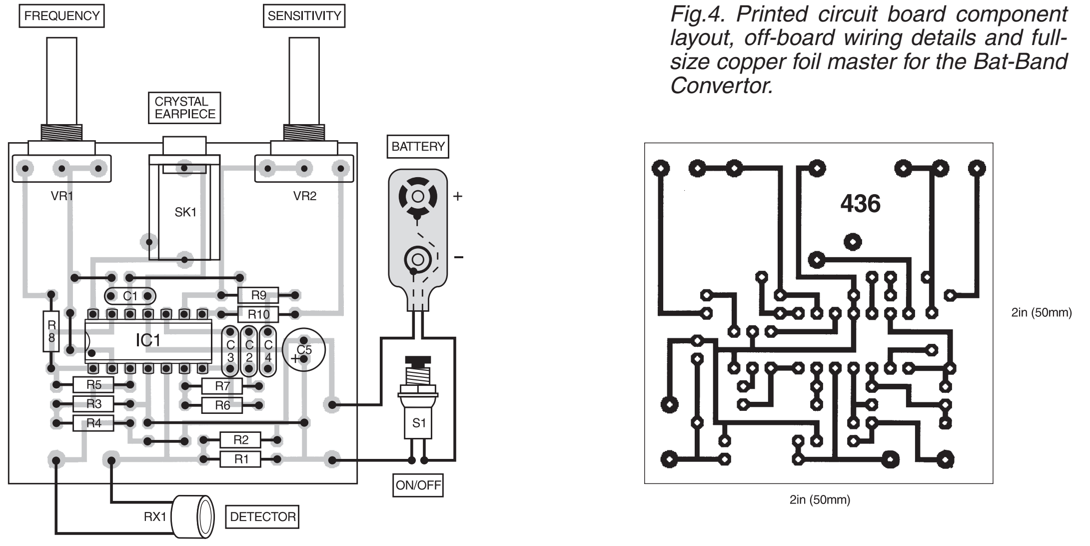


Fig.4. Printed circuit board component layout, off-board wiring details and full-size copper foil master for the Bat-Band Convertor.

CONSTRUCTION

The Bat-Band Convertor is a very sensitive circuit which operates at high frequencies, therefore it is recommended that all components be soldered *directly* to the printed circuit board (p.c.b.). The Convertor printed circuit board topside component layout, wiring and full-size underside copper foil master are shown in Fig.4. This board is available from the *EPE PCB Service*, code 436.

Begin construction by soldering the link wires and resistors in position. Insert four solder pins, if desired, for the off-board wiring to the battery and the ultrasonic transducer RX1. Position and solder the capacitors on the p.c.b. – noting the correct orientation of C5.

Next, insert and solder in position the 3·5mm jack socket for the crystal earpiece, and the two potentiometers.

Finally, solder IC1 directly on the p.c.b. Be quick with the iron, so as not to damage IC1 – at the same time, be sure to make reliable joints.

Depending on what should prove to be more convenient, solder the battery clip, on-off pushbutton S1, and the ultrasonic receiver transducer to the p.c.b. now, or once the p.c.b. has been mounted in its case.

BOXING-UP

The circuit board is mounted in a small ABS plastic case, which measures (externally) approximately 80mm × 60mm × 40mm. Drill holes in the case for the potentiometers and the jack socket as required, and insert and secure the p.c.b. in the case.

Drill additional holes for the on-off pushbutton switch and the ultrasonic transducer, and mount these also in the case. Then attach the battery to its clip. A little padding (non-conductive) may be used to hold the battery when the case is closed.

If it should happen that the circuit has been double-checked, yet still will not work, your first suspicion should be directed at the solder joints. Although these may seem to be sound, in a circuit as sensitive as this one, they may well not be. Re-solder the joints one by one until (hopefully) the circuit comes to life.

