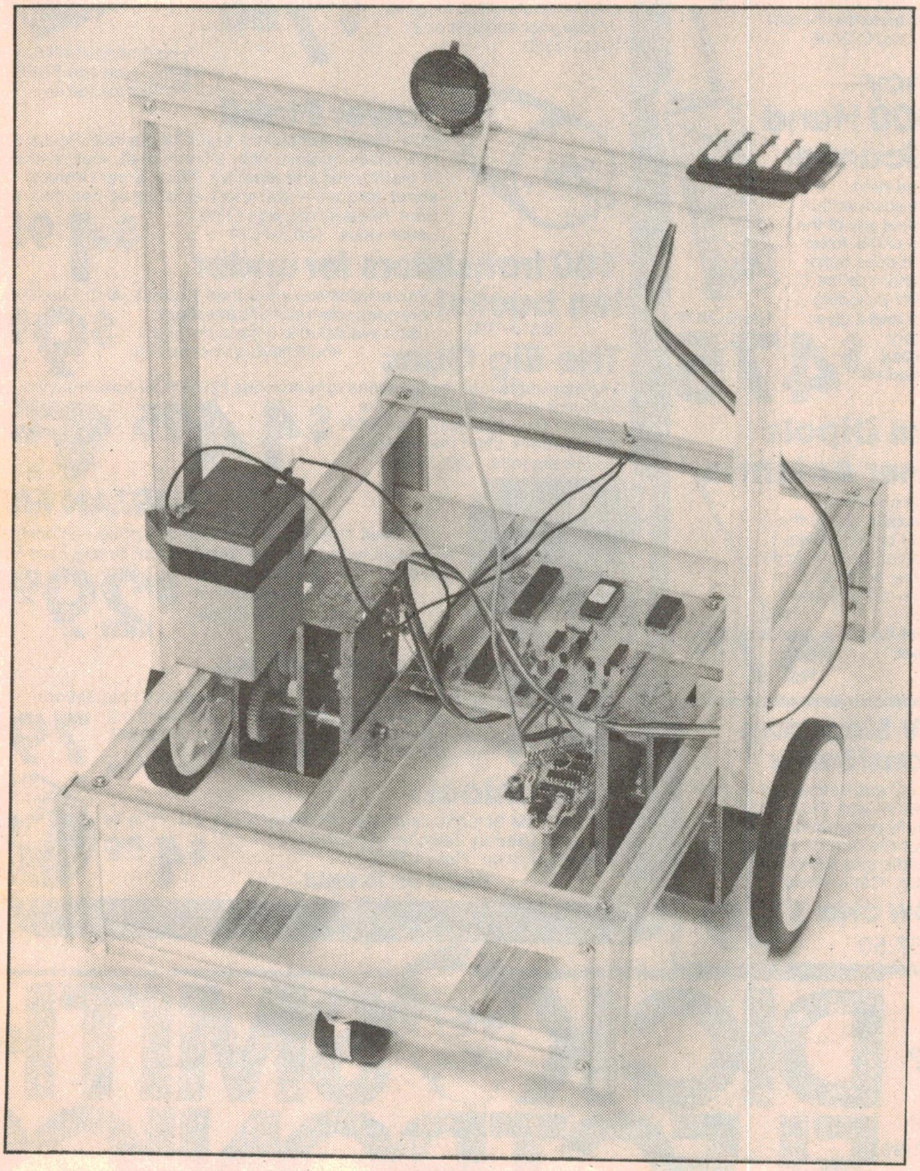
Project 664

HOBBYBOT Part 1

Allan Branch

easy-to-build navigating robot

This all-Australian designed, do-it-yourself robot can be programmed to do countless navigable tasks. You can use it just for fun or teach it to do practical things like following you while you work, carrying tools or food. You can even send it around the house on its own, performing various tricks.
In Part I we show you how to build your Hobbybot then in Part 2 (in next month's ETI) we'll show you how to program it.



SINCE THE PUBLICATION of the Tasman Turtle (ETI, April 1982) we've experienced a dearth of robot projects in Australia to cater directly for the electronic and computing enthusiast. Sure, there have been a number of personal robots available, but they have not been able to attract the large 'enthusiasts' market because they are too expensive or they do too little. Besides they are not designed to be customised by the purchaser.

With 'Hobbybot', all of that is about to change. This is a robot designed especially for the experimenter! It's a versatile, low-cost unit, which can be easily adapted or modified to suit your needs. And to make things simple a complete kit containing all of the hardware, electromechanics, microprocessor, software in EPROM and electronic circuitry has been developed.

You will be able to send your self-contained Hobbybot around the house, performing various types of behaviour, by programming it with an easy-to-use controller included in the kit. No external computer is used and no prior knowledge of computers, programming or electronics is required.

