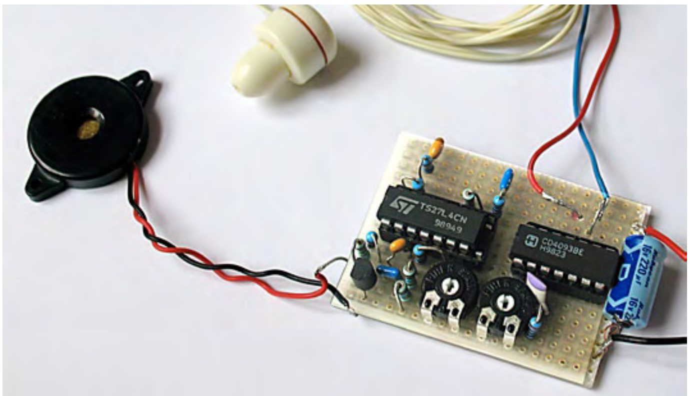
Christmas Holidays Circuits

Nicely timed for the Festive Season we present a compilation of circuits that make excellent workbench projects for the odd 'learn-while-U-tinker' hours you should be able to claim for yourself this December. Most of the parts used in the project we reckon may be in your junkbox or hidden in a cupboard or in a box in the attic or cellar. Good instructive stuff for the Christmas holidays period. Have fun!

Bat detector

By Thomas Scarborough (South Africa)



Bats are truly amazing creatures. Even in pitch-darkness they can still sense their surroundings by first producing a sound burst that's inaudible for humans and then listening to the reflections – a technique humans have mastered only relatively recently using electronic equipment called radar. The bat's brain then forms a picture detailed enough to recognise any form of potential food. To gain a little insight into the life of a bat the author has developed a bat detector. It almost seems as if the bats thought being a flying mammal wasn't enough to make them stand out. Their ability to 'see' with their ears works so accurately that it allows them to find their way in the dark of night and hunt for the tiniest of mosquitoes. As David Attenborough would say: stunning!

As already mentioned we can't hear the sounds produced by bats, since the frequency lies far above the upper limit for humans. A bat creates clicking sounds (burst) with a frequency between 12 and 150 kHz, in rapid succession with a rate between 20 to 100 times a second. The exact parameters depend on the species.

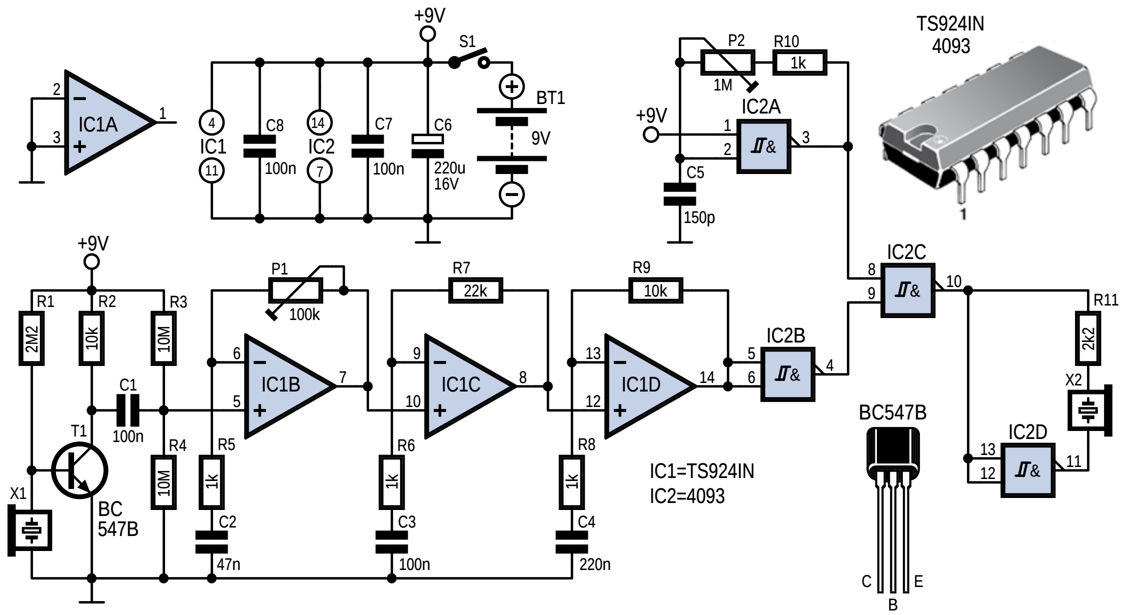
To convert these clicking sounds into something audible, you'll need a bat detector. In contrast to other designs, the project straightforward and compact; nevertheless it works perfectly.

When Thomas tested his detector for the first time, he was startled by the sheer volume these animals produce. It almost seems as if the bats were screaming their lungs out!

Regardless of volume, this circuit itself can handle the full bat sound spectrum. The only limiting factor is the microphone, for which Thomas 'misused' a so-called 'piezo-conetweeter'; a piezoelectric high-tone loudspeaker with a cone shaped membrane (as shown in the picture). A similar loudspeaker can pick up sound waves with frequencies up to 50 kHz, which is adequate to detect most species of bats.

