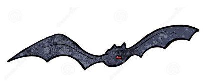
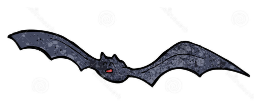


# A bat-snooping device



Jamie Davies, MM0JMI

As is well-known, most bat calls, and all bat sonar (“sound radar”) pulses occupy frequencies beyond the range of human hearing.  I often see bats hunting in the summer and occasionally hear a very high, mouse-like call from them: I wanted to hear more of their ultrasound world.

On the face of it, there are two ways of achieving this: (i) spectral compression, through which the entire sound spectrum from, say, 0-80kHz is compressed into the easily-audible range 0-10kHz, or (ii) transposition, in which a 10kHz-wide chunk of sound spectrum from anywhere of the user's choosing in the 10kHz – 80khz range is transposed down into the 0-10kHz range. The first method has the advantage that the entire relevant spectrum is surveyed at once, so any species of bat will be heard with no need for tuning. It has the disadvantage that it requires digitisation of the pulses followed by frequency division, and that would lose amplitude information. Getting amplitude information back would be possible, via a final amplifier controlled by the time-averaged amplitude of the ultrasonic input signal, but this would add quite a lot of complexity. The second method has the advantage that it is analogue-all-the-way, so more faithful. It has the disadvantage  that the user must tune the detector to the right frequency range for the bats in question, and that many species will make some sounds outside as well as inside the range even when the detector is properly tuned. Neither system will be faithful to harmonics of the bats' voices (the first because information about their amplitudes relative to the fundamental will be lost, the second because the harmonics will be out of the range of hearing).

On balance, I preferred the second approach, probably because I always feel willing to work with or around the vices of analogue systems whereas the vices of digital systems simply annoy me.

The block diagram of the bat-snooper (Fig 1, next page) is simple. A microphone adequate for ultrasonic use feeds its signal to a pre-amplifier, the gain of which is adjustable by the user. This amplified signal is fed into a multiplicative (non-linear) mixer, which is also fed by a local oscillator. The output of the mixer will contain the sum and difference of the frequencies of the input frequencies: a low-pass filter selects the signal at the difference frequency, which is then amplified and fed to a loudspeaker. The user is able to tune the local oscillator to anywhere within 10kHz of UK bat calls (about 30kHz – 80kHz).

