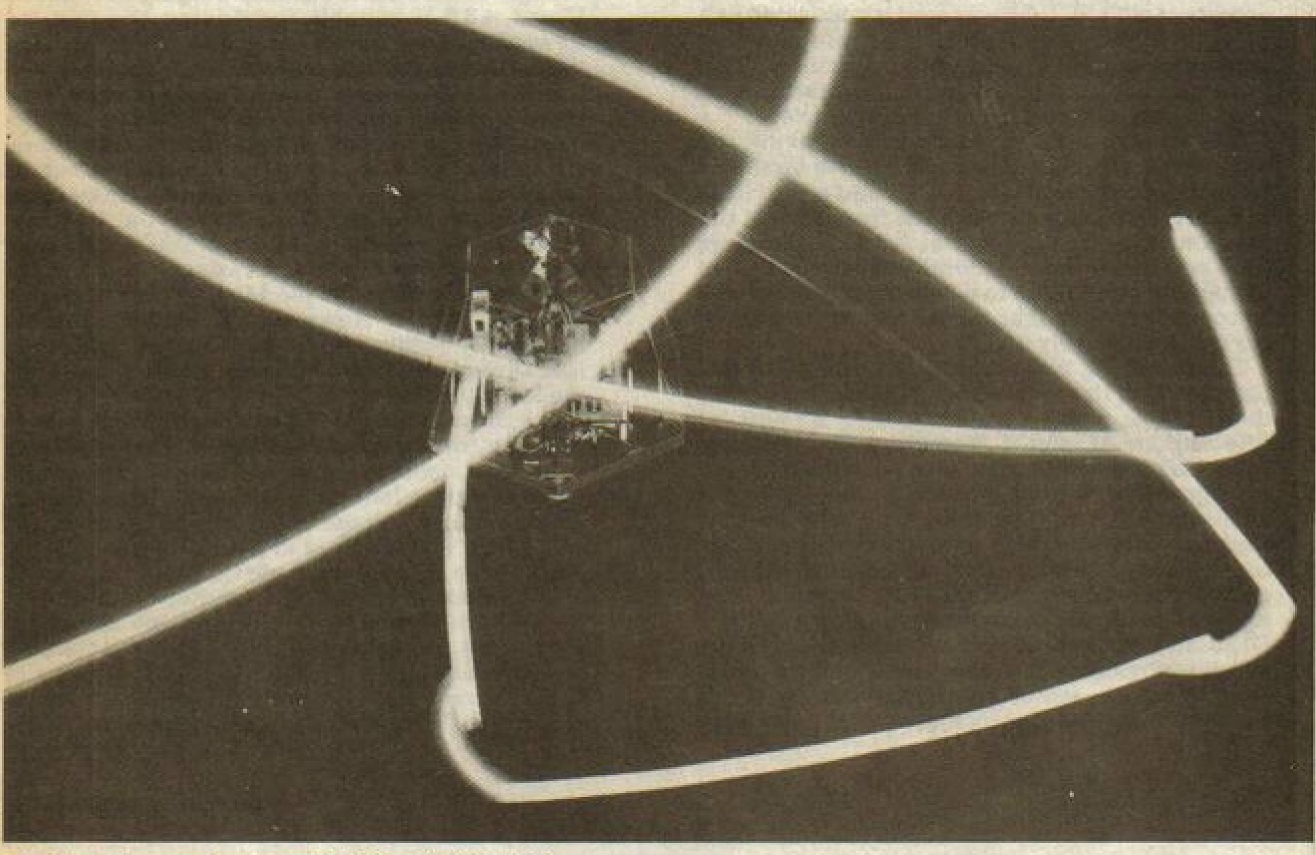
Hebot II

Continuing story of home Hebotics



Time-lapse photography shows HEBOT exploring a maze.

THIS MONTH we will begin to describe how to add sound to the Hebot and sensitise it to light, sound and electromagnetic radiation enabling Hebot to search for and find a recharging nest.

Before describing these functions in more detail, we will take a look at some of the points arising from last month's feature. As described in the text, unused inputs of IC3 should be connected to minus five volts to ensure proper operation of the chip. The uncommitted inputs of IC's 4, 5 may be left floating without any problems. As transmission gates, they are designed to accept any voltage within the supply range at their signal inputs anyway. The motor-servo-amps are very simple and depend for their proper operation on use of a split supply. If Hebot were to travel in one direction only for most of the time then only one half of the battery supply would be discharged. This is unlikely to cause any problems; however, to allow for any subsequent design changes in this section of the circuitry, this month's board has been designed to operate from a single supply voltage. The 'mid-rail' zero volt line is generated electronically 'on-board'. All the CMOS chips are buffered; 'B series', and the capacitors should be sixteen volts working or higher.