You could also experiment with a common piezo buzzer (as shown in the picture of the pre-built prototype) or with a piezo-horn tweeter. It worked for Thomas, so it should be worth a try.

Two methods exist to convert the ultrasonic bat sounds to something audible. The first simply compresses the ultrasonic sound spectrum between 20 and 100 kHz to an audible range (for exam-



ple, covering 2 to 10 kHz). In other words, it maps all the high frequencies to a range which is audible to humans.
A less complicated method — from a technical point of view — in the present design relies on the interference patterns which appear after mixing a frequency generated by an oscillator with the frequencies emitted by the bats. The resulting signal is composed of frequencies of both the sum and difference of the two input waves, like in superheterodyne receivers. So let's assume we pick up a constant tone of, for example, 40 kHz while the oscillator is set to 35 kHz. The mixer output signal will be composed of two frequencies: 5 kHz (the difference) and 75 kHz (the sum). The latter one is still inaudible, since it's outside our hearing range, but we'll hear the 5 kHz note without any problem. Using this approach, it's essential to set the oscillator to a fixed value which produces audible sounds after the mixer.

The circuit

Now for a more detailed approach. First, the bat cries picked up by microphone X1 (or, in our case, the piezoelectric tweeter), get substantially amplified by three opamps, IC1B, IC1C and IC1D. The circuit gain is controlled by preset P1 acting as a potential divider.
The three opamps are all housed in the same IC, the type TS924IN to be precise. This chip contains a total of four opamps. Since the fourth opamp (IC1A) remains unused in this circuit, its two inputs are connected to ground to ensure the component stays inactive.
After the amplification process, the signal gets fed through NAND gate IC2B, where it essentially gets NANDed with itself, the upshot being that it's turned into a neat square wave. Next, the signal is mixed in NAND gate IC2C with the adjustable frequency generated by oscillator IC2A and its surrounding components. The NAND function of this gate causes the difference of the two frequencies to appear on the output, which is then fed to the earpiece (X2). Hopefully, this process has produced a frequency within the audible range.
The remaining gate of the CMOS IC 4093B, IC2D (which, again, contains four separate gates) is used for a nifty technical trick. The gate is used to invert the signal at the other side of the earpiece. This trick essentially doubles the sound volume, because it makes the membrane in the earpiece move both inward and outward relative to its quiescent state. Without this trick, the membrane would only move in one direction; either constantly to the inside, or constantly to the outside, depending on the polarity of the earpiece.
The use of an earpiece like the one in the picture is highly recommended. The superheterodyne principle on which the circuit is based is quite sensitive to acoustic feedback between the microphone (X1) and loudspeaker (X2), which could cause a characteristic screech in the sound. This sensitivity is mitigated by placing the sound source straight in to the ear (hence the name earpiece). Another way of reducing the feedback issue, is to increase R11 (which is used for current limitation) to 1 megohm or to place the microphone X1 in a cylinder (a piece of PVC tubing for example). The latter solution even makes a kind of directional microphone!

Calibration and practical use

The calibration doesn't necessarily require a bat as a test subject. Your own voice creates inaudible high frequencies (which can be

Bat ‘transmit’ frequencies	
Greater horseshoe bat	83 kHz
Lesser horseshoe bat	95–125 kHz
Whiskered bat	30–80 kHz
Natterer’s bat	30–80 kHz
Dauberton‘s Bat	30–80 kHz
Greater mouse-eared bat	30–70 kHz
Bechstein‘s Bat	30–80 kHz
Common Pipistrelle	40–45 kHz
Serotine bat	25–80 kHz
Common Noctule	15–50 kHz
Barbastelle	30–70 kHz
Brown long-eared bat	15–50 kHz
Grey long-eared bat	15–50 kHz

heard by cats) whenever you produce a ‘ssssssh’ (like in the word ‘shell’) or a ‘psssst sound. The higher harmonics which are then produced can be used for the calibration of the circuit when in a quiet environment. Even snapping your fingers or rubbing dry hands together produce ultrasonic waves!

Connect the power supply, keeping in mind that the circuit requires approximately 10 mA, which can easily be supplied by a 9 volt battery. Then insert the earplug in your ear. Make sure P1 and P2 are set at maximum resistance, so both the volume and oscillator frequency are at their lowest. Now keep turning the sensitivity potentiometer P1 until the higher harmonics (which can be produced as indicated above) can be heard clearly. This allows the bat detector to be calibrated with relative ease. Anyone who wants to go the extra mile can fine tune the circuit by holding it close to an old cathode ray tube TV. Parking radars on cars are also known to produce ultrasonic sounds.

Now the hunt for bats can begin! But please bear in mind that bats aren’t the only creatures to emit ultrasonic sound bursts in nature. A wide variety of animals like birds or crickets also produce ultrasound waves. To make sure you’re really hearing a bat, you need to point the microphone at a flying bat. You should then hear a rattling or clicking noise. If the results are poor, potentiometer P2 might need some adjusting.

It should be noted that bats are protected animals in most countries, so never disturb them in their natural course of action!

One last tip: the detector described here can be used to listen to many other sources of ultrasonic sound. For example, it can aid fixing a bicycle tyre by locating the leak! Gas escaping through a narrow exit also produces ultrasonic sound.

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