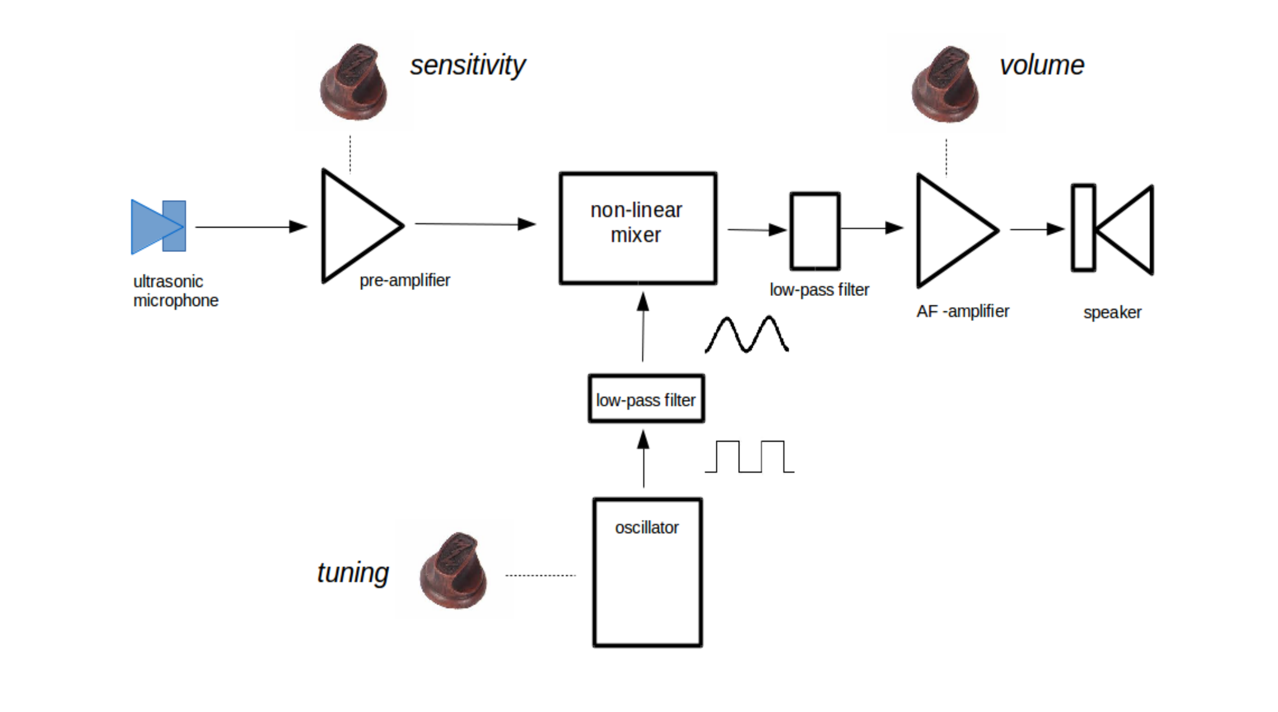


Fig 1: block diagram of the bat snooper.

**Detailed design**

As this unit was meant to be used outside, in the lanes near my house or on the canals on which I go boating, it was obviously going to be battery-powered. It contains nothing very power-hungry, so I used a PP9 9V battery as they are light-weight. All of the semiconductors I chose to use are happy at 5V and, like most home constructors, I always keep a stock of 5V regulators, so I chose to use a 7805 regulator in a completely standard way (Fig 2) to generate a 5V line voltage.

The choice of local oscillator came from a requirement to have something that could be tuned smoothly over a large range (about 30kHz to 90kHz; ie 1:3). My usual favourite sine wave oscillators (Colpitts, Hartley etc) have ranges that are much smaller unless a lot of component switching is used. The ubiquitous NE555 timer chip easily manages a 1:3 tuning range, and is cheap and reliable (again, there were plenty in the junk box). It is used in a completely standard way, the resistor network around pins 6 and 7 being designed to give the required frequency range. The output of an NE555 is a square wave – ie a wave containing the fundamental and all odd harmonics. For this reason, there is a simple low-pass filter, built around a 1nF capacitor, on the output. Some harmonic content will get through (though the signal did look reasonably sinusoidal on an oscilloscope) but this does not matter much: even when the fundamental is down at 30kHz, the harmonics will be from 90kHz and up – high enough that they will not cause an audible signal from the 30-40kHz bat voice to which the local oscillator is tuned. It is just about possible, though, that while the fundamental is being used to hear a bat at say 35kHz, another species at 80kHz will also be heard. Given how rare it is to have different species in the same place, I decided not to care about this.