If you're feeling innovative and have some adventurous ideas, the kit will pro-

THE DESIGNER — ALLAN BRANCH

Allan Branch, principal of Branch & Associates Pty Ltd of Glenorchy, Tasmania, has worked in Hong Kong and Japan on personal robots ('Elami' and 'Tomy's Omnibot' are adaptations of his original work) and in the USA as director of robotics for Commodore Business Machines, where he designed 'Chester'. He is a world leader in the implementation of autonomous navigation on mobile devices and has recently been granted research funds totalling $300,000 by the State government of Tasmania and the Federal government to develop navigation and guidance for industrial and defence robot applications.

In the April 1982 issue of ETI we published a D-I-Y educational robot, the 'Tasman Turtle', designed by Allan Branch when he was with Flexible Systems. This robot proved extremely popular both for educational and general applications. It and its successor, the 'Turtle Tot', have since gone on to capture the world market in educational robots.

'Hobbybot' and a new robot called 'Blinker' demonstrate Allan Branch's on-going commitment to developing useful and enjoyable household robots for people who want to participate in this exciting new technology.

Table 1. KEYPAD COMMANDS

Manual Commands: F B L R Stop
Program Control: REPEAT, WHILE, IF/ELSE DELAY
User Control: LEARN RUN COMM
Numerical: = > VAR RANDOM
Digits: 0 1 2 3 4 5 6 7 8 9
Parsing: { } , CLEAR
Peripheral Control: PORT RANGE

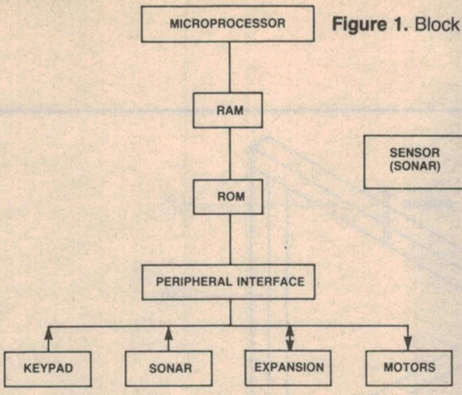


Figure 1. Block diagram.

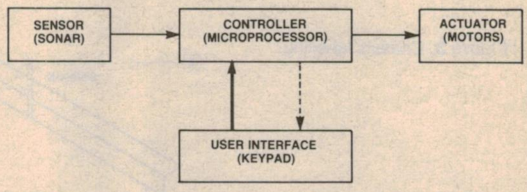
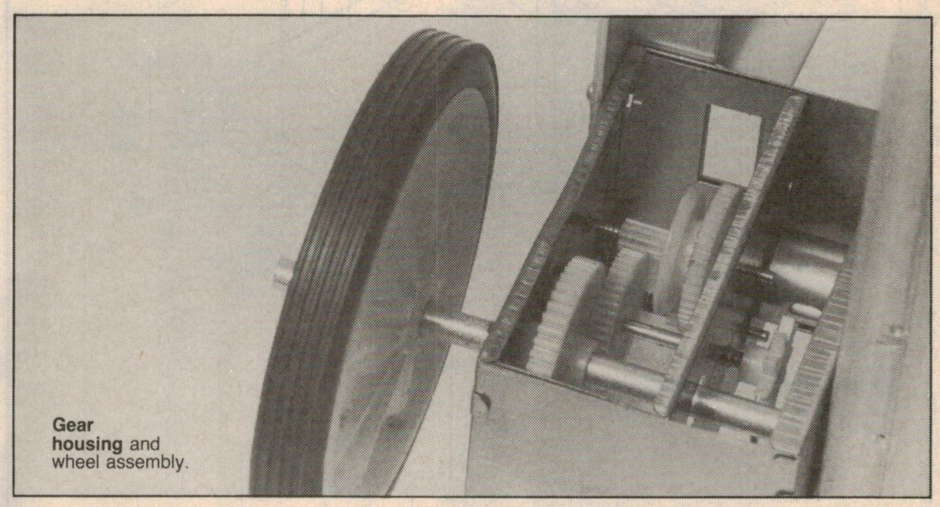


Figure 2. In-out diagram.


Gear housing and wheel assembly.

vide the starting point for your own experiments in robotics. Your own specialised sensors and actuators, or even additional electronic pc boards, can be attached to the Hobbybot and interface, increasing the power of its microprocessor 'brain'. Or the control software can be replaced by your own programs to give your Hobbybot its own 'personality'. Again you can expand the artificial intelligence of your Hobbybot by connecting it to your personal computer.

The design

The Hobbybot consists of several major parts — an aluminium frame, motor/gearboxes, ultrasonic sensor and pc board, microprocessor board, and ancillary hardware. The Parts List gives a complete rundown of the components needed to build the robot. These can be purchased separately or in the ready-to-assemble kit form mentioned above, which is available from Allan Branch & Associates (see Shoparound). The only other things you'll need are the batteries and the tools.

