Hebot

Combine economy and efficiency, form and function in a realistic, revolutionary and robust robot ready to roam around your residence.

Discussing **HEBOT** *in our workshop. John FitzGerald (seated) designed and built it, with Henry Budgett (Computing Today), Halvor Moorshead (HE's Editor) and Steve Braidwood (Assistant Publisher). In case you've any doubts, the* **HEBOT** *is the one on the table.*

OF COURSE, the pressing question is, 'will **HEBOTs** ever replace the family cat?'. Well. We are happy to be able to tell all the feline fanciers out there that the days of the family moggy are not numbered yet. Nonetheless, **HEBOT** represents the most sophisticated and versatile robot project to be offered to the hobbyist to date throughout Europe. (The Americans have a small robot but it requires an umbilical link to a controller. The Japanese probably did it smaller and cheaper five years ago.)

Hobby Electronics has co-operated with Remcon Ltd, one of the country's leading manufacturers of radio control equipment, to produce a 'classy chassis' we feel sure will become a 'standard' for many years to come.

The cornerstone of the design is a hexagonal aluminium chassis pan which carries the micro-drive units, batteries, sensors and PCBs on which are mounted the electronic components. We tried a number of different collision sensors and discovered, as Edison used to put it, an awful lot of ways NOT to do it. Our prototype features microswitches whose lever arms have been extended with pre-formed lengths of piano wire. However, the production kits from Remcon will probably feature sensors mounted integrally with the chassis pan. Another point worthy of note is our use of a perspex cover for the prototype. The production kit will feature a pre-formed three piece aluminium cover as the perspex version costs more than all the other components put together.

The microdrive units feature a fully enclosed gearbox and five pole motor with the drive wheel mounted on a steel shaft integral with the gearbox. Typical motor drive current is around 150mA giving between one and two hour's life from 450mAH capacity nicad cells (AA size). The chassis can turn on its own axis and will carry a payload of up to five pounds weight. Previously published robot designs in other magazines have been let down by poor mechanical design or the use of difficult to obtain or reproduce electronic components. The precision engineered design from Remcon which has resulted from our consultation with them removes one of the main pitfalls of any project of this type.

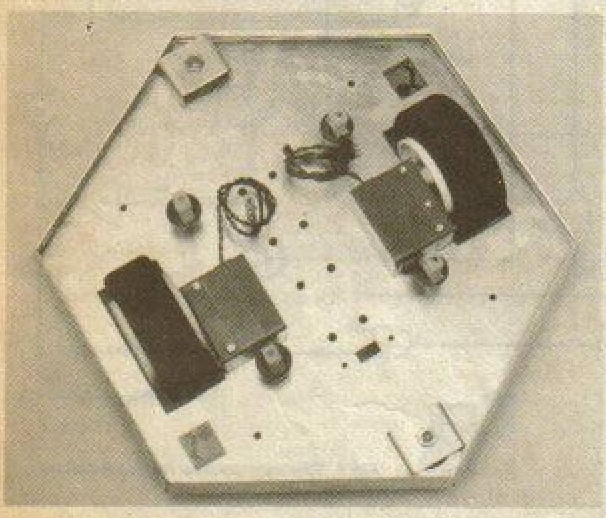
SUPERLATIVE

If HEBOT's chassis is good (which it certainly is), then words cannot do justice to the electronic design. Though composed of largely conventional circuit elements, the circuit represents a breakthrough in systematic design facilitating development and operation.

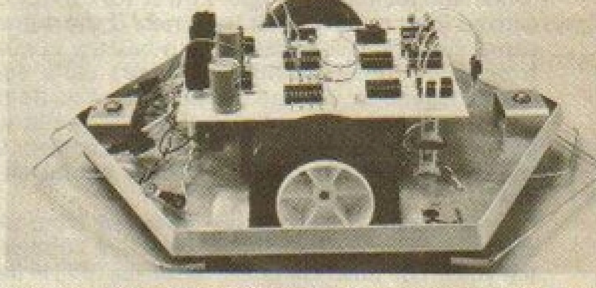
The novel feature of this system is the separation of executive and control signals. In a maximal system, up to eight pairs of motor control signals may be present simultaneously with **HEBOT** 'choosing' between them according to the state of 'priority' input sense lines. A possible arrangement might be

7	↑
6	external control
5	
4	↓
3	'avoid' manoeuvres
2	tracking
1	searching
0	random walk

Level seven has highest priority and zero lowest priority. Assuming **HEBOT** was not under external control and was neither tracking nor searching then a random walk would be executed. Following any collision, priority sense input three would become active and **HEBOT** would manoeuvre himself out of trouble before returning control to level zero: random walk. Of course, there is nothing special about the control signals chosen



Our prototype chassis showing micro-drive units.