TWIST AND SHOUT

The circuitry on the second board described here is mostly concerned with searching and driving towards a light (phototropism) and tracking a cable by detecting an AC energising signal. The details of operation of these circuits will be dealt with fully next month.

The rest of the circuitry enables Hebot to perform a random walk, generate a short tone and respond to loud noises. 'Random walk' is something of a misnomer as Hebot actually executes a series of spirals as shown in our photos enabling him to 'look around' his environment. The circuit which generates this motion is very simple and quite elegant consisting of a single op-amp connected as a conventional astable oscillator. To operate, all you need to do is connect pin 10, IC3 to plus five volts and connect pins A, B to pins 1, 12, IC4 (X 0 Y,0). It does not matter whether A or B goes to pin 1 or 12. This only affects the direction of the spiral motion.

We have also given Hebot a voice. The circuitry around IC5 accomplishes this. IC5 is a 555 timer connected as an astable oscillator whose output is gated on and off by driving the reset input via transistors Q6, 7. Whenever input pin Y is driven to plus five volts, a

How it Works

All the circuitry on this board is powered from the plus and minus five volt supply. Although the junction of the batteries (0 V) is available, an artificial 0 V is generated on-board by R2, 3, C2 and appears at pin 1, IC1. The op-amp is connected as a voltage follower and merely provides a low impedance output to drive other circuitry. This feature enables the board to be operated from a single supply ensuring a more flexible system.

The 'random walk' is produced by driving the servo-amps with signals from an astable oscillator formed by components R4, 5, 6, C1 and one of IC1's amplifiers. The outputs are taken from C1 and the junction of R5, 6 and appear at A and B. Resistors R1, 7 protect the diode networks inside the CMOS multiplexer chips IC4, 5 to which these outputs will be connected. Note that the bottom of R6 goes to pin 1, IC1; effectively 0 V.

The remaining two amps in IC1 and all of IC3 together form the wire tracking circuitry enabling the Hebot to follow a cable back to its nest by detecting an AC signal. There are two identical input stages whose outputs are pins 7, 8, IC1. An AC signal from the sensor coils is coupled to the inputs (pins 6, 9, IC1) by capacitor Cx or directly. Each amplifier operates as a current-to-voltage converter and produces an alternating voltage output. The detection stages are identical. The signal at pin 8, IC1 is coupled via C3 to rectifiers D1, 3 and charges C5 producing a DC voltage which is proportional to the strength of the input signal from the sensor coils. This voltage varies between —5 V and approximately +1 V and appears at pins E, F where it should be coupled to pins G, H. Two of the amps in IC3 are used with resistors R16, 17, 18, 19 to convert the output voltages from C5, 6 to signals swinging between 0 V and +3.5 V suitable for driving the motors forward via the multiplexers and servo amps. The signals appear at pins I and J.

Hebot needs to know whether there is any useful signal at these outputs and this is accomplished by measuring the average voltage across capacitors C5, 6. This signal appears at pin 14, IC3. When it rises above about 0.7 V (measured with respect to Q1 emitter) transistor Q1 is biased 'on' and the voltage at its collector will fall towards —5 V. This signal is input to the Schmitt trigger (pin 9, IC3) and appears inverted at pin M. An identical signal appears at pin L. However, this output may be disabled by pulling pin K to —5 volts. Resistors R25, 26 and capacitor C7 provide a bias voltage for the Schmitt trigger.

The circuitry around IC2 enables Hebot to detect and steer towards a source of light. The two input stages are identical. A current flows through Q2 which is proportional to the incident light. This is converted to a voltage which varies between 0V and +3.5 V and is output at pin 1, IC2 (pin P). The output from Q3 appears at pin Q.