Chassis and frame

The bulk of the kit is made up of pieces of aluminium bracket (25 x 25 x 3 mm) which when assembled form the robot chassis.

The chassis has been designed to allow the circuit boards, batteries, gearboxes and sensor to mount conveniently, leaving plenty of room for your own additions at a later time. Across the top of the chassis a single frame holds the sensor and also serves as a handle for you to move the Hobbybot around or to pick it up. A robot arm could be designed to use this frame as a 'shoulder' support for holding motors and associated electronics.

Motors, gearbox, wheels

The Hobbybot has two motors, each able to provide 20 kg force from around 200 mA. This is more than enough to move the unit around most floor surfaces and to carry additional loads. A small castor completes the classic three wheel base traditionally found on mobile devices from turtles to wheelchairs.

Sensor

The basic project uses an ultrasonic sensor instead of touch switches, however switches can be easily added. Indeed, a depth switch mounted under the robot would make a good 'edge detector' for avoiding stairways, etc.

The sensor for this basic project is a Polaroid sonar device. We mounted ours on the top of the aluminium frame, but you can choose a different place if you prefer.

The Hobbybot's interface circuit is more suitable for microprocessor interfacing than the original Polaroid pc board. Techniques for using multiple sensors are given later, so you can place sensors all over the robot if you wish.

The controller

The controller is a 4 x 3 keypad. If further software projects are designed the keys will take on functions as required, however our first EPROM uses the keys according to Table 1.

By pressing the keys in a sequence determined by the required action, you will be able to program the Hobbybot even if you do not have any prior experience with a high level computer language. It is much like programming in the more advanced languages like 'C' and LOGO — simple programs can be written immediately and there is no limit to the eventual complexity you will be able to build into later programs.

It is possible to put an infrared link on the controller, but in the basic project it is connected to the Hobbybot by a seven strand ribbon cable. You will need to put labels on the keypad to indicate the functions.

The main pcb

Except for the sonar interface all electronics are on the main pc board. This board holds the microprocessor, EPROM, RAM, PIA and associated logic as well as the voltage regulator and clock oscillator. The keypad, batteries, sonar interface and motors are all plugged into it.

An expansion port is provided so that you can add your own gadgets, and provision is made for a personal computer to be interfaced directly to the robot.

The complete circuit diagram can be considered in two stages. Firstly, there is the 6502 microprocessor and its associated electronics. This is a fairly conventional circuit with a 2K RAM in the form of a 6116 (IC4) and a 2764 8K EPROM (IC3) which holds the special robot language software. The highest three address lines — A15, A14 and A13 — are used to select eight different 8K blocks of the possible 64K address space of the 6502. Address decoding is done by the 74LS 138 logic chip, (IC7), however only four blocks are used in the Hobbybot. They are RAM, EPROM, EXPANSION and INTERFACE. ▶

Figure 3. Chassis labelling.

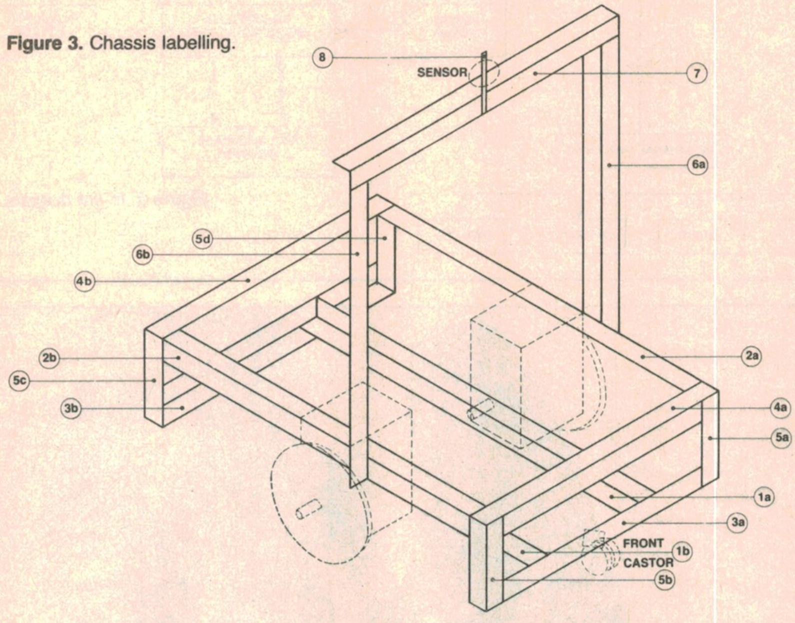


Figure 4. Wheel/gearbox assembly.