We mounted the PCB above the micro-drive units. The batteries are sited underneath.

and any group of signals could be assigned priorities and connected to the appropriate inputs. Control levels may vary between +5V (Full forward) and −5 V (full reverse) with intermediate voltages giving variable speed and zero volts halting the machine. As described here, **HEBOT** executes all manoeuvres at full speed.

We are presenting **HEBOT** in three parts. This article deals with simple forward motion and manoeuvres following collisions. Part two will describe how to make **HEBOT** sensitive to specific sources which it will approach or flee from. In part three **HEBOT** will be internally sensitised to monitor the state of charge of his battery supply and when necessary find and use the recharging station.

HEBOT is an open-ended project whose scope is limited only by your resources of imagination, skill, time and (inevitably) money. Accordingly, the schedule may be changed to accommodate design developments and should in any case be used only as a springboard for your own ideas.

CONSTRUCTION

The chassis, aluminium cover and mechanical components are available from Remcon. The electronic components are mounted on one PCB which is supported from the chassis pan by plastic 'clik-fit' pillars.

There are a large number of wire links on the PCB which MUST be soldered into place first as many of them pass beneath components. Integrated circuit sockets are recommended for the IC's and normal CMOS precautions should be observed to avoid destruction of the chips by static charges. Flying leads are used to interconnect some of the IC's and should be soldered into place after the other components have been mounted but before inserting the chips. It is impossible to give precise constructional details for this project which ideally will be developed by the constructor. However, you should find our photos helpful.

If, initially, only four inputs are required then IC5 may be omitted. Uncommited inputs of IC3 should be tied low (to the −5 V rail) and not left floating. We used heat sinks on the motor driver transistors though they hardly get warm at all.

HEBOT opens the door to home robotics. The constructors of today are the engineers of tomorrow. There is not a moment to lose.

How it Works

Circuit operation may be most easily understood by considering the operation of three units separately; the motor servo amp, signal multiplexer and manoeuvre logic. Power for all three is derived from two five volt batteries. If the voltage seems strange, it is because each battery is made from four nickel-cadmium (nicad) cells each having a nominal voltage of 1.25 volts. You do not have to use nicads, ordinary HP7 dry cells will power the circuit quite happily though battery life will be restricted to a couple of hours' operation or less.

The integrated circuits are powered from plus and minus five volts giving an effective voltage of ten volts. The junction of the batteries (0V) is used only as a bias point for the non-inverting inputs of IC1 and IC2 and as a return for the motors.

The servo amplifiers formed around IC1 and IC2 could hardly be simpler. Each op-amp functions in a standard inverting amplifier configuration with a gain of one (ie the output voltage equals the input voltage but is of opposite polarity). Transistors Q4, 5 and Q6, 7 function as complementary emitter followers and supply the motor drive current; about 150mA. IC1 and IC2 deserve a special mention. These chips are BIMOS op-amps and feature CMOS output stages enabling the output to swing very close to the supply rails, very important in this application. Ordinary 741 op-amps could be used but would have a very limited and unequal output voltage swing giving low motor drive and loss of torque. The 3130 is a high speed uncompensated device and capacitors C1, 2 are essential to prevent high frequency oscillation which would cause excessive dissipation in the semiconductors and could result in overheating in the motors. Using the circuit shown and our PCB no problems should be experienced.

Control voltages are applied to the servo amps via input resistors R1 and R2. If you follow the connections from these resistors, you will see that they disappear mysteriously into IC4 and IC5. In fact these chips do not alter the control voltages passing through them at all. They are simply multiplexers; an electronic rotary switch used to select control signals. Each chip functions like a four-way two pole switch whose 'position' is determined by the state of three control lines at pins 6, 9, 10. The binary 'address' on pins 9 and 10 selects one pair of four pairs of inputs. The most significant address line from IC3 is used to select either IC4 or IC5 by driving the 'enable' inputs of those chips.