The output levels at P, Q are suitable for driving the motors forward via the multiplexers and servo-amps. Resistors R27, 28, 29 form a potential divider which drives the Schmitt trigger (input pin 9, IC2) whose output is normally 'high' (at about +3.5 volts). When the average voltage at P, Q rises

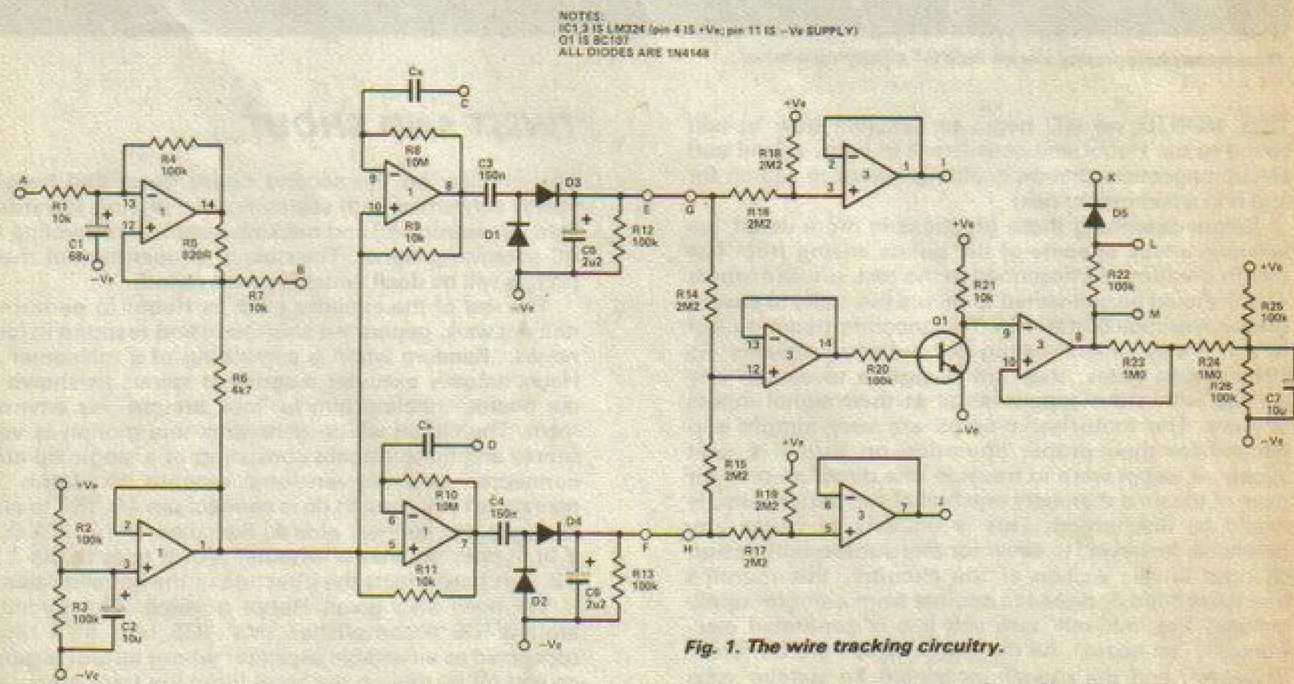


Fig. 1. The wire tracking circuitry.

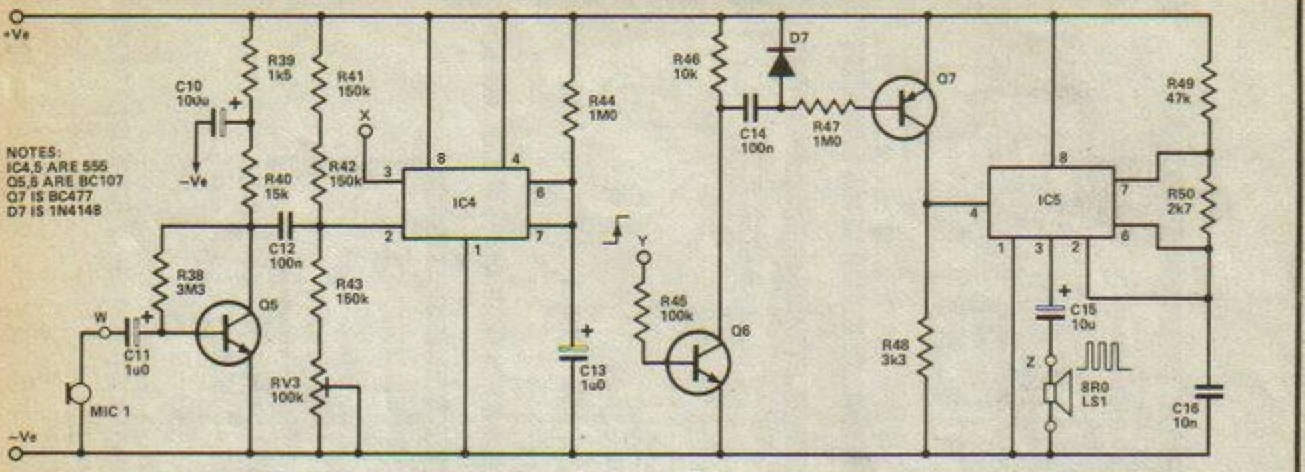


Fig. 2. Sound detection and generation circuitry.