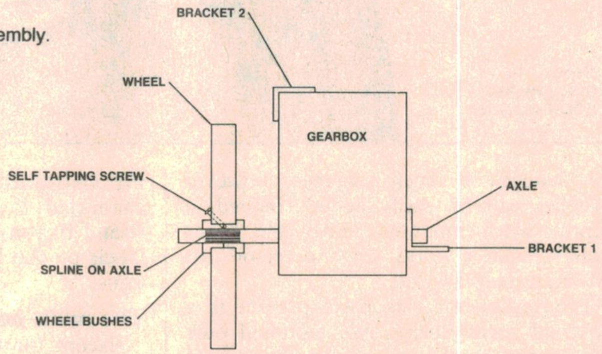


Figure 5. Castor (from under the robot).

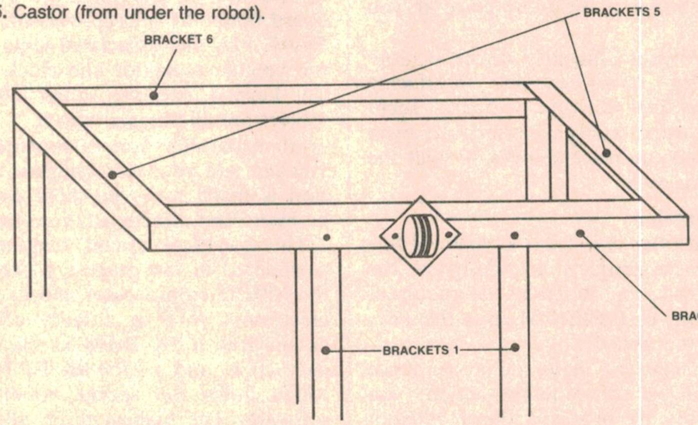
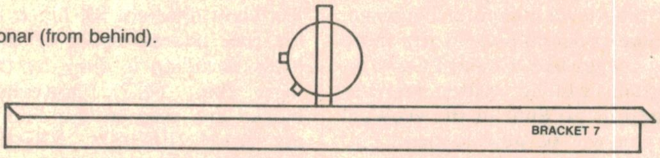


Figure 6. Sonar (from behind).



The second part of the circuit connects the microprocessor to the other robot parts. It uses a peripheral interface adaptor, called a PIA (IC1, 6821), for controlling the sonar range finder and the robot drive motors, as well as for reading the keypad.

All control functions are handled by the software in the 2764 (IC3) and hardware functions are straightforward.

Batteries

Many battery configurations can be used to power the Hobbybot. As on-board voltage regulation is provided you can choose from dry cells, NiCads or gel cells. Although reasonably expensive, gel cells are recommended because they can be used in any position — a distinct advantage considering that the Hobbybot is a mobile device! In the long run they will also be the most cost effective.

To begin with, however, the kit can be powered with D-size batteries which will give acceptable life.

When completed the robot will require 6 volts dc at approximately 500 mA.

What can the robot do?

Figure 1 shows a block diagram of the Hobbybot electronic system. To help the experimenter, circuitry has been kept as uncomplicated as possible. Basically there is a conventional microprocessor system consisting of the Hobbybot program stored in EPROM, some RAM to store your instructions as entered via the controller, a 6502 microprocessor and an interface circuit to the rest of the robot.

In this basic configuration the Hobbybot can be represented as in Figure 2, which shows an in-out diagram typical of a large number of open-loop systems.

The control software (in EPROM, IC3) is able to read the sensor and actuate the drive motors according to instructions given at the keypad. Provision is made for the controller to indicate any relevant information directly back to you via green LED2. Of course you can also verify the program by watching what the robot does — as this is an indirect method it is shown as a dashed link in Figure 2.

A complete programming language has been written especially for this project.

The source code, written by Branch & Associates' senior programmer John Colegrave, includes a set of commands and features that give you powerful tools with which to instruct Hobbybot. Taking a reading from the sonar, for example, is accomplished simply by entering the command RANGE. Moving the robot is done just as easily by entering one of the motion commands such as FORWARD. These commands can be inserted in high level instructions such as WHILE-DO, IF-THEN-ELSE, REPEAT X TIMES.

As well, you can store up to 10 separate programs in RAM and even call other programs within current programs.

The following program, which enables your Hobbybot to follow walls around your house in a clockwise fashion, gives an example of the power of control language:

REPEAT {LEFT 3, WHILE 35 > RANGE {RIGHT 1}, RIGHT 2, FORWARD 3}

By using the controller you can easily instruct your Hobbybot to follow people, look for doorways or repeat lists of movement commands.

Construction

To construct the Hobbybot, begin with the aluminium frame followed by the electronic pc board then the peripherals.

Frame assembly

Putting the Hobbybot frame together is not much different from playing with a mechano set.

