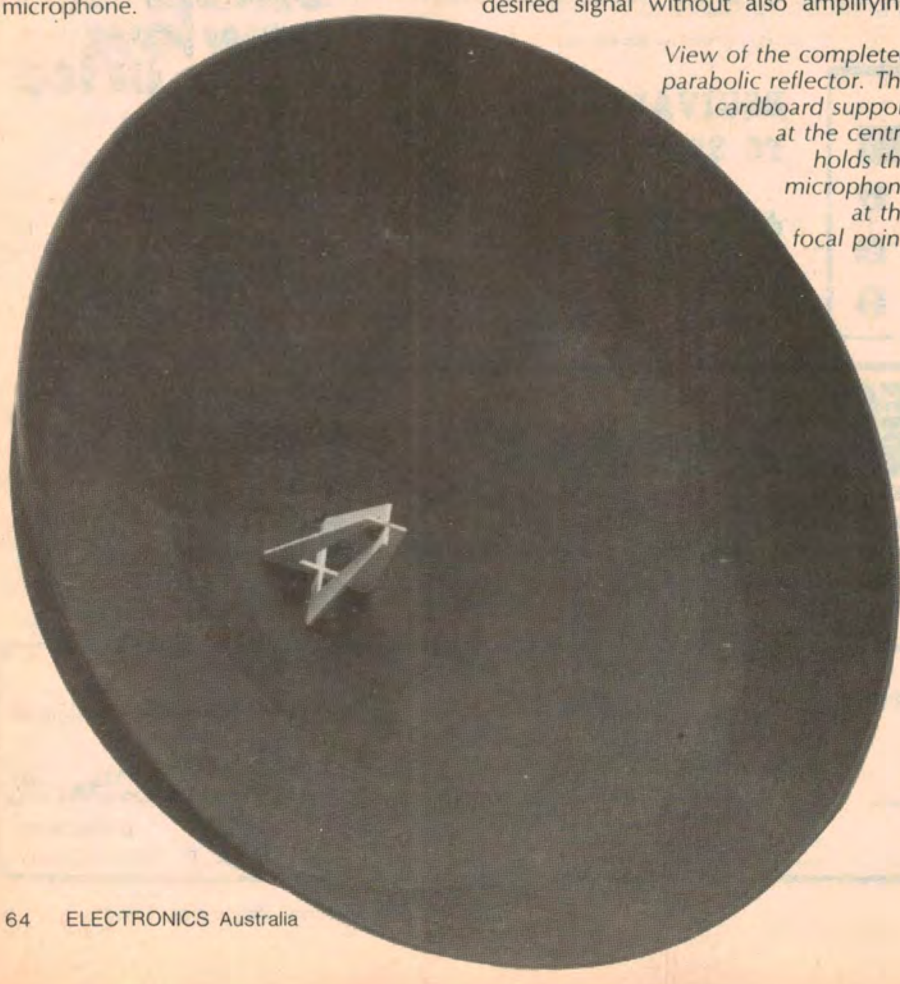
Parabolic Microphone for recording birdsong

We explain how to build a low cost parabola, along with a high gain headphone amplifier. Just the thing for listening to birds, or perhaps for other more sinister activities. (Move over ASIO!)

The text book definition of a parabola goes something like this: "the locus of a point which moves such that it is equidistant from both a point (the focus) and a line (the directrix)." So far as we are concerned, its main purpose in life is to be used as a reflector. The most common example of a parabola in this application is the reflector of headlamps, where rays of light emitted from the bulb are reflected in an almost parallel beam. In our case a reciprocal mechanism applies; incoming parallel sound waves are reflected onto a single point, ie, the microphone.

Parabolic reflectors provide gain (up to 20dB in this case) for any sound which is "on axis". This characteristic enables a microphone to respond to sounds which would otherwise be very mute or inaudible. Equally important is the fact that the reflection pattern is directional. This means that as the sound source is moved off-axis, the gain becomes progressively lower. For a sound source 90° off-axis, the gain will be around unity and for a sound behind the reflector, attenuation will occur. This is important because it allows us to amplify the desired signal without also amplifying much of the ambient noise.



View of the completed parabolic reflector. The cardboard support at the centre holds the microphone at the focal point.

The design of a reflector is a compromise between performance and convenience. To optimize frequency response, it is basically a matter of "the bigger the better". For reasonably flat response down to 100Hz, the reflector would have to be over 3m in diameter! Besides the difficulties involved in construction, attempting to use such a device could not be achieved in an inconspicuous manner.