above about 0.5 volts, ie when Hebot sees light, the output of the Schmitt trigger goes 'low' (to about −5 volts) biasing off Q4 and causing the voltage at its collector (pin T) to rise from −5 V to +5 V. This signal is repeated at pin U but may be disabled by pulling pin K to −5 volts.

The remaining section of IC2 may be used to give a visual indication of operation of other parts of the circuit. It is connected as a conventional inverting amplifier with an input resistance of ten million ohms.

With the input (pin S) disconnected, the LED will glow at medium brilliance. Connecting pin S to pin V will cause it to glow brightly indicating a positive input, while connecting a negative input (pin R) will extinguish the LED.

Integrated circuits IC4, 5 enable Hebot to detect and generate sound. Both devices are 555 timers. IC4 will produce a positive output at pin x of monostable period determined by R44, C13 (about one second with the values shown) when triggered by a sound at the microphone, MIC1. The sensitivity of the circuit is set by adjustment of RV3. The trigger input of the chip (pin 2, IC4) is normally held above the trigger voltage of one-third of the supply voltage by bias resistors R41, 42, 43, RV3. Any sound picked up by the microphone produces an alternating voltage at Q5 collector which is coupled to the trigger by C12. A loud noise will produce a signal of sufficient amplitude to trigger IC4. The output signal (pin X) could be used to throw Hebot into reverse, a spin, or just stop him in his tracks.

IC5 produces a short burst of sound each time input Y is taken from −5 volts to +5 volts. Each positive transition of this input causes Q6 collector to go low to −5 volts. This signal, coupled to Q7 by C14, R47 causes the reset input (pin 4, IC5) to be pulled to +5 volts enabling the oscillator to produce a short tone burst. Any digital signal may be input to pin Y. If 'avoid' (pin 12, IC11 board one) is connected, a tone will be produced each time Hebot encounters an obstacle. The loudspeaker is AC coupled to IC5 to avoid excessive current flow. The frequency can be changed by adjustment of R49 or C16.

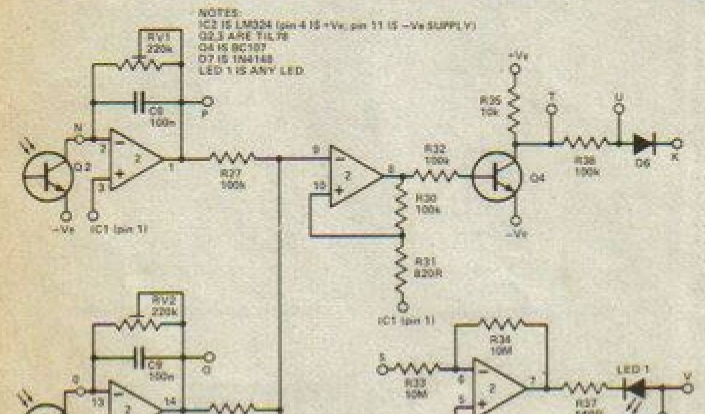


Fig. 3. The light seeking circuitry.