As this signal is inverted by Q1 before being passed on to IC5, only one chip is enabled at any time. The disabled chip behaves as though it were a disconnected switch and exhibits a very high resistance between all inputs and outputs. This arrangement enables any pair of eight possible pairs of control signals to be selected according to the control signals from IC3 and used to drive the servo amps.

IC3 is an eight-input priority encoder. The operation of the chip is quite straightforward. There are eight individual inputs and a single 'enable' input (pin 5) which is tied high to enable the chip. The eight input lines should be held normally low. When any input is asserted high (ie connected to +5V), the group select (GS) output goes high, enable (E) output goes low and the binary address of the selected input appears on pins 9 (lsb), 7, 6 (msb). For example if input '3' (pin 13) is asserted high then 110 will appear on pins 9, 7,

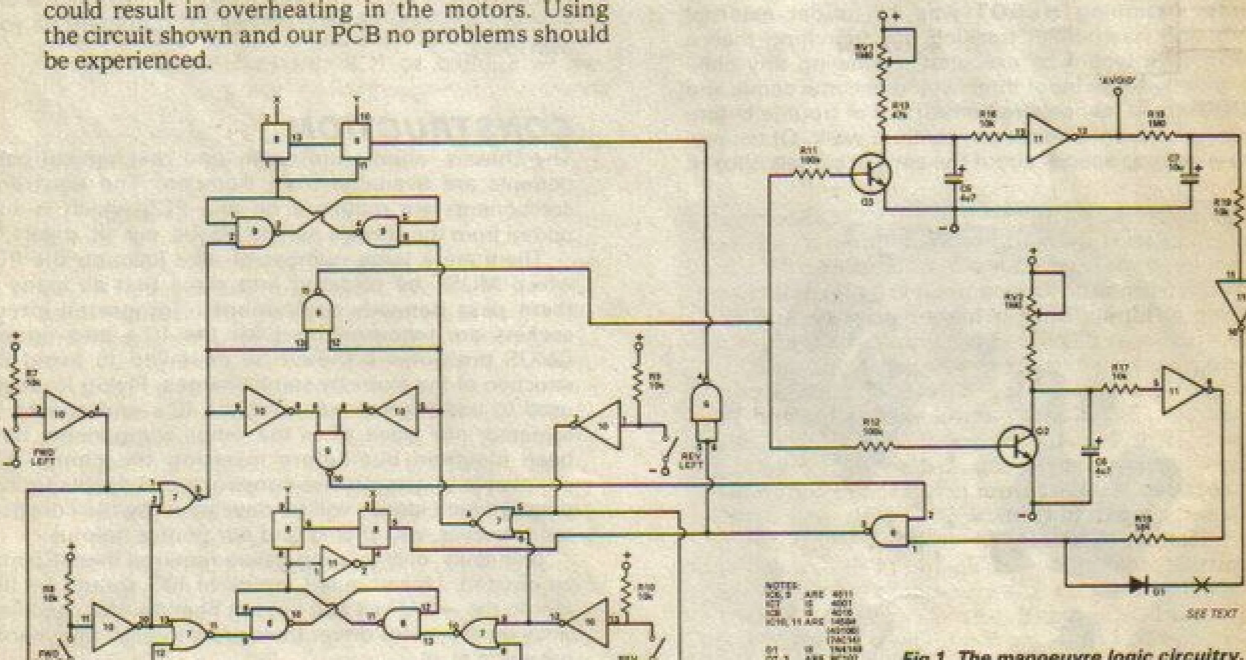


Fig 1. The manoeuvre logic circuitry.