We have settled for a reflector diameter of 60cm which results in a loss of efficiency for sounds below about 500Hz. This should present no problem with the majority of bird song, which is well above this frequency. Speech will not fare quite so well. Although still intelligible, it may sound thin and unnatural.

Even more important than the diameter of the reflector is the focal length, since the actual parabolic curve is built around this dimension. We chose a 10cm focal length, based on test results obtained by G. N. Patchett, PhD ("Tests on Parabolic Reflectors," EA Oct '73). Compared with several other focal lengths which Patchett had tried, this gave a much better low frequency response. Such a reflector is rather deep, but this has the advantage of shielding the microphone from the wind.

Because all of the sound waves striking the reflector are focussed onto a single point, it is possible to use a small microphone. In this respect, electret microphone inserts are ideal. They are readily available and quite cheap, and a light cardboard framework is all that is necessary to locate the microphone at the focus.

Making the reflector

Coming up with a workable process for building the parabola caused more than a little head scratching around our office. We had to find a process that was inexpensive, reasonably accurate, and above all something that could be easily duplicated by readers. As a temporary

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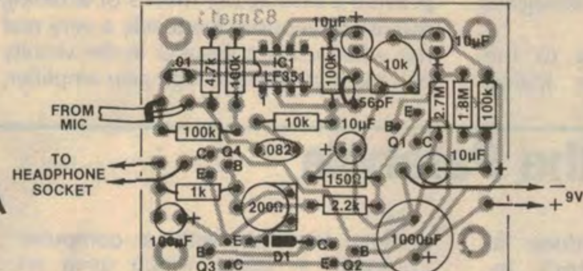
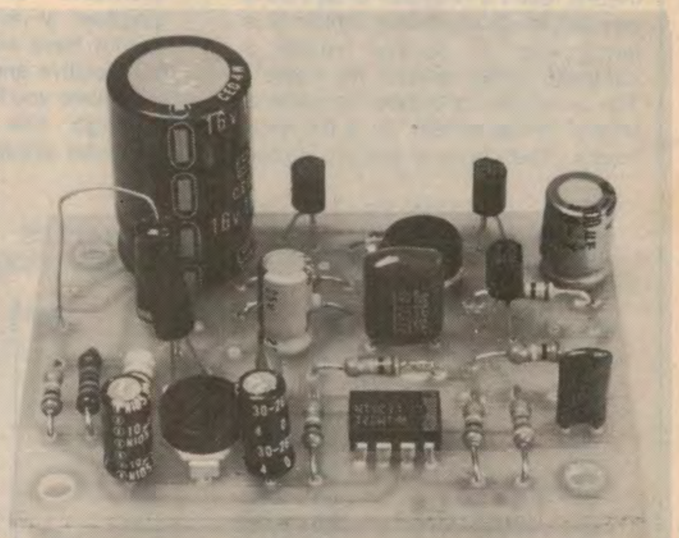


Below: PCB parts overlay diagram. Use shielded cable for the microphone connections.

We estimate that the current cost of the components for the project is approximately

$15

This includes sales tax, but not the cost of batteries or headphones.



Right: view of the assembled PCB. Take care with polarised parts.

measure, we decided to build a cardboard parabola using 12 segments.

After struggling with innumerable pieces of cardboard and sticky tape, a triumphant staff member proudly displayed his "pseudo-parabola". This ungainly-looking object tended to collapse unless supported by at least four hands at once. Perhaps surprisingly, it actually performed quite well. From G. N. Patchett's results, the greatest amount of gain we could expect was 20dB, and we achieved nearly 17. Certainly the design looked promising.