Figure 3 and the accompanying photograph will help in assembling the gearboxes, wheels and various pieces of angle bracket that make up the chassis. Be careful that the correct mirror image pieces are used since the brackets come in right and left handed pairs. To arrange the pieces see the list of chassis parts.

Start by loosely assembling the frame using brackets 2, 3, 4 and 5.

Then attach a wheel to each gearbox, on the longer end of the axle. (See Figure 4.)

Next loosely attach the gearboxes to brackets 2a and 2b, slide brackets 1a and 1b over the short axle of the gearboxes, and attach them to brackets 3a and 3b.

Make sure all the brackets are squarely set, then tighten all the screws. *Do not tighten any of the screws until this point to ensure a tension-free structure, which is essential for long life of both the gearbox and the drive mechanism.*

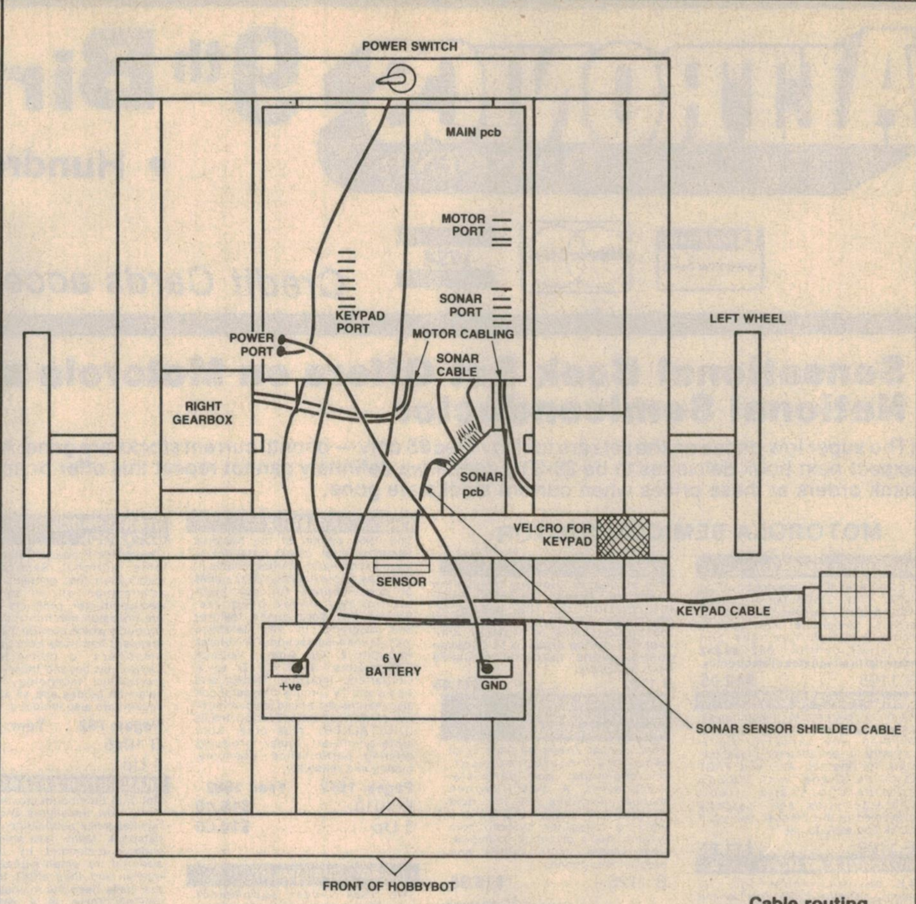
Now loosely assemble the handle using brackets 6 and 7, and fix it to brackets 2a and 2b on the frame. Ensure that the handle is sitting square and tighten all screws.

Fix the castor on to bracket 3 at the front of the frame (see Figure 3) with the diagonal holes of the castor's plate sitting as in Figure 5.

Finally, fix bracket 8 to bracket 7 and slide the sonar sensor into place, making sure that it is facing in the direction of the castor (see Figure 6). If you wish to, you can bend back the free end of bracket 8 to doubly ensure the security of the sensor.

Main pcb

Now that the frame is assembled with sonar sensor, gearboxes, motors, wheels and castor all in place it is time to prepare the electronics.



Cable routing.

After checking that you have all of the pcb components listed in the Parts List, solder in each socket taking care to ensure correct orientation. Only sockets for IC1, IC2, IC3 and IC4 are provided since these semiconductors are expensive to replace if accidentally overheated during soldering. (Before soldering, check that all the pins are through the pcb and not bent under the socket. Check also that no tracks are shorted together when you solder the pins.)

Next cut to length the 21 short jumper links required on the pcb. The cost of the pcb is considerably reduced by keeping it single sided, but the trade-off is that these links are required. Don't try to make the links too exact since they will be difficult to position. A moderate loop is quite satisfactory.