The HEBOT, conceived by the HE design team led by Ray Marston

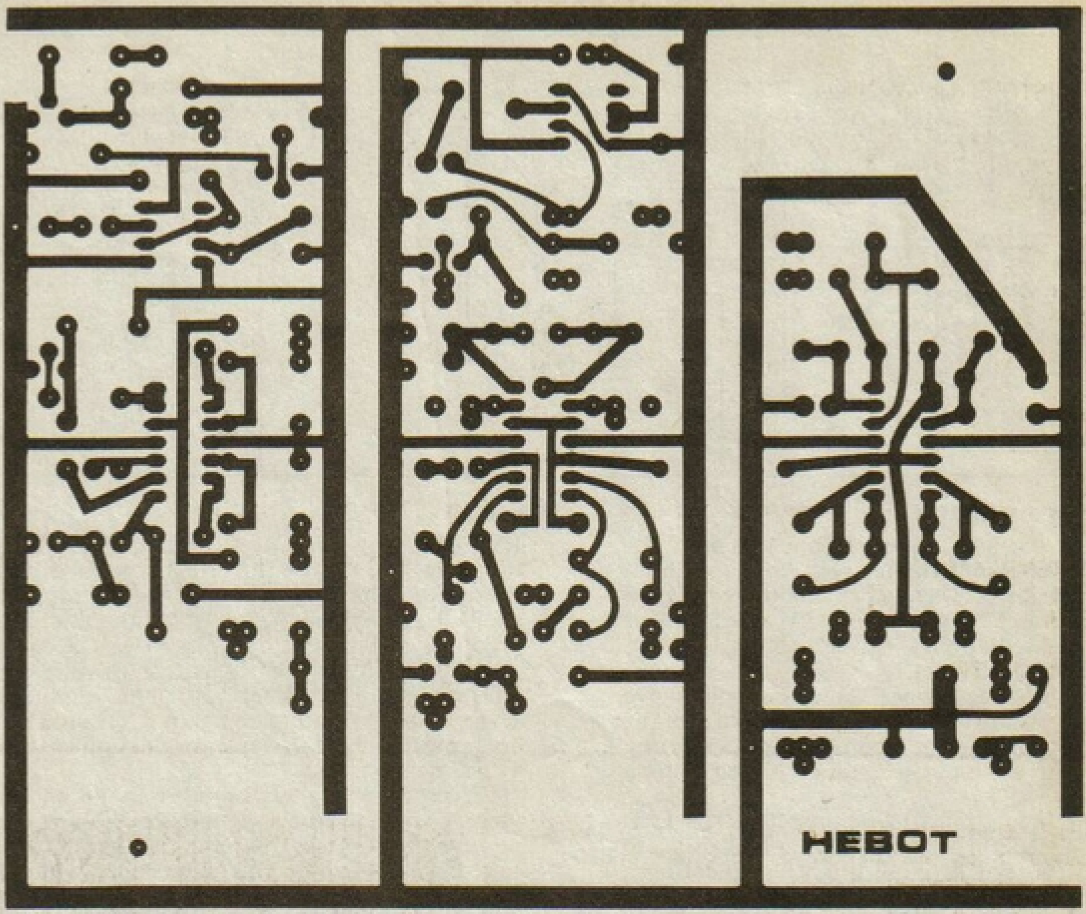


Fig. 4. PCB foil pattern for HEBOT.

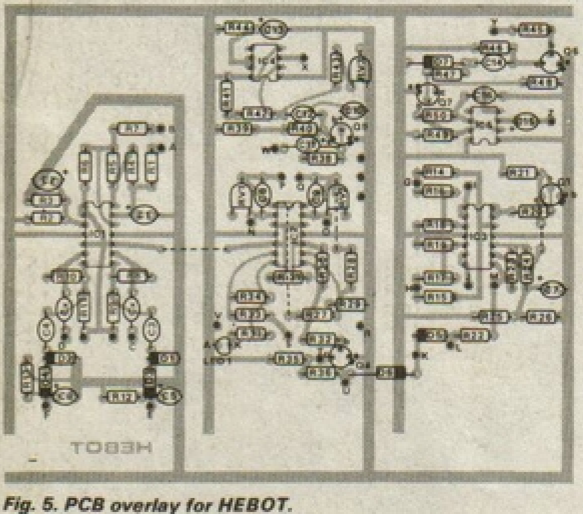
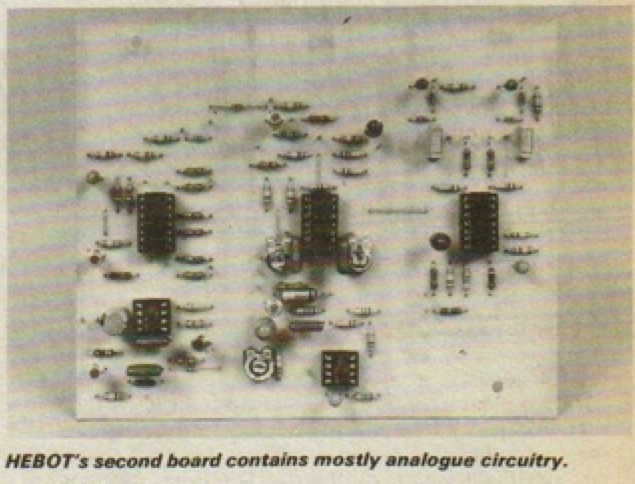


Fig. 5. PCB overlay for HEBOT.