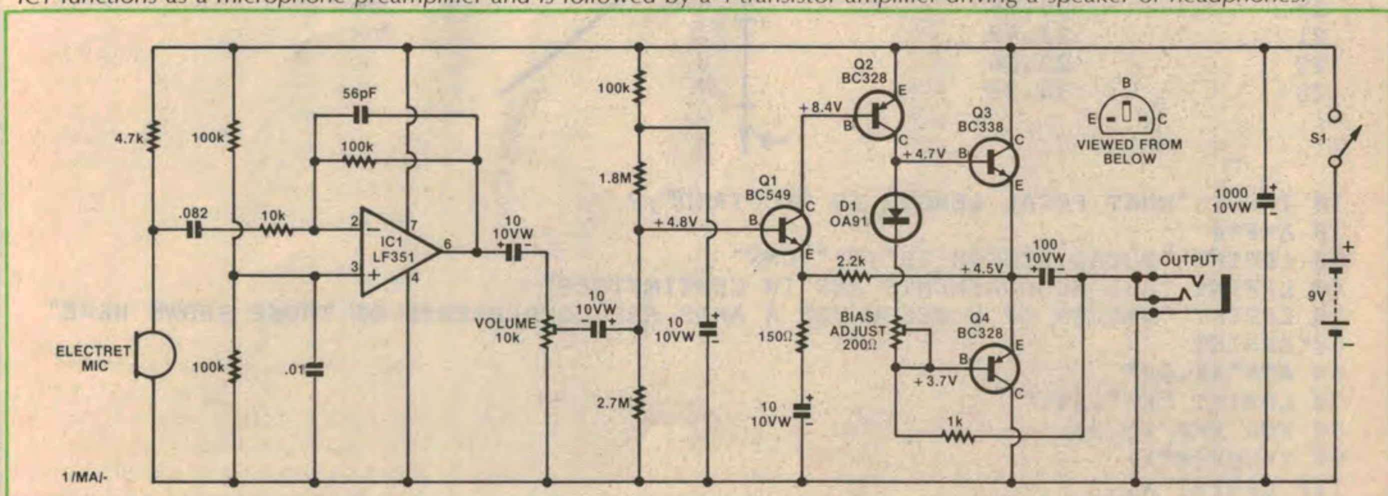
The most obvious improvement was to strengthen the parabola so that it became self supporting. This was achieved by pasting strips of paper over the cardboard, papier mache style. We made the mistake of making the first layer too wet so that the parabola became a nondescript gelatinous heap of paper. It had to be reshaped frequently whilst drying.

The final solution was to apply the strips to the inside of shell and we now suggest that they be applied to this side only. Since we had already applied one outside layer, we found that two inside layers were sufficient to provide the required stiffness, suggesting that three or four inside layers only should be about right.

Despite its shortcomings, we think this is still a feasible approach to building the parabola. If the constructor avoids our mistakes, the process should be reasonably straightforward. Alternatively, if you feel ambitious you could try a sand mould method for making a fibreglass reflector which was described in the RSGB publication, "VHF-UHF Manual" by Evans and Jessop.

The method involves shaping a mound of sand with a rotatable profile to produce the parabolic shape. The sand is then sprayed with a coat of paint to stabilise it and then mats of fibreglass impregnated with resin are laid over it to build up the required thickness and strength.

IC1 functions as a microphone preamplifier and is followed by a 4-transistor amplifier driving a speaker or headphones.



Parabolic Microphone

involve the use of an old umbrella to form the foundation of a fibreglass reflector.

When it comes to listening to the sound, headphones are the logical choice. Apart from anything else, they provide a satisfactory means of avoiding the risk of acoustic feedback; a very real risk when using a speaker in the vicinity of a microphone and high gain amplifier, directional characteristics of the reflector notwithstanding.

In addition, they provide a high level of sound with a modest power input, and block out most of the background noise. To drive them we have designed a low power utility amplifier – just the thing to use with headphones. The whole circuit

How to plot the Parabola

Just how do you produce a parabola-shaped reflector? In theory, such a reflector is termed a paraboloid of revolution which is a fancy way of saying "rotate a parabolic curve around its x-axis". The parabolic curve has the general form $y^2 = 4ax$ where "a" is the focal length. The curve is shown plotted below together with a computer program in Basic which uses an alternative form of the parabolic function: $y = \sqrt{4ax}$. Note that x cannot have negative values but y has positive and negative values.

To save you the trouble of running through the calculations the computer printout below shows the values of y for all values of x from 0 to 23 in 1cm steps. This is adequate to allow you to draw a full-size profile of the reflector.

Note that as far as the appearance of the parabola is concerned it is nice if it can be as smooth and as free of bumps as possible. For all practical purposes though, small bumps and undulations will not make a great difference to the performance.