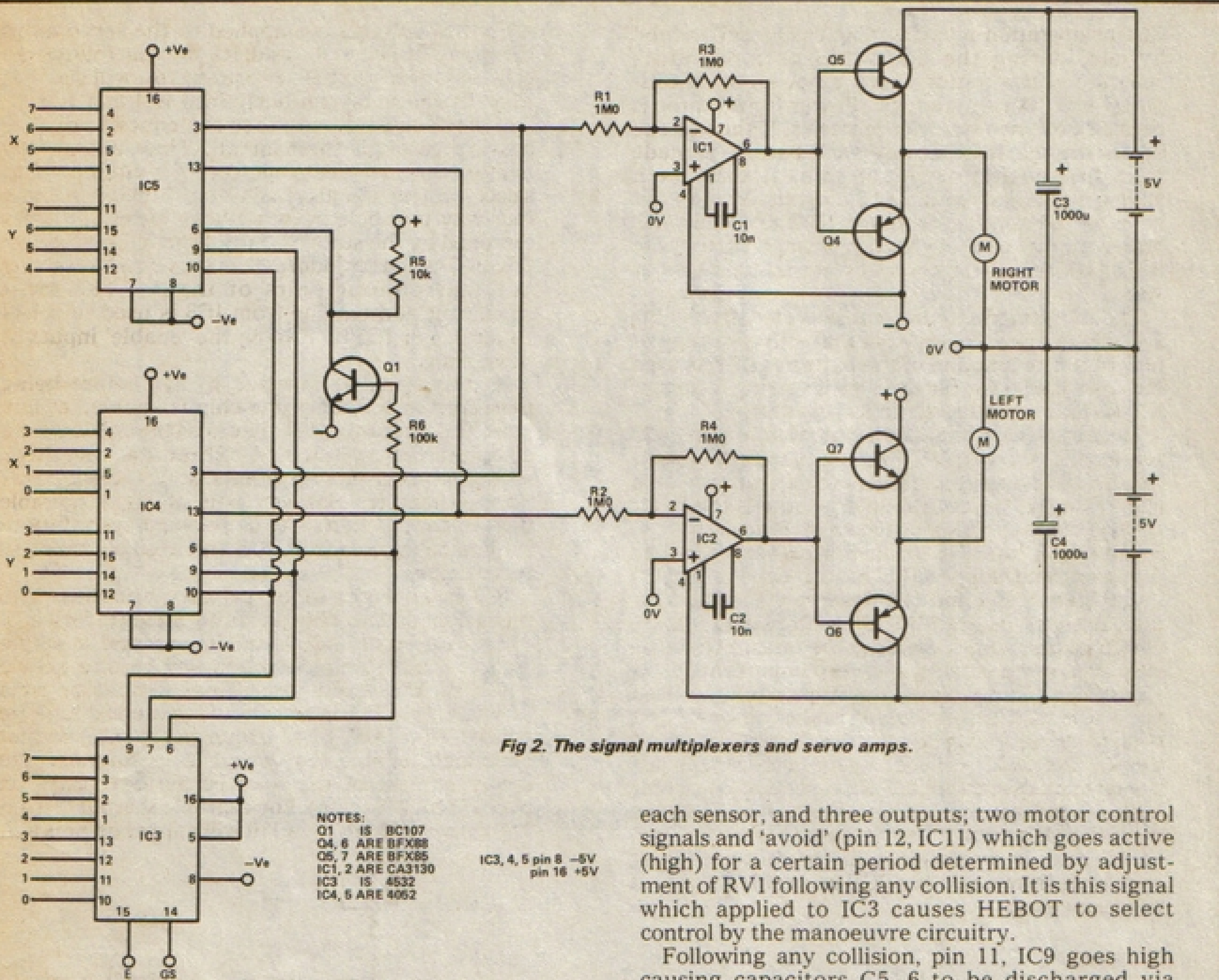


Fig 2. The signal multiplexers and servo amps.

