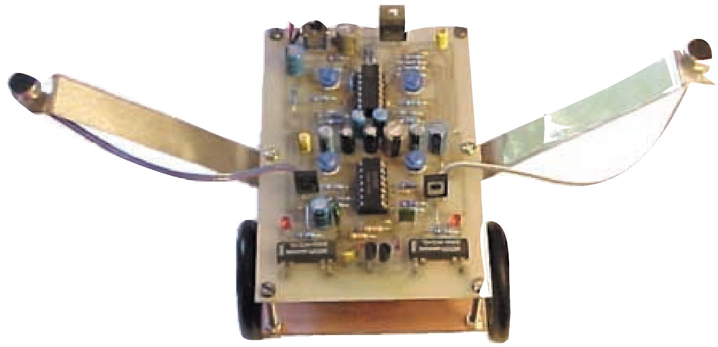
Constructional Project

BIG-EARS BUGGY



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Clap your hands, "hear" comes Big-Ears! Our sound-activated mobile "pet" (buggy) will give hours of fun.

SOUND travels in waves as it moves through the air at a speed of roughly one-third of a kilometre per second. Sound also has *direction*, so that a sound wave will strike one ear one three-thousandth of a second before it strikes the other – assuming, that is, that one is standing sideways to the sound source.

By electronic standards, this is very slow. Considering that many op.amps will detect differences of just millionths of a second, a simple electronic circuit will easily pick this up. Even if two electronic "ears" are mounted relatively close to each other (say two or three centimetres apart), a modern integrated circuit will readily detect that a sound passed one "ear" before the other.

The circuit described here takes advantage of these basic characteristics of sound, triggering a switch when one "ear" hears a sound before the other – and vice versa. This is specifically applied to the small mobile robot, which we have called the Big-Ears Buggy. This is capable of responding to sound from three directions, and of driving up to the source.

APPLICATIONS

Although the "Big-Ears" Buggy is the application described here in detail, the circuit is potentially very diverse in application. Through the use of the two relays provided (RLA and RLB), there are many interesting possibilities – among them the following:

Since it is a very human trait to be able to respond to the direction of sound, the circuit may be used to seemingly imbue objects with human characteristics. For instance, two small motors wired to a pulley arrangement behind a painting of Great-Grandad would make his eyes move in your direction when you speak. Similarly, an advertising board could move to face talking shoppers, or a head could turn in people's direction.

It could be used as a novel audio "snap" indicator, or as an audio "Who was first?" indicator, finally settling any arguments as to who spoke first!

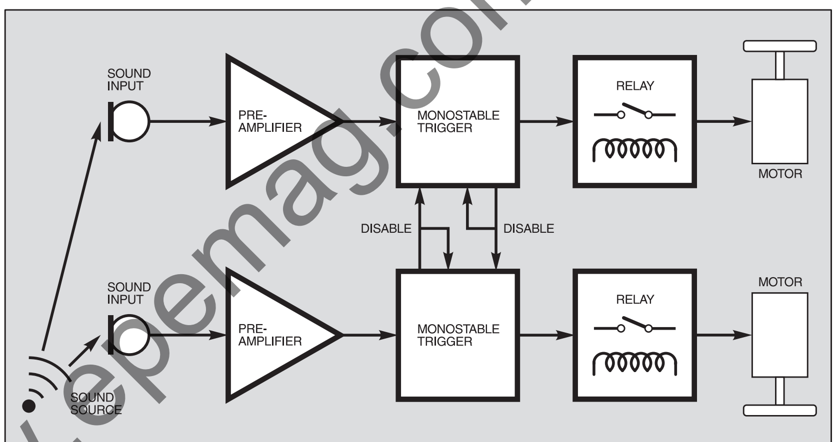


Fig.1. Basic block diagram for Big-Ears Buggy

It could also serve as an aid for the deaf, giving a visual indication that a sound is coming from a particular direction.

CIRCUIT DETAILS

The Big-Ears Buggy circuit itself is remarkably simple in concept, and is shown in block schematic form in Fig.1 and the full circuit diagram shown in Fig.2. At the heart of the circuit are two monostable timers. The first one to receive a sound input disables the other (as well as its own trigger input) so that only the relay which is closest to the sound source is activated.

Two inverting amplifiers, IC1a and IC1b, feed two non-inverting amplifiers (IC1c and IC1d), and two variable presets (VR1 and VR2) control gain. These preamplifiers directly clock monostable timers IC2a and IC2b. There are no coupling capacitors at the outputs, and this improves the ability of the preamplifiers to clock monostable timers IC2a and IC2b directly.