Resistors and ceramic capacitors are next to go in. The electrolytic capacitors' leads are marked negative (−); the positive (+) leads are longer.

The two LEDs, electrolytic capacitors and transistors must be inserted the correct way round. If not, they will be permanently damaged! The component overlay shows the three leads of the transistors from the component side of the board. Be careful not to overheat the transistors when soldering them in.

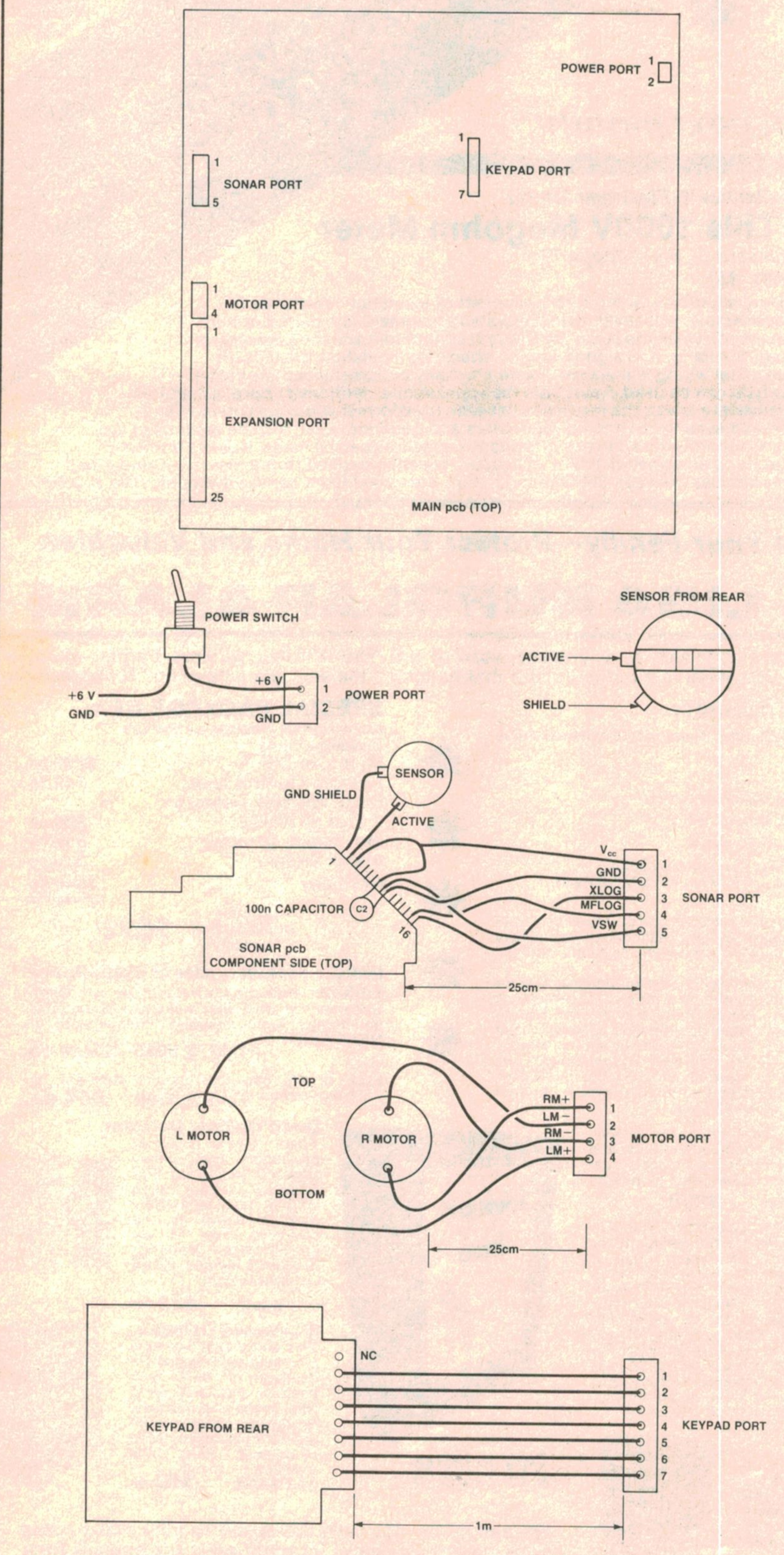
Both a green and a red LED are needed — the red as a power indicator and the green as a syntax error indicator. The red LED1, to be situated near-IC14, the 7805 voltage regulator, goes in next followed by the green LED2. The long lead of the LED is the positive one.

Refer to the component overlay for orientation of IC14 and solder it in next followed by the crystal.