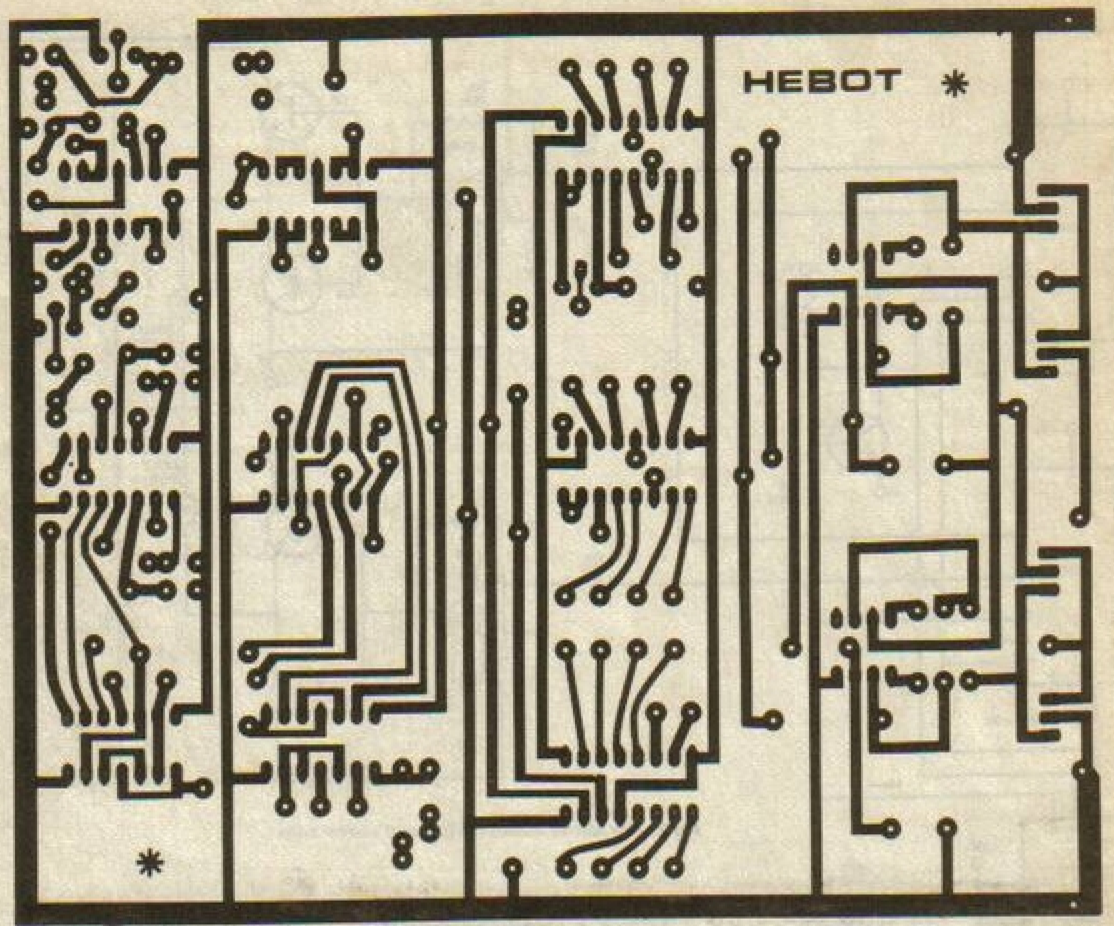
6. However, if — while '3' is still high — '5' is also asserted high then the address output will change to 101 as five has a higher priority than three and the inputs corresponding to that number will be connected to the servo amp by multiplexer IC5. In this way, the motors are controlled by signals from one set of inputs until a higher priority line becomes active at IC3 when the address will change and another set of inputs will be selected.

In our prototype, input '2' (pin 12, IC3) is connected to +5V. Motor control inputs 2X and 2Y (pins 2, 15, IC4) are connected to +5V via 560k resistors giving a slow forward speed. Following any collision, a signal from the manoeuvre circuitry asserts input '3' (pin 13, IC3) high and motor control inputs 3X and 3Y are selected. The X and Y outputs (pins 2, 3 and 9, 10, IC8) from the manoeuvre circuitry are connected to inputs 3X and 3Y and these signals are used to steer HEBOT out of trouble. Following the manoeuvre, control is returned to the next lowest priority level which is currently high; in this case level 2 — slow forward.

The manoeuvre logic has four inputs, one for each sensor, and three outputs; two motor control signals and 'avoid' (pin 12, IC11) which goes active (high) for a certain period determined by adjustment of RV1 following any collision. It is this signal which applied to IC3 causes HEBOT to select control by the manoeuvre circuitry.

Following any collision, pin 11, IC9 goes high causing capacitors C5, 6 to be discharged via transistors Q3, 2 and monostable timing periods to be initiated.