A TL074CN quad preamplifier is chosen here particularly for its fast slew rate – the slew rate determining the voltage rate-of-change as a function of time. A good slew rate is important, since the circuit needs to respond rapidly to any sound waves received.

An NE556N dual monostable timer, IC2, is chosen for its ability to trigger when pin 6 or pin 8 goes "low" (logic 0), while ignoring any voltages above one-third of supply voltage. This is in contrast with many logic devices, which enter a state of uncertainty between one-third and two-thirds of supply voltage, and would be less suitable here.

The maximum timing periods of IC2a and IC2b may be altered by swapping capacitors C15 and C16 for higher or lower values – higher values for longer timing periods, and vice versa. The component combinations of preset VR3, R20, C15 and VR4, R21, C16 allows the time periods, for which monostable timers IC2a and IC2b trigger, to be adjusted. A short time delay is provided, via the combination of capacitor C12 and resistor R17, at switch-on through reset pins 4 and 10, so that switching on does not activate the buggy.

Monostable timers IC2a and IC2b control the duration for which relays RLA and RLB are activated on reception of a sound signal. The on times of the monostable timers may be set between about 0·02 and 1·1 seconds.

The timing periods are calculated as $t = 1{\cdot}1 \times C15 \times (VR3 + R20)$ and $t = 1{\cdot}1 \times C16 \times (VR4 + R21)$. The outputs at pins 5 and 9 provide current for switching transistors TR3 and TR4, and in turn the relays.