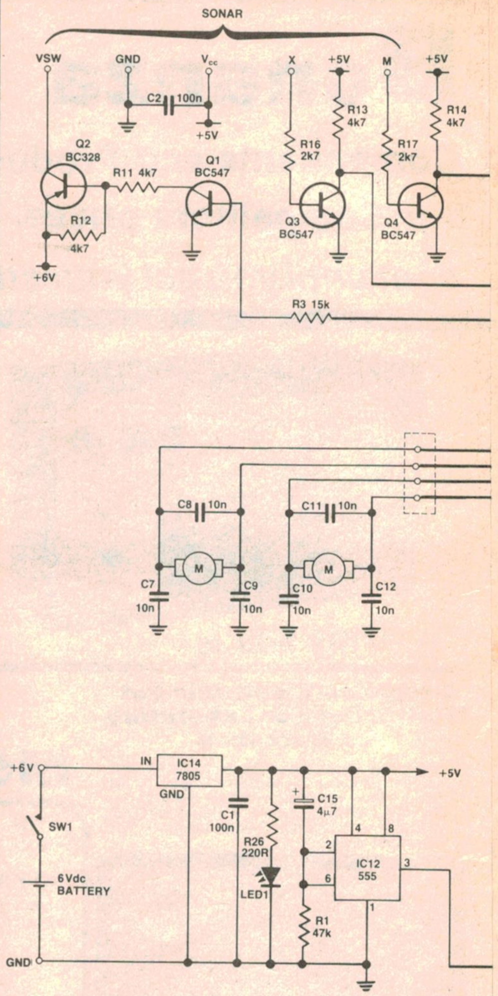
Finally, solder in the integrated circuits which do not have sockets. Some of these are CMOS chips (IC5, IC6, IC8) and should be handled carefully to prevent static charges. Hold them only by the plastic body and solder in pins 8 and 16 first. If you are an inexperienced solderer you should consider buying extra sockets for your kit so that you don't damage the ICs. Again, don't overheat the chips. It's a good idea to go along each IC sequentially, soldering in only one pin on all the ICs then repeating for the other pins. This allows each chip to cool before you come back to solder the next pin.

Cables and peripherals

Now it's time to prepare the expansion cables to connect each port of the main pcb to the peripherals. These are the motors, keypad, battery and sonar pc board. Divide the rainbow cable to form a five strand length and a seven strand length, for the sonar and keypad respectively. Leave the seven strand length one metre long, but cut the sonar cable to 25 ▶



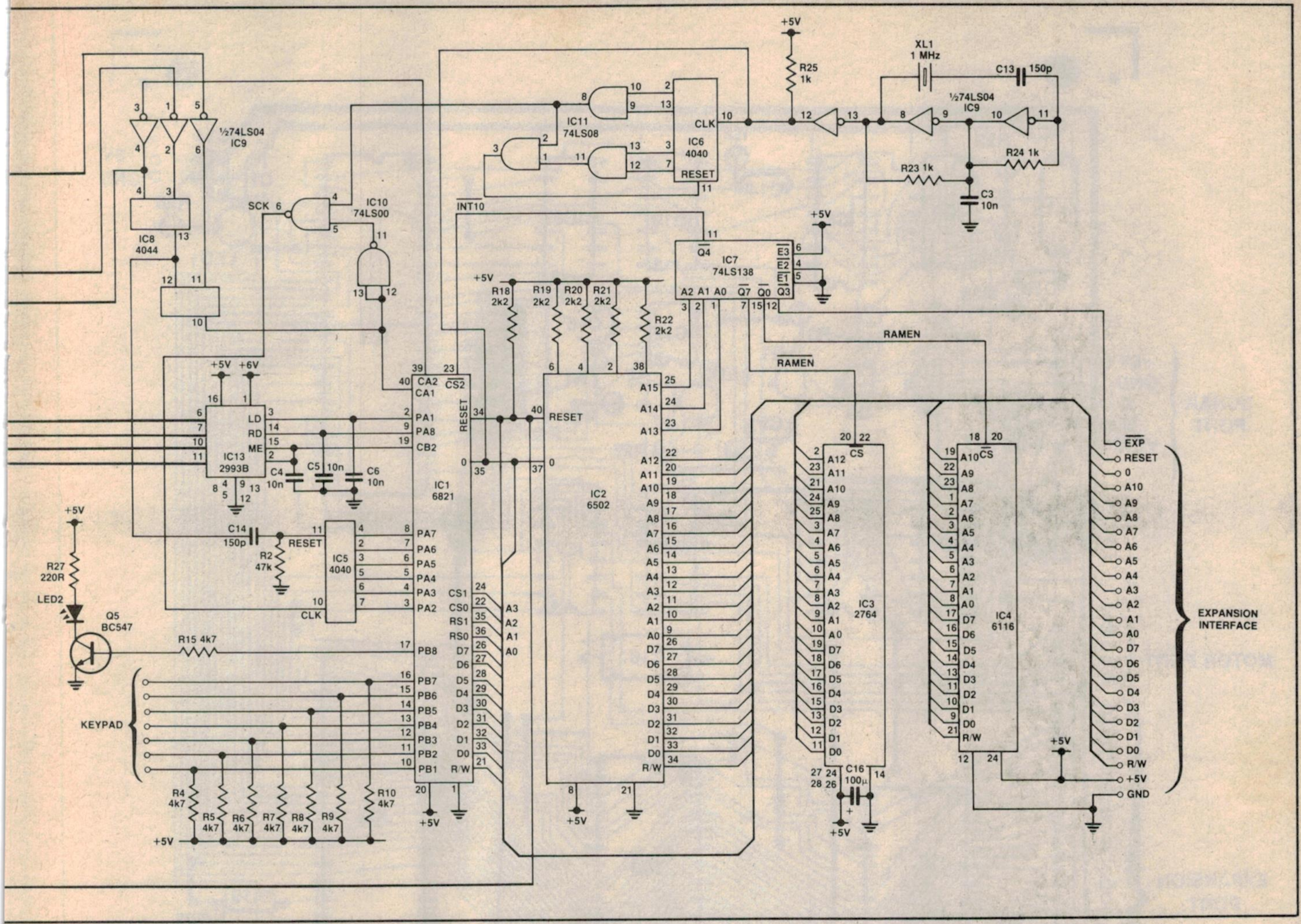
Wiring diagram.