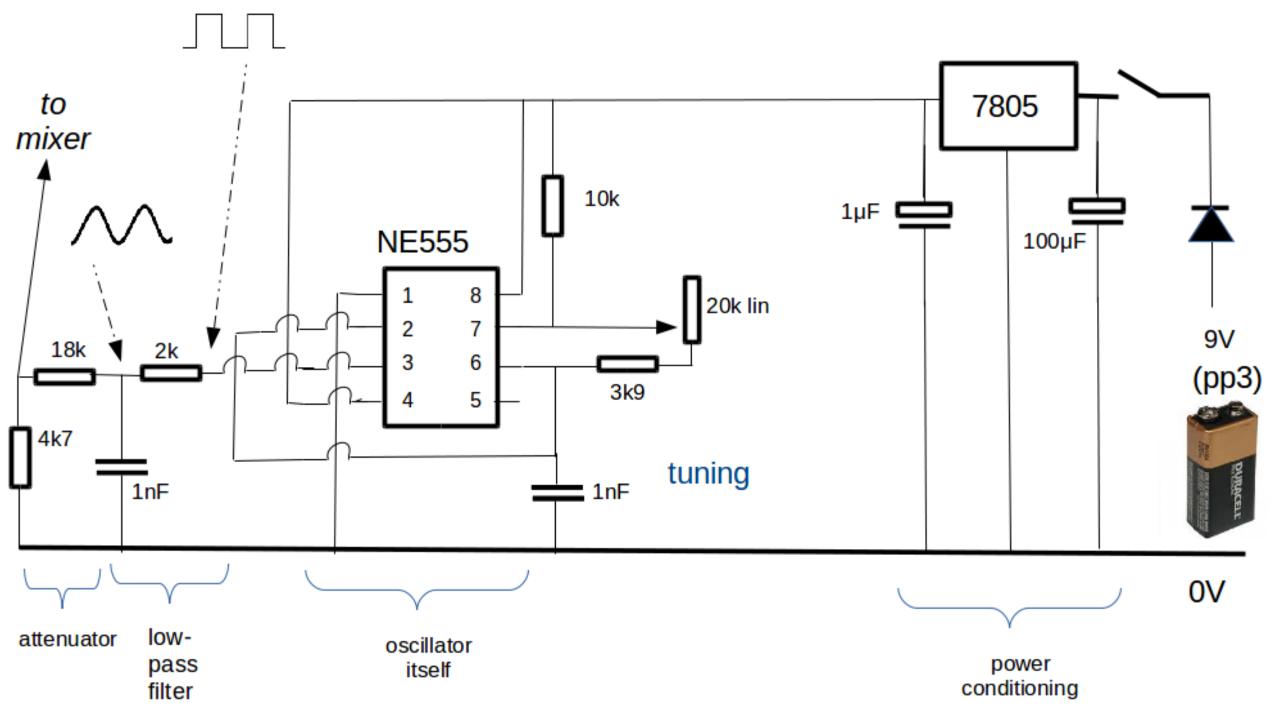



Fig 2: Power, and the local oscillator.

Leaving the local oscillator for a moment, let us turn to the main (bat's voice) signal path. For a microphone, I used the detector half of an ultrasonic transducer pair, Murata MA40S3R (the microphone) and MA40S3S (the speaker), supplied as a pair by *sinequanon-uk* who trade on ebay.co.uk. The units are sold for distance measurement in robot projects. I fed the output from the microphone into a very standard audio amplifier, the LM381-N1, again chosen because I have a bag of them bought cheaply as a job lot at ham fest some years ago. The first one, used as a preamplifier, is configured to have a fixed gain of 46dB (ie a voltage gain of x200) and uses a circuit straight from the data-sheet provided by the manufacturer (National Semiconductor).