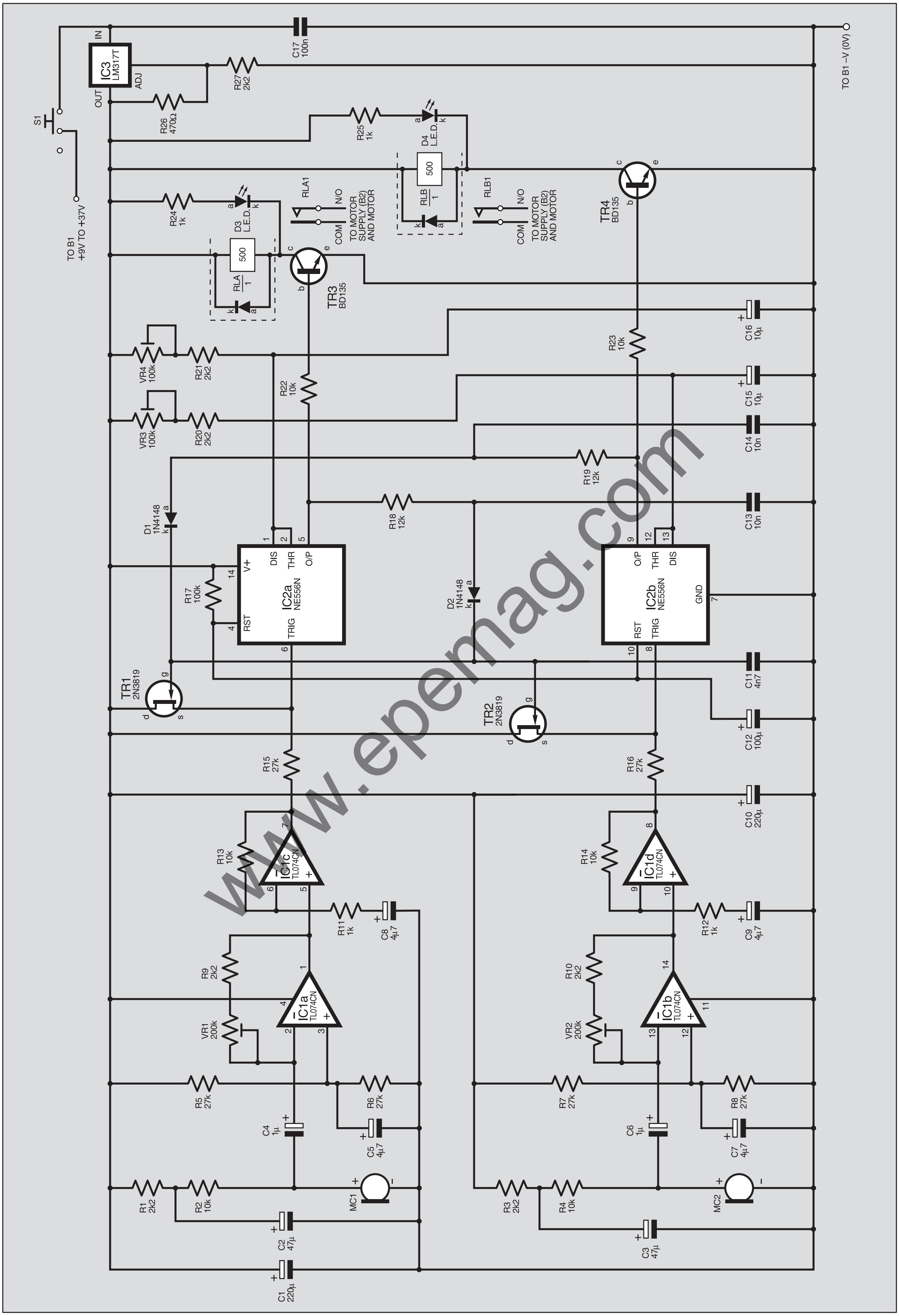


Fig.2. Complete circuit diagram for Big-Ears Buggy. Note that the motors (not shown here) are powered by a separate battery (B2).

Depending on the application for which the circuit is used, presets VR3 and VR4 are adjusted to give the required on times for the two relays – for example, to activate a pulley, or to turn on the motors for Big-Ears.

Depending on the motors used, and whether these will be running independently of one another or not (see cross-head Mechanical Assembly), VR3 and VR4 are adjusted accordingly. You might wish to make Big-Ears take long, trundling turns towards the sound source, or, on the other hand, short sharp turns. This hinges on the adjustment of monostable timers IC2a and IC2b – and, of course, on the speed of the motors, and the way they are wired up.

The most distinctive aspect of the design is the use of f.e.t.s TR1 and TR2. These disable the trigger inputs of both monostable timers when a sound wave is received, which they do by taking these inputs "high". Resistors R15 and R16 form potential dividers with the two f.e.t.s to make such switching possible. This happens so quickly that a sound wave striking one "ear" transducer will find the other "ear" already "deaf" by the time it reaches it. The circuit takes advantage here of the speed of electrical conduction (very fast) versus the speed of sound (slow).

INNOVATIONS

Transistors TR1 and TR2 are put to further use. The gain of the preamplifiers is relatively high. Due to audio feedback from the motors it would ordinarily be impossible to combine them with all but the bluntest of amplifiers.

However, a simple device is used to blank out the noise of the motors – in the form of capacitor C11. This is charged through diodes D1 and D2, and continues to hold the trigger inputs of IC2a and IC2b high through TR1 and TR2, until the motors stop turning.

In effect, the buggy "pricks up its ears" only when it has come to rest. If a motor takes longer to stop, the value of capacitor C11 may be increased to offer a longer period of blanking.

Capacitors C13 and C14 cause a very brief delay in the Big-Ears "hearing", so that both IC2a and IC2b are triggered at the same time (both motors turn) when a sound comes from directly ahead or behind. Thus, instead of responding only to two directions of sound, the buggy now responds to three. Capacitors C13 and C14 may be removed if a response to two directions only is required. Resistors R18 and R19 may be increased to widen the arc of frontal hearing, and vice versa.

The outputs of monostable timers IC2a and IC2b are used to switch l.e.d.s D3 and D4, as well as two reed relays (RLA and RLB), which may be used to switch a wide range of devices. These relays include integral diodes as protection against back-e.m.f.

Note that the specified reed relays have a maximum switched current of 1A, and a maximum switched power of 15W, up to 200V. Their operating voltage lies between 3·7V and 10V. Select other relays if higher ratings are required.

The benefit of voltage regulator IC3 is that the circuit may be used in conjunction with devices which have different power requirements. The regulator is set to just over 7V, so that the circuit may be used with any d.c. supply between 9V and 37V. The formula for calculating the output voltage of the regulator is $V_{OUT} = 1{\cdot}25 (1+R27/R26)$ volts. It is, however, best if the motors are supplied from a separate supply to avoid interaction and noise affecting the circuit.

CONSTRUCTION

Big-Ears Buggy is built up on a single-sided printed circuit board (p.c.b.) measuring 110mm × 75mm. This board is available from the *EPE PCB Service,* code 362. Details of the topside component layout, together with the full-size underside copper foil master pattern, are shown in Fig.3.