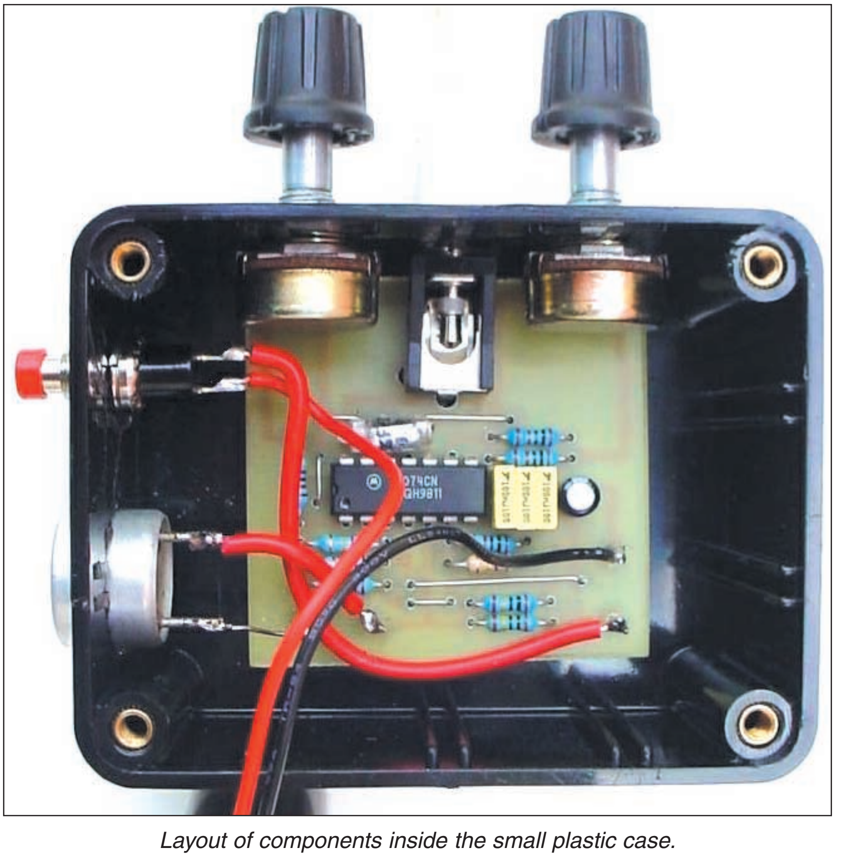
SET-UP AND USE

Sources of pure ultrasound are hard to find, although there are many sources of ultrasonic *noise* (e.g. paper tearing, hands rubbing together, keys jingling). A standard piezo sounder will respond well to such noise, as will the piezo tweeter mentioned earlier, while a 40kHz transducer will respond much better to pure frequencies.

One of the first things that the author discovered with a bat detector, many years ago, was that a cat will respond more keenly to "Puss!" than e.g. to "Marmalade!"for the reason that the "sss" in "Puss" creates a wide range of ultrasonic noise. This is the sound we shall use initially to test the Bat-Band Convertor.

Turn potentiometer VR1 fully clockwise (that is, to 180kHz), and turn sensitivity control VR2 fully back (anti-clockwise). Place the crystal earpiece in your ear, and switch on.

Now slowly turn up VR2 while gently saying "sssss" at about 10cm from the ultrasonic receiver transducer. A hiss will gradually become louder in the earpiece, until at a certain point clipping and severe distortion is likely to occur. Since this is random *noise*, it will not be as loud as a pure frequency might be (it will be louder if a piezo tweeter is used).

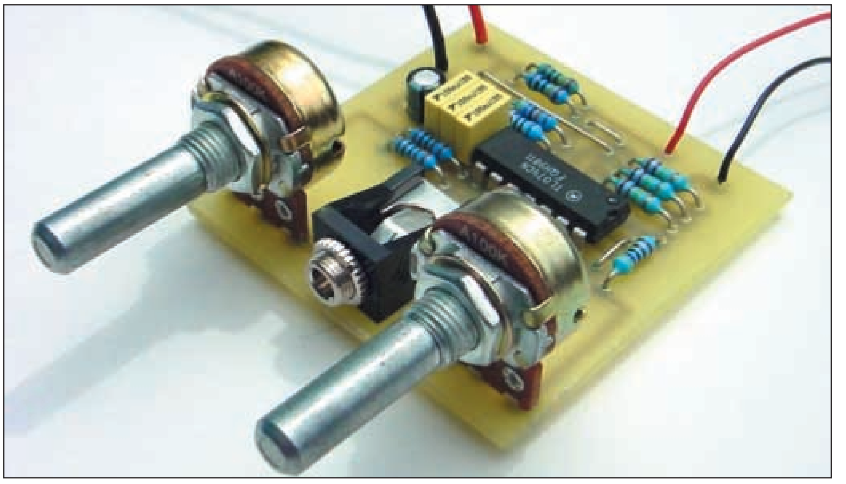


Layout of components inside the small plastic case.

As a further test, switch on your computer monitor or television set, and hold the Bat-Band Convertor near the rear of the enclosure. Turn up Sensitivity control VR2 to a suitable level (i.e. no clipping), then turn VR1 (Frequency) slowly through its entire range. You should pick up a number of pure ultrasonic frequencies.

It will be found that a pure frequency has a "null point", and that it will be heard at both sides of this point. When frequency adjustment VR1 is turned exactly to the null point (that is, silence), the Convertor is tuned exactly to the pure frequency.

When listening to bats, bear in mind that an ultrasonic transducer is highly directional, and there will be a large difference in reception depending on whether it is pointed directly at a bat or not (that is, there should be no more than about 15 degrees deviation from the source of the sound).



Completed Bat-Band Convertor circuit board.

IN CONCLUSION

A Bat-Band Convertor opens up a whole new world that is normally closed to us. Not only will it hear bats, but also many other creatures which emit ultrasound – in particular certain kinds of insect. In the author's surroundings, this includes some unusual creatures called cicada. These are so noisy they can be heard at 400 metres.

Apart from this, the Bat-Band Convertor will have a number of practical and scientific applications. It could be used as a puncture finder, since escaping air emits ultrasound. Likewise, it may be used to detect leaks in pipes. It may also be used to detect beetles or bumble-bees in wood.

It could also be used as a rough and ready "ear" for electronic experiments, or to determine the frequency response of ultrasonic transducers and piezo devices. If the frequency dial were calibrated, it could be used as a reasonably accurate frequency meter, with an accuracy better than 5%.

Finally, readers might recognise in this circuit both a v.l.f. (very low frequency) receiver and a complete digital voice transmitter.

In the case of the v.l.f. receiver, an aerial and earth are substituted for the ultrasonic transducer RX1, with a d.c. blocking capacitor being used with the aerial. A high pass filter would need to be inserted in the circuit to filter out mains interference in particular.

With regard to the digital voice transmitter, the reference oscillator would, in this case, modulate the voice for transmission.

The author was able to prove the idea, and digitally transmit and receive sound over a light beam, without any modification to the p.c.b. itself. A piezo sounder replaces the ultrasonic transducer, and a current amplifier may be added at the output to pulse an ultrabright l.e.d. A simple receiver may then feed an earpiece or headphones directly, without the need for any conversion of the received signal.

With a little further development, such a circuit should outperform similar analogue designs, since, being digital, it will transmit at full brightness all of the time. □