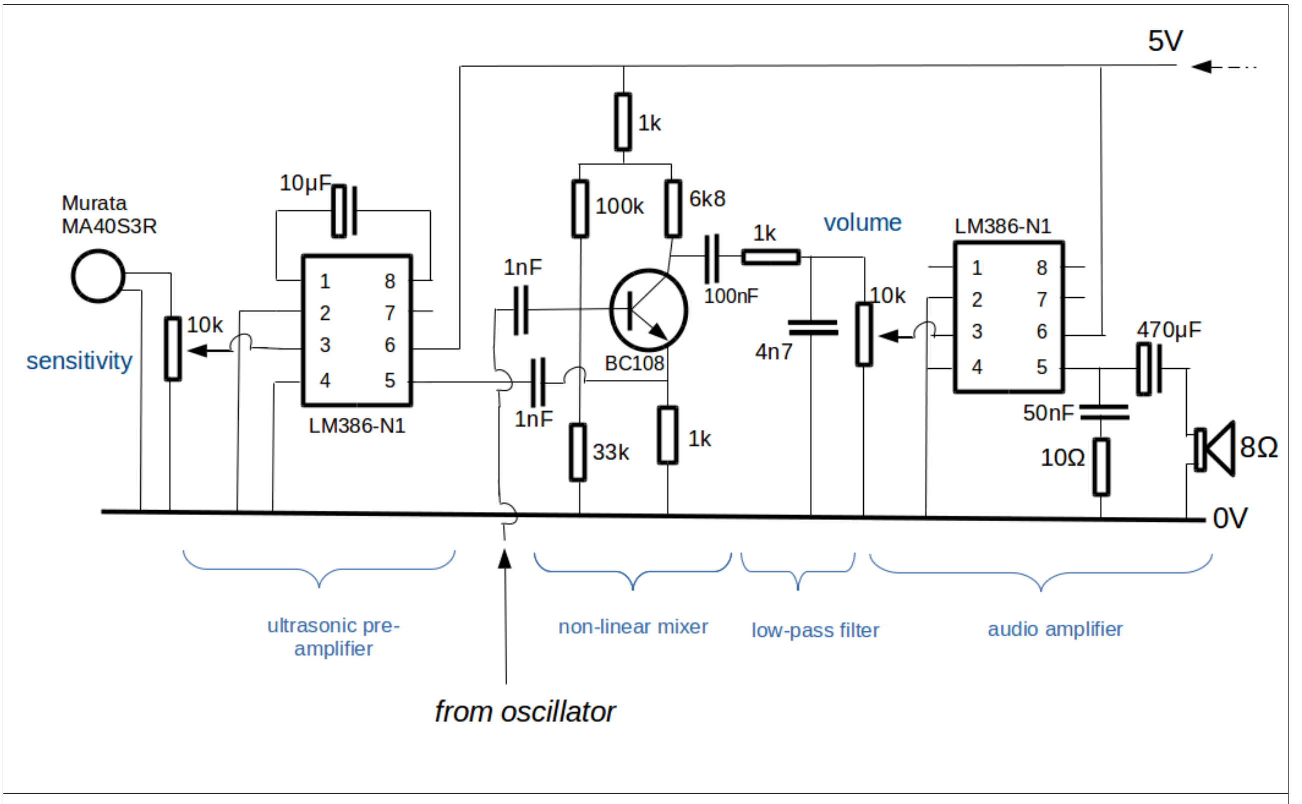



Fig 3: the main signal path.

The transistor in the centre of Fig 3 is configured as a non-linear (multiplicative) mixer. The bat's voice from the pre-amplifier is fed, via a 1nF decoupling capacitor, to the emitter, placing a signal directly on the main collector-emitter current flow. The signal from the local oscillator is applied, via a 1nF decoupling capacitor, to the base of the transistor so that the amount of current the transistor 'wants' to conduct is modulated by this signal. The total current flowing is therefore a function of the signal imposed on the emitter multiplied by the signal imposed on the base.

As I wrote in the accompanying article on the Termen-vox, trigonometric algebra includes an interesting result of multiplying the sines of two different angles together. In general terms,

$$\sin(A) \times \sin(B) = 0.5 \{ \cos(A-B) - \cos(A+B)\}$$

If we replace the simple angle terms A and B with terms more relevant to description of a wave, in which instantaneous amplitude is sin ($2\pi ft$), then we can rewrite the above in terms of two input frequencies $f_1$ and $f_2$;

$$\sin(2\pi f_1 t) \times \sin(2\pi f_2 t) = 0.5 \cos([2\pi f_1 - 2\pi f_2]t) - \cos([2\pi f_1 + 2\pi f_2]t)$$

In other words, **if we can arrange for a circuit to multiply the input waves of $f_1$ and $f_2$ , it will generate two new waves of frequencies $|(f_1-f_2)|$ and $(f_1+f_2)$**.

The output of the transistor (eg voltage at the collector) will therefore be a mixture of the sum and difference signals between the inputs. The difference signal (eg 35kHz bat – 32kHz local = 3 kHz human-audible) is the one we want. This is selected by another simple low-pass filter around a 4.7nF capacitor, and fed to another LM386-N1 configured as a variable gain amplifier. This feeds an 8 Ohm speaker.