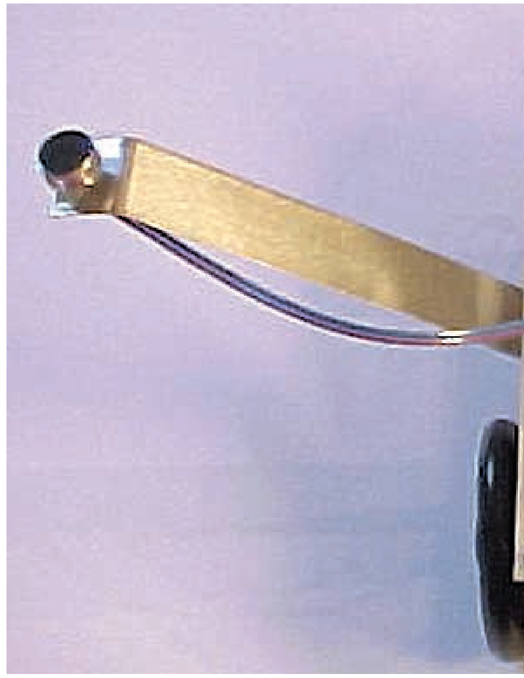
Begin construction by soldering in position the twelve link-wires. Continue with the lead-off solder pins and the two dual-in-line (d.i.l.) sockets.

Next, solder in place the slider switch S1, resistors, l.e.d.s, d.i.l. relays, capacitors, diodes, transistors, regulator IC3 and battery clip.

Field effect transistors TR1 and TR2 should be soldered with care, since these are more sensitive devices. So also are the electret microphones, which each contain an internal f.e.t. Finally, insert IC1 and IC2 in their d.i.l. sockets.

In the prototype, the electret microphone inserts were mounted on arms (ears), about 15cm from each other. This helps the buggy to distinguish sound waves better, and makes the adjustment of presets VR1 and VR2 less critical.

However, the microphones may be mounted as close as 3cm from each other with more delicate adjustment of the



Completed prototype Big-Ears Buggy showing the electret microphone inserts mounted on two aluminium "ears", about 22cm apart from each other.

COMPONENTS

Approx. Cost Guidance Only **£20** *excluding extras & batt*

Resistors

R1, R3, R9, R10, R20, R21, R27	2k2 (7 off)
R2, R4, R13, R14, R22, R23	10k (6 off)
R5 to R8, R15, R16	27k (6 off)
R11, R12, R24, R25	1k (4 off)
R17	100k
R18, R19	12k (2 off)
R26	470Ω
R28	2M2 (see text)

All ¼W 5% carbon film

See SHOP TALK page

Potentiometers

VR1, VR2	200k single-turn cermet preset, horiz. (2 off)
VR3, VR4	100k single-turn cermet preset, horiz. (2 off)

Capacitors

C1, C10	220µ radial elect. 50V (2 off)
C2, C3	47µ radial elect. 50V (2 off)
C4, C6	1µ radial elect. 50V (2 off)
C5, C7 to C9	4µ7 radial elect. 50V (4 off)
C11	4n7 ceramic
C12	100µ radial elect. 50V
C13, C14	10n polyester (2 off)
C15, C16	10µ radial elect. 50V (2 off)
C17	100n polyester
C18	470n polyester or ceramic (see text)

Semiconductors

D1, D2	1N4148 signal diode (2 off)
D3, D4	3mm l.e.d. (desired colours) (2 off)
TR1, TR2	2N3819 j.f.e.t. transistor (2 off)
TR3, TR4	BD135 *npn* transistor (2 off)
TR5	BUZ11 MOSFET (see text)
IC1	TL074CN quad j.f.e.t. op.amp
IC2	NE556N dual timer
IC3	LM317T 1·5A variable voltage regulator