The overall manoeuvre time is adjusted by RV1 while RV2 sets the duration of straight motion before a turn is executed. If RV1 is first set then adjustment of RV2 will alter the degree of turn. HEBOT chooses forward or reverse and the direction of turn by examining internal registers which 'remember' which sensor signalled a collision. The registers comprise bistable latches formed by parts of IC6 and 9 which are set or reset by associated gates. If there are 'too many' collisions within a certain period then pin 10, IC11 will go low. This output may be optionally connected to pin 1, IC6 where it will cause HEBOT to execute a turn immediately following a collision without any straight motion. The usefulness of this strategy will depend on the settings of RV1, 2 which may be optimised for different obstacles. The circuitry has been designed to enable a flexible and versatile system to be developed and there may be many changes which can be made to adapt HEBOT's behaviour to his environment.



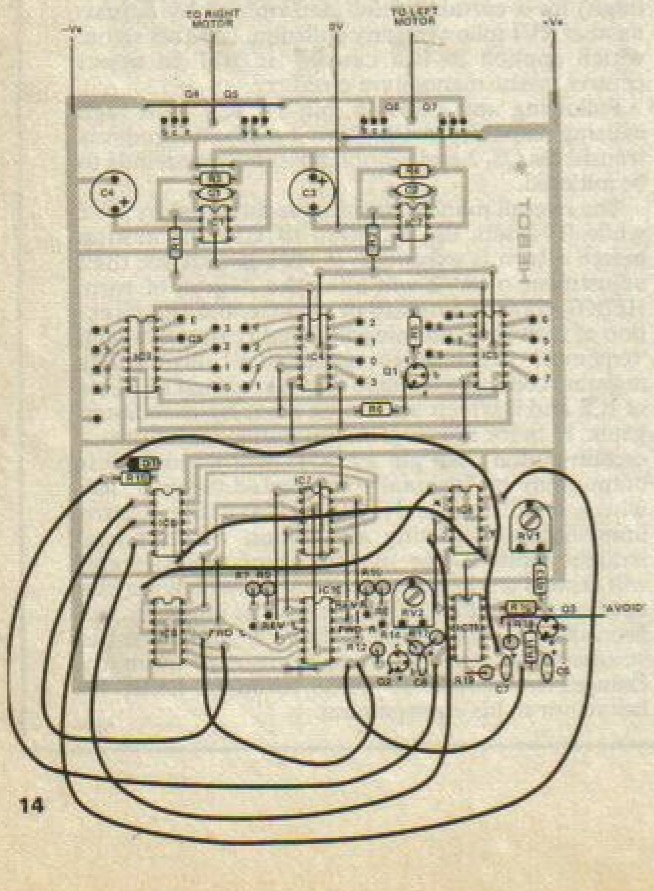
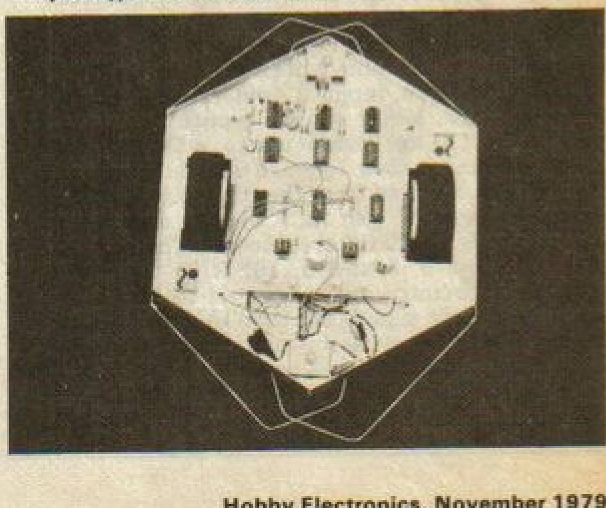


Fig. 3. PCB foil pattern for HEBOT

Fig. 4. PCB overlay for HEBOT

Our prototype used wire collision sensors.