**Construction**

I built the whole unit into an aluminium box, tough enough to be used outside. The circuits were assembled on some unetched, undrilled PCB material using Manhattan construction (in which the main PCB is used as ground and small 'pads' of PCB material are stuck down with superglue to carry other connections: Fig 4). I used standard pads from *qrpme.com* and some special IC-mounting pads that this supplier once sent me as a free sample with the standard ones I ordered. You could, of course, go to the trouble of designing, etching and drilling a conventional PCB but, while this form of construction lends itself to mass-production, I have never seen the point of going to all that trouble for a one-off project. You could also use Veroboard, but all that track cutting is time-consuming. Also, with both Veroboard and PCBs, you need access to both front and back of the board. Manhattan construction really is very much easier to do, and very, very much easier to alter/correct.

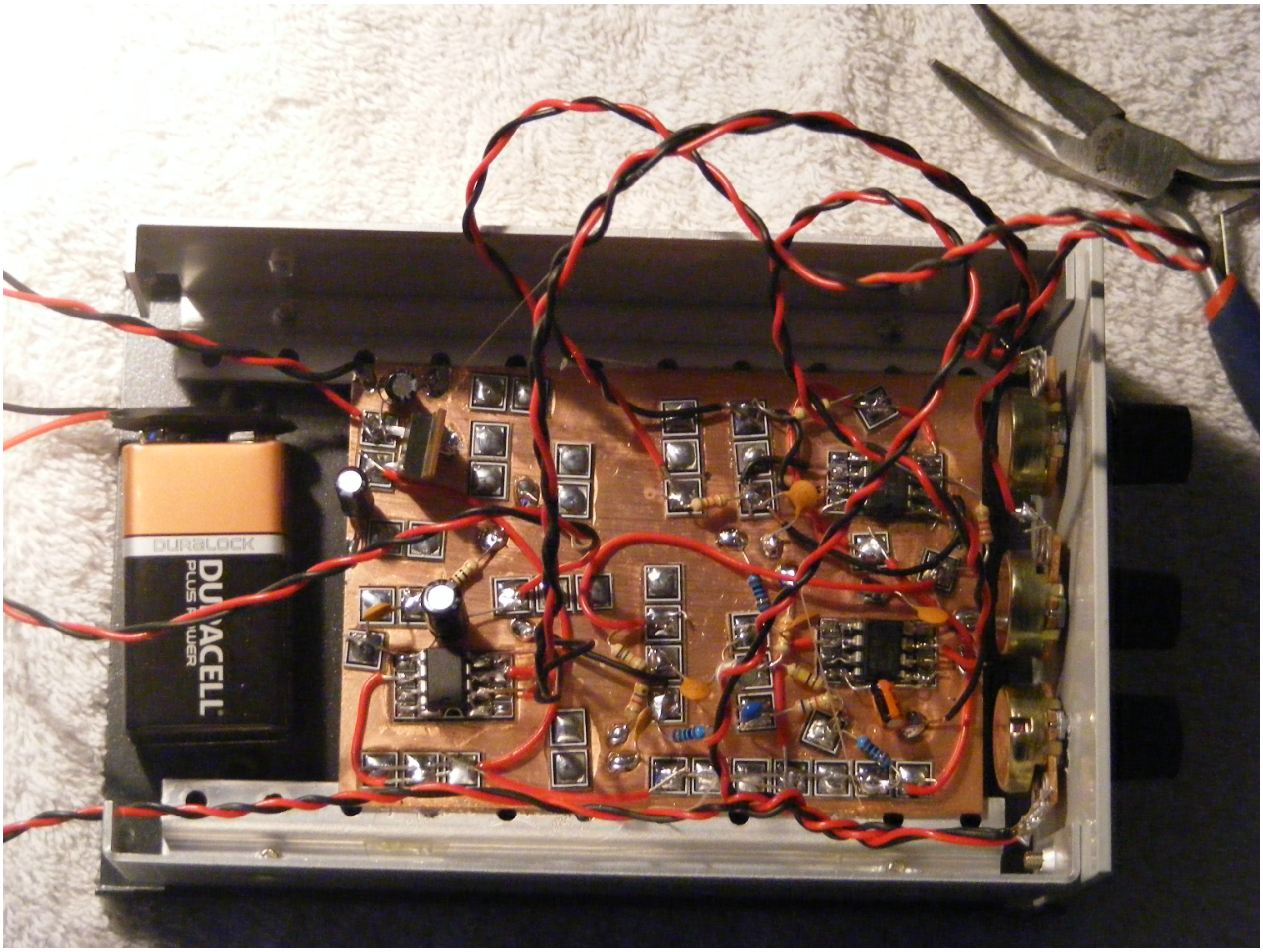



Fig 4: The completed unit with the cover off and before a plastic plate separating the battery from the rest of the unit was fitted. The three control knobs project through the right-hand-side, the microphone and on/off switch are in the metal plate at the other end (see wires going off to left) and the speaker is mounted in the lid (not shown).

**Testing.**

If you have a signal generator, you can set it to about 45 kHz and couple it directly across the spare MA40S3S ultrasonic transducer that came with the ultrasonic microphone and thereby create a fake bat (indoors please, and in the daytime – you do not want to upset real bats with loud noises). Set the volume controls to about half way, and the tuner to one extreme. If your circuit is working properly, as you turn the tuning knob you will be able to hear your fake bat as a descending then rising note, as you tune past its fundamental pitch. If you do not have a signal generator, you can make a 45kHz oscillator with another NE555.

If things are not working, first check the 5V is live, then check (oscilloscope) that the NE555 is putting out a square wave and that this appears as a sine(ish) wave on the emitter of Q1. Tune the