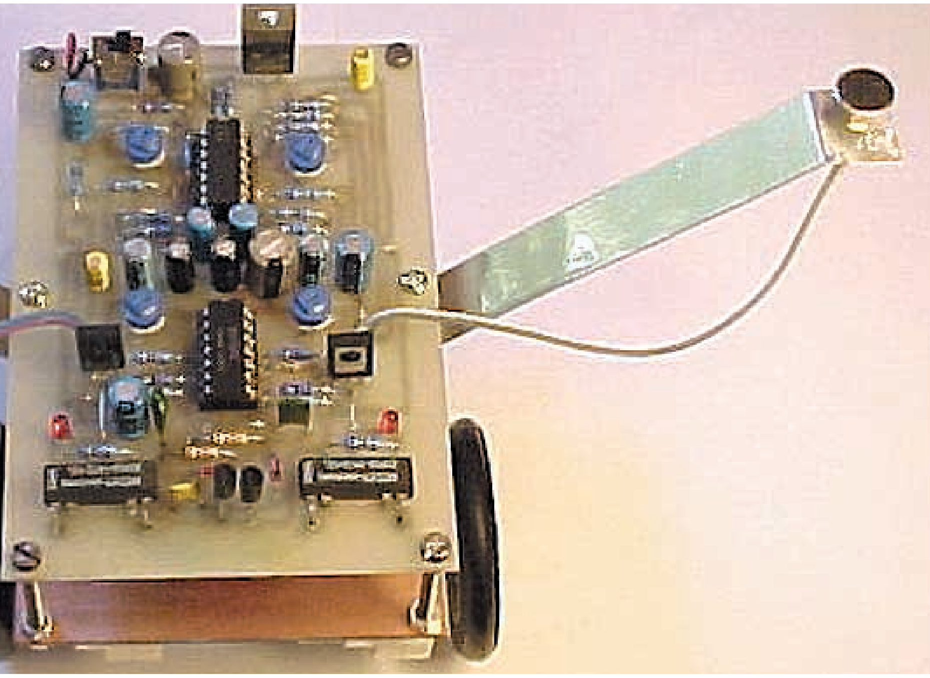
Miscellaneous

MIC1, MIC2	min. electret microphone insert (2 off)
RLA, RLB	s.p.n.o. reed type d.i.l. relay (2 off)
RLC, RLD	double-pole changeover relay – see text (2 off)
S1	s.p.d.t. ultra-min slider switch
S2	lever-operated microswitch (see text)

Printed circuit board available from the *EPE PCB Service*, code 362; 14-pin d.i.l. socket (2 off); link wire; multistrand connecting wire; 9V PP3 type battery (or desired d.c. voltage supply), with connecting clips (2 off); solder pins; solder etc.

EXTRAS

Solar motor, with gears (2 off – see text); large wheel (2 off); small rear wheel; baseboard, size 110mm x 75mm; resistors RX and RY (33Ω 5W and 22Ω 5W – see text); aluminium strips for microphone insert (ears) – 2 off; epoxy glue; M2·5 nuts and bolts etc.



presets, in which case the values of resistors R18 and R19 will also need to be reduced to readjust the arc of frontal "hearing" (try 6k8 for 5cm).

Be careful to observe the correct polarity of the electrolytic capacitors (these have various orientations on the board), and the correct orientation of the transistors, diodes, i.c.s, and the specified d.i.l. relays. The cathodes (k) of the l.e.d.s (D3, D4) will have a flat side on their plastic encapsulation. The negative terminals of the electret microphones are connected to their case.

SETTING UP

Begin testing of the completed p.c.b. by turning back (anti-clockwise) presets VR1 to VR4. Then turn them all up (clockwise) by about a quarter. Presets VR1 and VR2 adjust the buggy's sensitivity to sound, while VR3 and VR4 adjust the periods of time for which monostable timers IC2a and IC2b will trigger.