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FOCAL LENGTH IS 10  CMS
ALL MEASUREMENTS ARE IN CENTIMETRES
VALUES OF Y BELOW THE X AXIS ARE COMPLEMENTS OF THOSE SHOWN HERE

X=           Y=
 0            0.00
 1            6.32
 2            8.94
 3           10.95
 4           12.65
 5           14.14
 6           15.49
 7           16.73
 8           17.89
 9           18.97
 10          20.00
 11          20.98
 12          21.91
 13          22.80
 14          23.66
 15          24.49
 16          25.30
 17          26.08
 18          26.83
 19          27.57
 20          28.28
 21          28.98
 22          29.66
 23          30.33
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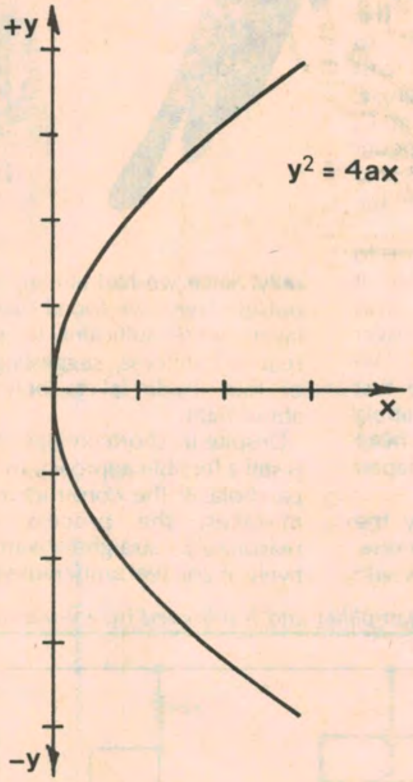


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10 INPUT "WHAT FOCAL LENGTH IS REQUIRED";F
20 A=F*4
30 LPRINT "FOCAL LENGTH IS";F;" CMS"
40 LPRINT "ALL MEASUREMENTS ARE IN CENTIMETRES"
50 LPRINT "VALUES OF Y BELOW THE X AXIS ARE COMPLEMENTS OF THOSE SHOWN HERE"
60 LPRINT
64 A$="##.##"
70 LPRINT "X=","Y="
80 FOR X=0 TO 23
90 Y=SQR(A*X)
100 LPRINT X,
110 LPRINT USING A$;Y
120 NEXT X
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can easily be powered from a "six-pack" of penlight cells.

How it works

An op-amp microphone preamplifier is followed by a direct coupled transistor power amplifier. The output stage has two transistors in a fully complementary push-pull arrangement. This power amplifier is a design we have used a number of times in the past, with the earliest variants dating back to the days of germanium. We can't be accused of using an unproven circuit!

Refer now to the circuit. The electret microphone needs a bias current and this is supplied by the 4.7kΩ resistor connecting it to the positive supply rail. The signal appears at the junction of this resistor and the microphone and is coupled to the inverting input via the .082μF capacitor, which serves to isolate the inverting input from the bias voltage.

From the 0.082μF capacitor signal is fed via a 10kΩ resistor to the inverting input (pin 2) of the op-amp. The non-inverting input (pin 3) is connected to the mid-point of a voltage divider consisting of two 100kΩ resistors connected across the supply. This holds pin 3 at half the supply voltage.

Negative feedback for the op-amp is provided by the 100kΩ resistor connected between the output (pin 6) and pin 2. It is the ratio of the 10kΩ input resistor and this 100kΩ feedback resistor which determines the gain of the op-amp. A 56pF capacitor connected in parallel with the 100kΩ feedback resistor limits the bandwidth of the op-amp so that it will not respond to RF signals picked up by the input leads.

The output of the op-amp is capacitively coupled to the volume control, a 10kΩ potentiometer. This in turn is capacitively coupled to the base of Q1.

The base of Q1 is biased to approximately half the supply voltage by the divider consisting of the 1.8MΩ and 2.7MΩ resistors. There is also a 100kΩ resistor in series with the 1.8MΩ and this, in conjunction with the 10μF capacitor, forms a decoupling network which

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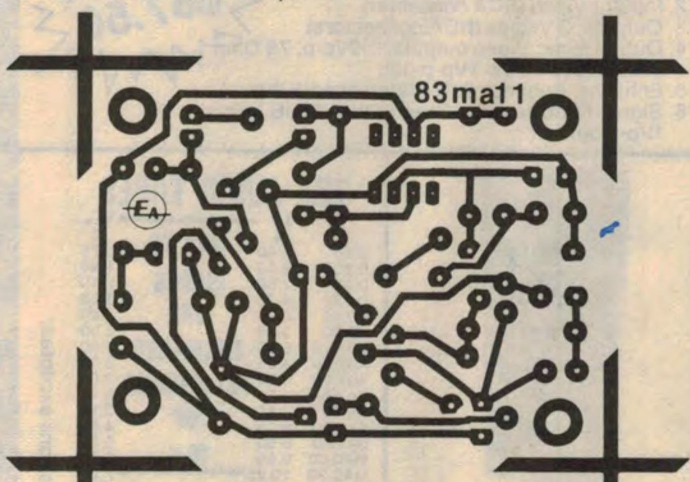
Below: this diagram gives the dimensions of the reflector segments. You will need 12 segments in all.