NE555 and watch the waves shorten and lengthen; do a sanity check on the frequency, either using the 'scope or a frequency meter. Next, check that your signal generator is working to make a fake bat – never take any piece of test equipment for granted! - and look for a *small* (10s to hundreds of microvolts) signal on the microphone outputs when the microphone is facing the fake bat. Assuming it is there, follow the signal into the preamplifier and out again. If all is well, set your oscilloscope to an AF frequency range and monitor the output of the mixer as you tune the local oscillator – you should get an AF signal. If you do but you still cannot hear it, check whether the AF signal emerges from the last LM386 – this will tell you if your problem is in the amplifier or the speaker itself.

For field tests, set the preamplifier to full gain and reduce this only if you need to (Pipistrelles in the lane outside my house are fairly quiet and keep at least ten feet away from me, so I leave the gain up. Daubenton bats ('water bats') are louder and fly very much closer to me, within mere inches if stand still, and they sound better if the preamplifier is turned down to about half-way.

**Things I might do differently if I made another one.**

1) I should have fitted a carrying strap.

2) More power on the output perhaps, or headphones. The unit performs perfectly at home, where the loudest night-time sounds on windless nights are the waves on a shingle beach about 2 miles away or the occasional rumble of freight trains on the East Coast Main Line about 7 miles away. You can hear rabbits sneezing across a field. When I took the unit down to the English canals, I quickly realized that the English Midlands are ridiculously noisy even at night, with a non-stop background roar of traffic, and planes criss-crossing overhead. I ended up having to hold the unit near my ear to hear the sounds coming from the speaker. I was aware of light-pollution down there, blotting out all but the brightest stars, but the idea of acoustic pollution blotting out the quiet sounds of the countryside had never really struck me the same way.

3) A retro-reflective stripe to find the thing when I put it down in the dark! (This was easy to apply post-hoc: I cut out a strip from a Halfords plastic cycle 'clip' (the kind that uses velcro).

4) An audio-out jack for recording (in parallel with the speaker would be fine).