Attach a battery or d.c. power supply between 9V and 37V to the battery clip,

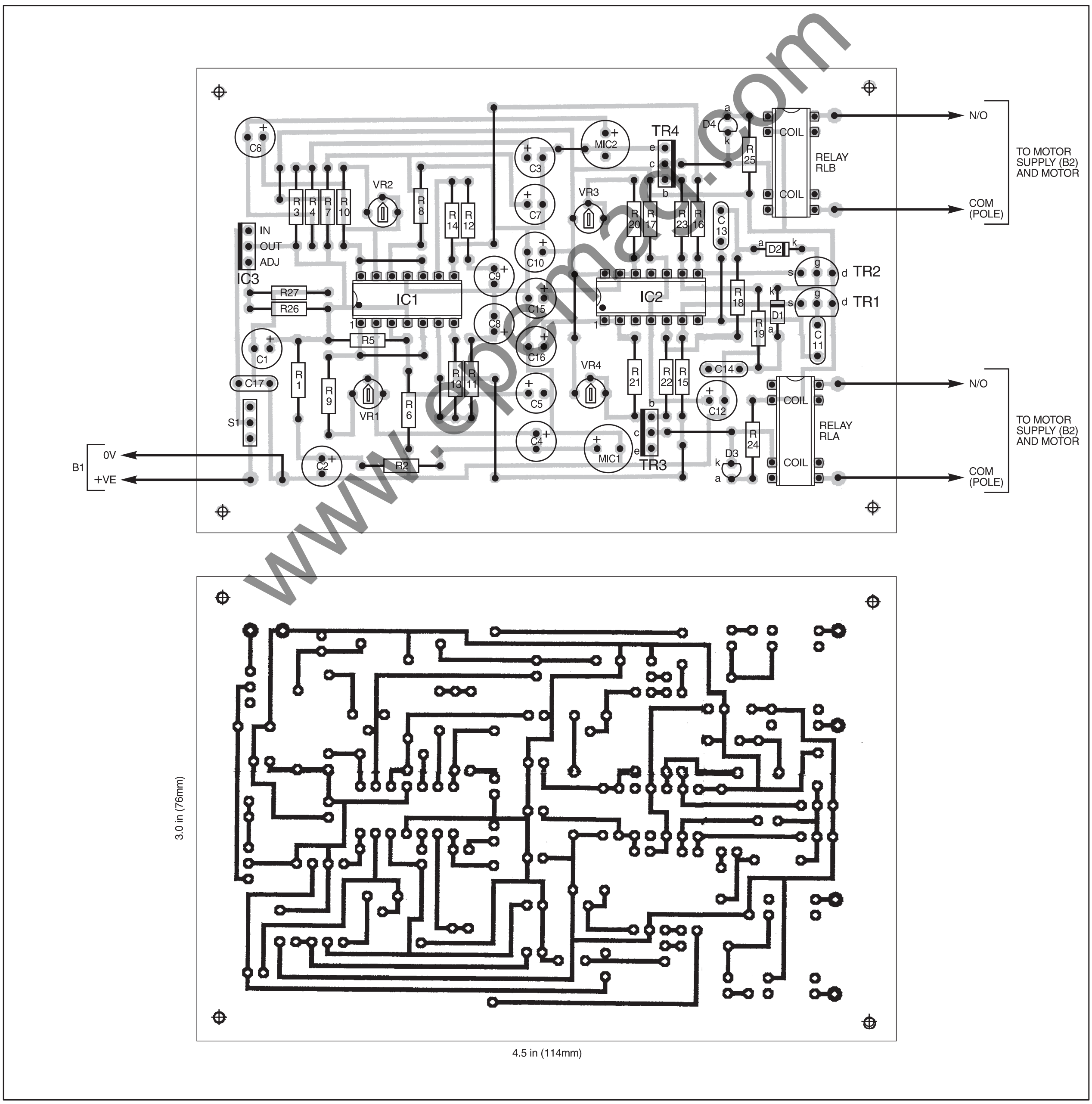
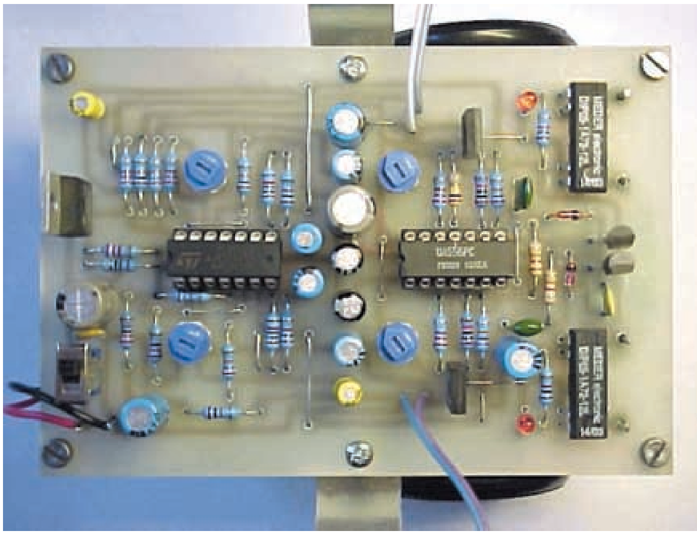


Fig.3. Big-Ears Buggy printed circuit board component layout and full-size underside copper foil master pattern.



Above: Component layout on the completed printed circuit board.

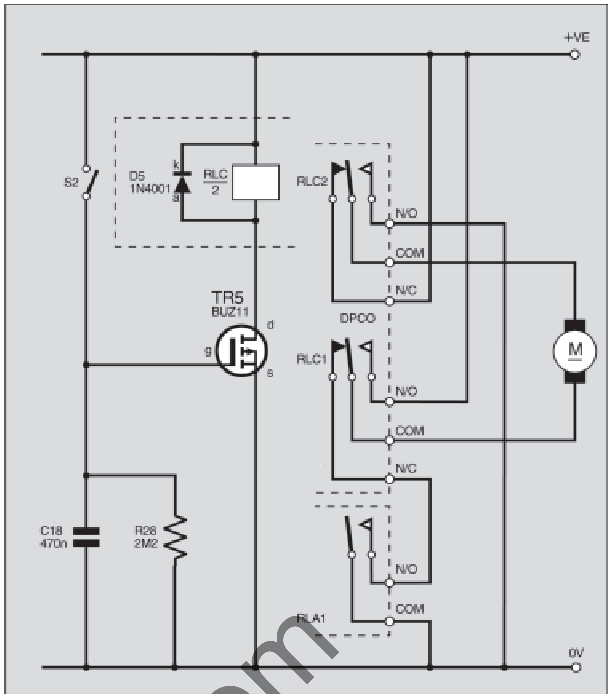


Fig.5. Circuit modifications for adding a simple "bump-and-reverse" feature. This is for one motor, a second relay (RLD), wired in parallel with RLC, will be needed for the other motor.

observing the correct polarity. Switch on the buggy circuit board by means of slider switch S1.