Actual-size reproduction of the PCB pattern.

PARTS LIST

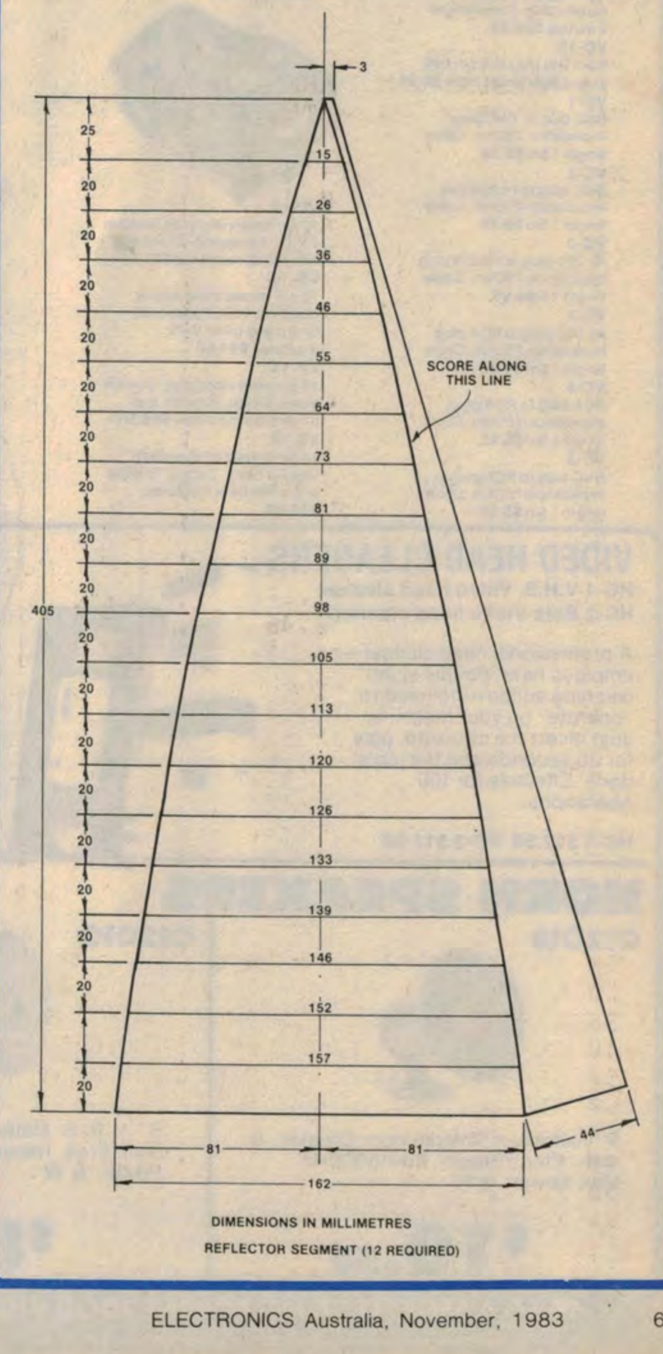
1 Printed circuit board 68 x 51 mm, code 83ma11
1 Electret microphone insert
1 Single pole single throw (SPST) switch
6 1.5V batteries (Eveready AA or equivalent)
1 Battery holder to suit
1 Battery snap
1 Metre of single core shielded cable
1 Stereo audio socket to suit (either 3.5 or 6.5mm

SEMICONDUCTORS
1 LF 351, TL071 FET input op-amp
2 BC328 PNP transistors
1 BC338 NPN transistor
1 BC549 NPN transistor
1 OA91 germanium diode

CAPACITORS
1 1000μF/10V electrolytic
1 100μF/10V electrolytic
3 10μF/10V electrolytic
1 10μF/10V axial electrolytic
1 .082μF metallised polyester (greencap)
1 .01μF metallised polyester (greencap)
1 56pF ceramic

RESISTORS (¼W, 10%)
1 x 2.7MΩ, 1 x 1.8MΩ, 4 x 100kΩ, 1 x 10kΩ, 1 x 4.7kΩ, 1 x 2.2kΩ, 1 x 1kΩ, 1 x 150Ω, 1 x 10kΩ small horizontal trimpot, 1 x 200Ω small horizontal trimpot

MISCELLANEOUS
Hook-up wire, cardboard, newspaper etc.



isolates the bias network from any noise imposed on the supply line. It is not necessary to resort to such measures for the op-amp, since it has excellent supply rejection.