Parts List

RESISTORS (all ¼W 5%)

R1, 2, 3, 4, 18	1MO
R5, 7, 8, 9, 10	
15, 16, 17, 19	10k
R6, 11, 12	100k
R13, 14	47k

POTENTIOMETERS

RV1, 2	1MO preset

CAPACITORS

C1, 2	10n polyester
C3, 4	1,000µ electrolytic
C5, 6	4µ7 tantalum
C7	10µ tantalum

SEMICONDUCTORS

Q1, 2, 3	BC107
Q4, 6	BFX88
Q5, 7	BFX85
D1	1N4148
IC1, 2	CA3130
IC3	4532
IC4, 5	4052
IC6, 9	4011
IC7	4001
IC8	4016
IC10, 11	14584 (40106, 74C14)

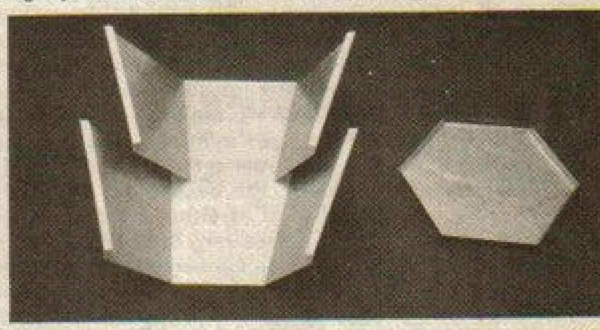
All CMOS 'B' series.

Buylines

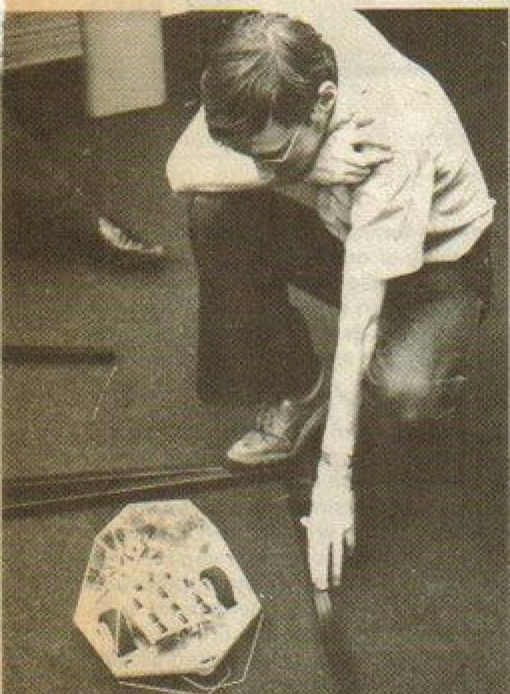
The electronic components should be readily available from any of the larger mail order companies.

The chassis and associated mechanical components are available from Remcon.

The castors used on the production version of HEBOT differ slightly from the ones shown on our prototype



Remcon's three-part aluminium cover which will be supplied with their production kits.



HEBOT *demonstrates its amazing(!) ability to negotiate a labyrinth.*

APPROXIMATE SPECIFICATION

Main chassis pan.	Anodised Aluminium 18g. thick. 10'' across flats with ½'' flanges all round. Ready punched for all electro mechanical hardware. Will carry loads of at least 5lbs evenly distributed.
Cover.	Ready formed in aluminium, to fit over chassis flange, and give internal height of 6'' approx.
Microdrives.	Copolymer moulded gears and gearbox for long life, driven by micromotor 4-6v dc, current consumption 120/150ma each. Anticipated duration from two 500mah batteries 3/4 hrs. Sponge tyre wheels 3'' dia keyed to output shaft by square fit. Will operate on any smooth surface including low pile carpet. Level ground speed 9''/sec. Will climb slopes approaching 1 in 1.

Prices (excluding VAT at 15%)

Complete mechanics kit as detailed below or separately	£35.00 P&P £2.00
Main Chassis and instructions	£6.50 P&P 75p
Microdrive units wheels and couplings, per pair	£19.50 P&P 50p
Ballbearing stabilizers and fixings per pair	£3.00 P&P 50p
PCB standoffs — 12 supplied	£1.00 P&P 25p
Ready formed cover for easy assembly	£7.00 P&P £1.50

To use Robot One for the 'Hebot' design you will also require kit HE101 comprising four fibre-glass switch arms, springs and pivots — price to be announced. PCB (kit HE102) is also available for £4.25 plus P&P 25p.

Available from: Remcon Electronics, 1 Church Road, Bexleyheath, Kent. DA7 4DD.