Now stand to one side of the p.c.b. (in line with the two microphones), and clap. The l.e.d. at the near side of the circuit board should illuminate, and the corresponding reed relay briefly close. Stand at the other side of the p.c.b., and clap again. Again, the l.e.d. at the near side of the circuit board should illuminate, and the corresponding reed relay close.

Clapping directly in front or behind should cause *both* diodes to illuminate and both relays to activate. If they do not, the value of resistors R18 and R19 needs to be increased. If both l.e.d.s always illuminate, the value of these resistors needs to be reduced.

Presets VR1 and VR2 may be used to even out any imbalance between the sensitivities of the preamplifiers. These need to be fairly carefully balanced, so that IC1a and IC1b do not respond to different sound waves of different amplitudes. If the buggy tends to respond too much to sound from one side, increase the gain of the opposite side, or vice versa.

MECHANICAL ASSEMBLY

Now we have completed the p.c.b. and tested it, we need to mount the board on a suitable "chassis" or baseboard. A general guide of the mechanical assembly can be seen in the accompanying photographs.

Two d.c. motors (with wheels) are mounted on a baseboard of equal size to the p.c.b. The baseboard is bolted to the p.c.b. with through-bolts at the four corners. Solar motors would be best suited here, since they do not stall as easily as other d.c. motors when slowed.

The two motors must be mounted in parallel with through-axles (not at 180 degrees, or there may be differences in torque), and are wired to each of the reed relays in such a way that the relays switch them on and off. A third wheel (which must be able to swivel as it trails the buggy) is mounted at the back. It is important that this wheel should touch the ground at a position that is central to the two wheels which are attached to the motors (see photo). If this wheel is not central, the buggy is likely to "list" to one side.

Instead of switching the two motors alternately when sound is received from the right or left, one motor may merely be *slowed* while the other is at full power. The wiring arrangement shown in Fig.4 may be used, whereby both motors will turn when a sound is detected from the right or left, but one will turn more slowly than the other through series resistor RX (if using solar motors, try about 33 ohms 5W to begin).

A series resistor RY (try 22 ohms 5W) may be inserted in a power line to prevent overload of the motors. If there are imbalances in the torque of the motors, a resistor together with series diode (e.g. the 1N4001 – orientated as required), may be wired in parallel with RX (more current now passes in one direction). Also test what effect presets VR3 and VR4 have on steering.

All in all, a fair bit of tweaking and experimenting may be required to get Big-Ears to operate smoothly.