HEBOT's second board contains mostly analogue circuitry.

Buylines

All the components for this board should be readily available from your usual suppliers.

Parts List

RESISTORS (all ¼W 5%)

R1, 7, 9, 11, 21, 35, 46	10k
R2, 3, 4, 12, 13, 20, 22, 25, 26, 27, 28, 30, 32, 36, 45	100k
R5, 31	820R
R6	4k7
R8, 10, 33, 34	10M
R14, 15, 16, 17, 18, 19	2M2
R23, 24, 44, 47	1M0
R29	470k
R37	560R
R38	3M3
R39	1k5
R40	15k
R41, 42, 43	150k
R48	3k3
R49	47k
R50	2k7

POTENTIOMETERS

RV1, 2	220k
RV3	100k

CAPACITORS

C1	68µ tantalum
C2, 7	10µ tantalum
C3, 4	150n polyester
C5, 6	2µ2 tantalum
C8, 9, 12, 14	100n polyester
C10	100µ tantalum
C11	1µ0 electrolytic
C13	1µ0 tantalum
C15	10µ electrolytic

SEMICONDUCTORS

Q1, 4, 5, 6	BC107
Q2, 3	TIL 78
Q7	BC 477
D1 thru D7	all 1N4148
IC1, 2, 3	LM324
IC4, 5	555

MISCELLANEOUS

MIC1	any microphone (crystal or balanced armature inserts work well)
LS1	any loudspeaker (we used an 8 ohm 1½ inch loudspeaker)
PCB, IC sockets, terminal pins	
LED1	any LED (we used TIL 220)

short tone is produced. If you connect pin Y to the 'avoid' output of last month's board, Hebot will emit a surprised squeak following each collision.

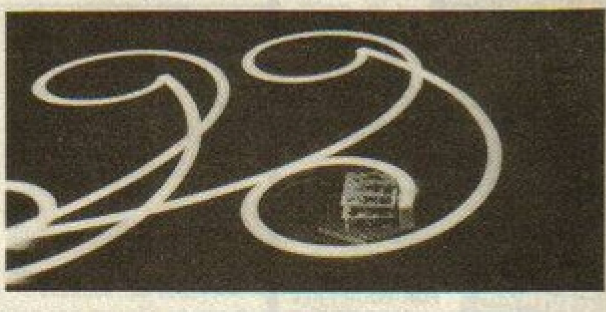
The other 555 is used with Q5 to detect sounds. Hebot can be made sensitive to loud noises by adjustment of RV3. Any sufficiently loud noise will cause the 555 output (pin X) to rise from minus to plus five volts for about one second. Pin X may be connected to any of the inputs of IC3 (only one connection to each input though!) to make Hebot select control from any X, Y set of inputs. If pin X were connected to input '7' (pin 4, IC3 board one) and X7 (pin 4, IC5) were connected to plus five volts with Y7 (pin 11, IC5) connected to minus five volts then Hebot would execute a spin following each loud noise. Note that in this case, the avoid manoeuvre circuitry would be inoperative as level seven has the highest priority.

CONSTRUCTION

Use of our PCB is essential (try putting it together on 'S-DEC!). The wire links should be inserted first; note that one passes beneath an IC holder. Sockets are recommended though none of the chips on this board are sensitive to static discharge. The other components may be inserted in the usual order; resistors, capacitors and semiconductors. Take care not to overheat any components and beware of shorting copper tracks with solder bridges as some of them pass quite close to each other. Also, of course, note the polarity of the semiconductors, IC1, 2, 3 point up while IC4, 5 point down.

Do not be afraid to experiment with other configurations than the ones described and try designing your own circuitry. Make Hebot a vehicle for *YOUR* ideas.

HEBOT's avoidance manoeuvre (above) and the 'random walk' (below).



Next month's article will describe the beacon circuitry and ni-cad charging unit with a pin by pin account of how to get the rest of the circuitry up and running and elicit express action from the educated electrons as they run around the tracks. Chips with everything . . . don't miss it!

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