The series resistor and capacitor in the emitter circuit of Q1 provide AC negative feedback for that transistor. DC negative feedback is provided by the 2.2kΩ resistor between Q1's emitter and the output.

The collector of Q1 is coupled directly to the base of Q2, a BC328 PNP transistor. This drives both output transistors, one of which is another BC328 and the other an NPN BC338. It would be feasible to connect the bases of the two output transistors directly to each other but this would result in severe crossover distortion. This accounts for the diode and trimpot connected between the bases.

As the trimpot is adjusted to minimum resistance, the quiescent current of the output stage is minimised. In this condition the whole circuit will have a quiescent current of around 6mA but crossover distortion will be quite apparent, particularly for pure tones at low signal level.

Adjusting the quiescent current is a compromise between battery current drain and crossover distortion. With around 10 milliamps current through Q3 and Q4 the crossover distortion is largely eliminated while still giving a modest no-signal current drain of around 16 milliamps.

The output signal is taken from the junction of the emitters of Q3 and Q4. This is passed through a 100μF capacitor before being fed to the headphones, preventing any current from flowing in the output circuit unless there is a signal present.

Construction

All of the electronics except the microphone are on the printed circuit board (PCB). This PCB is coded 83ma11 and has dimensions 51 x 67mm. No problems should arise with construction, so long as you mount the low profile components, such as resistors, first. Take care with the orientation of the polarised components, ie, diode, transistors, IC, and electrolytic capacitors. Particularly watch the electrolytic with axial leads – it's very easy to put it in with reversed polarity.

Although we have not built our amplifier into a box, there are a number of plastic project boxes which would be suitable for the purpose. Remember that it also has to accommodate the six batteries. The most important consideration in using the project as a microphone amplifier is to keep the input lead as short as possible. This may necessitate mounting the PCB directly on the back of the parabolic reflector.

Making the reflector is probably the most time consuming and tricky part of the project. We have given the dimensions of the parabolic curve on which our reflector is based, and this should assist in determining the correct shape for the cardboard assembly.

We have also indicated the dimensions of the segments used – you will need 12 of these. The best approach is to carefully draw one segment to the given dimensions and use this as a template when it is cut out. Note that each segment has a flap on one side. Bending the segments to shape will be easier if you score along the boundary of the flap and the segment proper and also cut across the flap at a number of points. These cuts provide stress relief so that the cardboard can accept a double curvature.

Each segment side will have a slight curvature and to achieve the parabolic shape, adjacent curves must butt up to each other for the full length of the side. They are held in place initially with adhesive tape, although this may later be replaced with a suitable glue. Joining the

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segments will initially seem very awkward but the parabolic shape should eventually emerge. Use the profile drawing to verify the shape when all of the segments have been joined, and make any necessary adjustments.

When the reflector has been assembled, the paper pasting can commence. Take several newspaper pages and tear them into strips about 10 to 15cm wide, and long enough to run from the centre to the edge of the reflector. Then mix up a simple flour paste, using plain flour. The ratio of flour to water depends on how viscous you want the paste to be – for the first layer, not too much water. As you are ready to use each strip of paper, run it through the paste so that it is well and truly impregnated.

The first layer of paper took around half a day to dry and subsequent layers a couple of hours. It is wise to remove any irregularities as they occur – this becomes increasingly difficult after each layer. Just moisten a small area with a damp cloth and manipulate it into the correct shape. Using this method, each damp patch will dry in about 10 minutes.

When the parabola is complete, a small mounting frame for the microphone will have to be manufactured. Again, cardboard can be used. Remember, the face of the microphone should be at the focus.

To test the project, plug in a pair of headphones and set both trimpots to their anti-clockwise extreme. Allow the circuit a few seconds to stabilize after switch on and then slowly advance the volume control. Background noise should quickly become apparent but just to make sure, whistle at the microphone. If you are nearly deafened by the noise, everything is OK.