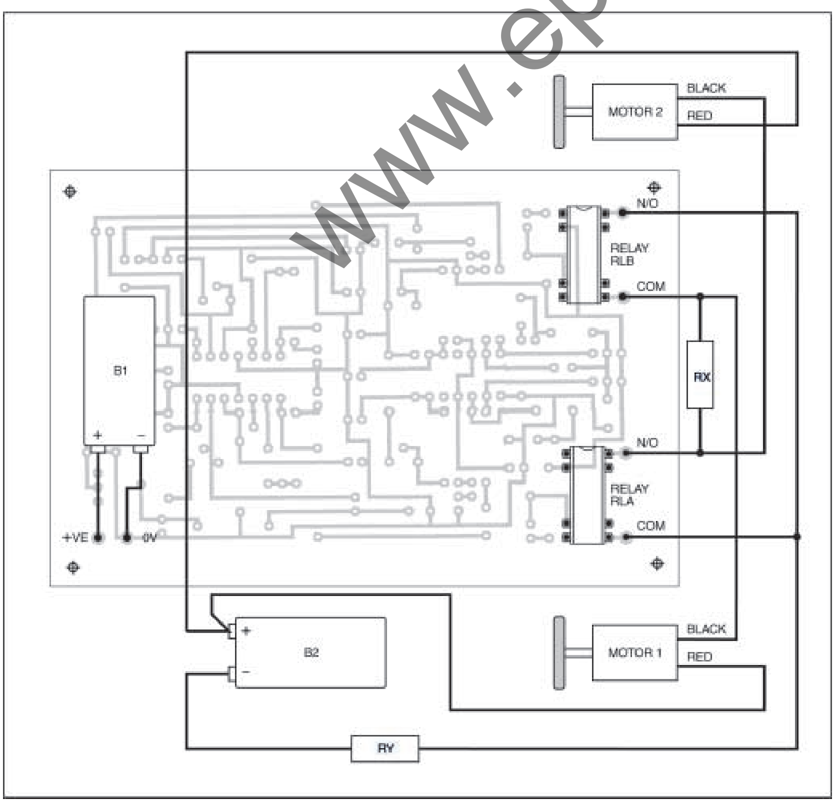
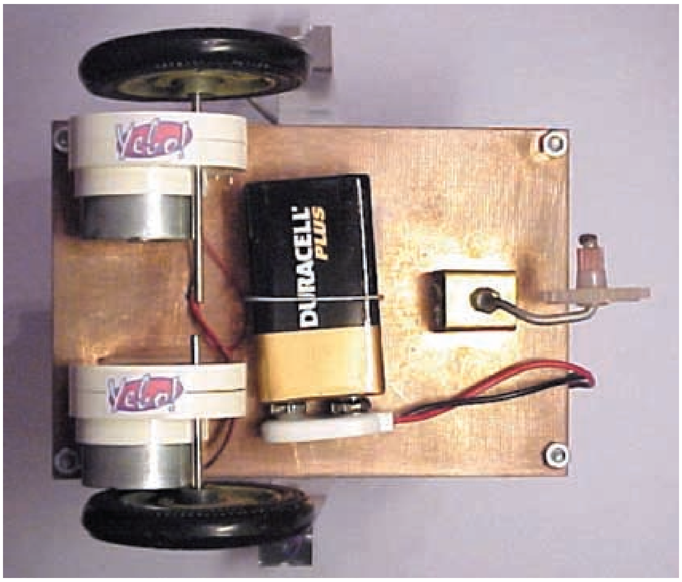
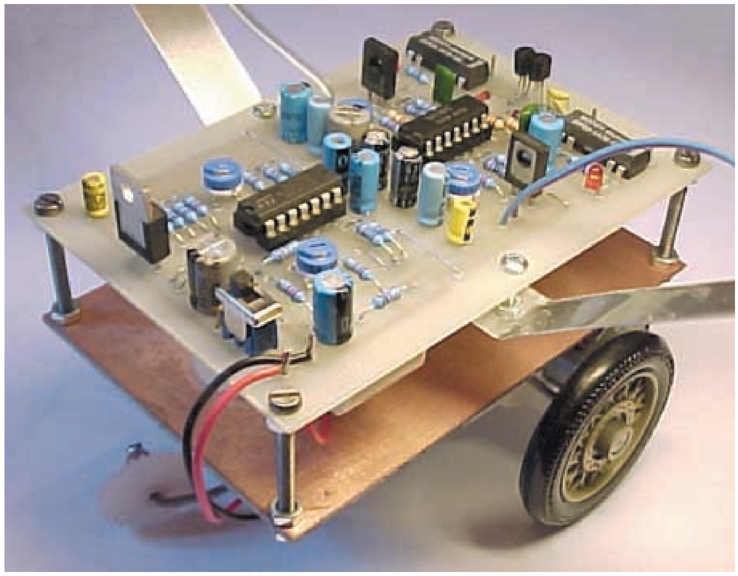


Fig.4. Interwiring from the circuit board and between the motors. Optional resistor RX controls the amount of "steer" and RY helps to prevent any possible overload of the motors.



Underside view of the prototype buggy. It has been found that powering the motors from a separate battery improves the performance of Big-Ears.



General buggy layout showing the p.c.b. mounted on the baseboard, one large motor-driven wheel and the small trailing wheel. Batteries can be sited between boards or below the chassis board.

BUMP-AND-REVERSE

A simple add-on circuit for a "bump-and-reverse" feature, which uses virtually zero current on stand-by, is shown in Fig.5. This is for one motor – wire a second relay coil (RLD) in parallel with RLC for both motors and repeat the circuit.

The switch S2 may be a sensitive lever-operated microswitch, the transistor any "logic MOSFET" (e.g. BUZ11), the value of capacitor C18 should be about 470n, and the additional relay a double-pole change-over (d.p.c.o.) type.

This will override the buggy's circuitry, and cause it to reverse directly out of a collision.

SUMMARY

Finally, the Big-Ears Buggy may be used for animation. For instance, if through-axles are used for the motors, circular discs may be mounted on the insides of the motors, and used to make a little person/animal pedal.

The vertical axle of the trailing wheel may rotate gears which cause the person's/animal's head to turn as the buggy changes direction. Another gear may be used to turn a steering column. Note that when the buggy reverses, it would turn their head to look backwards. □