HOW IT WORKS — ETI-664

On power up capacitor C15 brings Vcc (5 V) to pins 2 and 6 of the '555 timer (IC12). This condition keeps the timer output pin 3 low. The low signal resets the CPU (IC2) and the PIA (IC1) on power up. As C15 gradually discharges through R1, pin 2 of IC12 goes low and a high is generated on pin 3 of IC12, allowing the CPU and the PIA to come out of the reset condition simultaneously. The CPU will output addresses FFFF, FFFE (in HEX) to fetch the reset jump vector stored in the EPROM (IC3) where the starting address of the control program is stored, allowing the controls to start to execute the instructions.

IC1, the 6821 PIA is responsible for communicating with the controller (basically IC1, IC2, IC3, IC4, IC7) and with the peripherals. Seven bits of port B (PB1-PB7) of the PIA are dedicated to the 4 x 3 matrix keypad. With the help of IC13, the two motors could be controlled by just three lines from the PIA. Six bits (PA2-PA7) from port A are used to check the output of a counter, which starts counting once a pulse is sent to enable the sonar. The reflected ultrasonic echo generates a transition to CA1 (pin 40 of IC1). The PIA is programmed to trigger an interrupt to the CPU whenever an edge is detected by CA1. The same transition also stops the counter and the value of the delay time (hence the distance) is directly available to PA2 to PA7. The interrupt routine will scan the value and react accordingly.



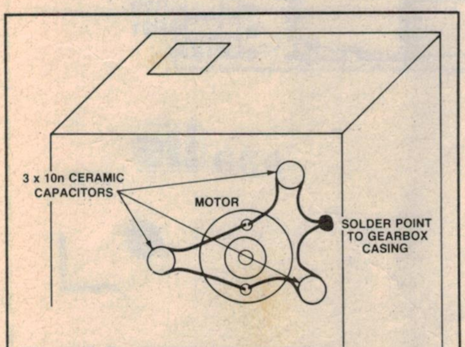
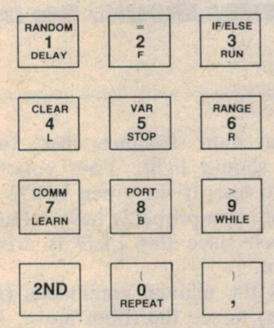


Figure 7. Suppressor caps on motors.



Keyboard layout.

cm. Strip, then tin each strand at both ends and pass them through the strain relief holes on the main pcb, from the bottom. Solder them to the corresponding donuts on the pcb. The other end of each cable will be soldered to the sonar pcb and the keypad according to the wiring diagram.

When connecting the five strand cable (25 cm long) to the sonar pcb, solder to the top of the designated pins on the angled edge of the odd-shaped sonar pcb. Pins 3 and 8 are joined with a short jumper and then a 0.1 μF ceramic capacitor is soldered across the Vcc and ground pins on the pcb itself.

Connect the battery wires (the heavier cable) to the switch and power port of the pcb as shown (in the diagram) and then connect the motors to the motor port. Figure 7 shows how to connect the three suppressor capacitors at each motor by soldering across the motor lugs and to the gearbox.

Don't be anxious to turn on the power to the main pcb yet as it is possible to damage the sonar pcb if everything is not connected correctly. Wait until the final checklist is completed.

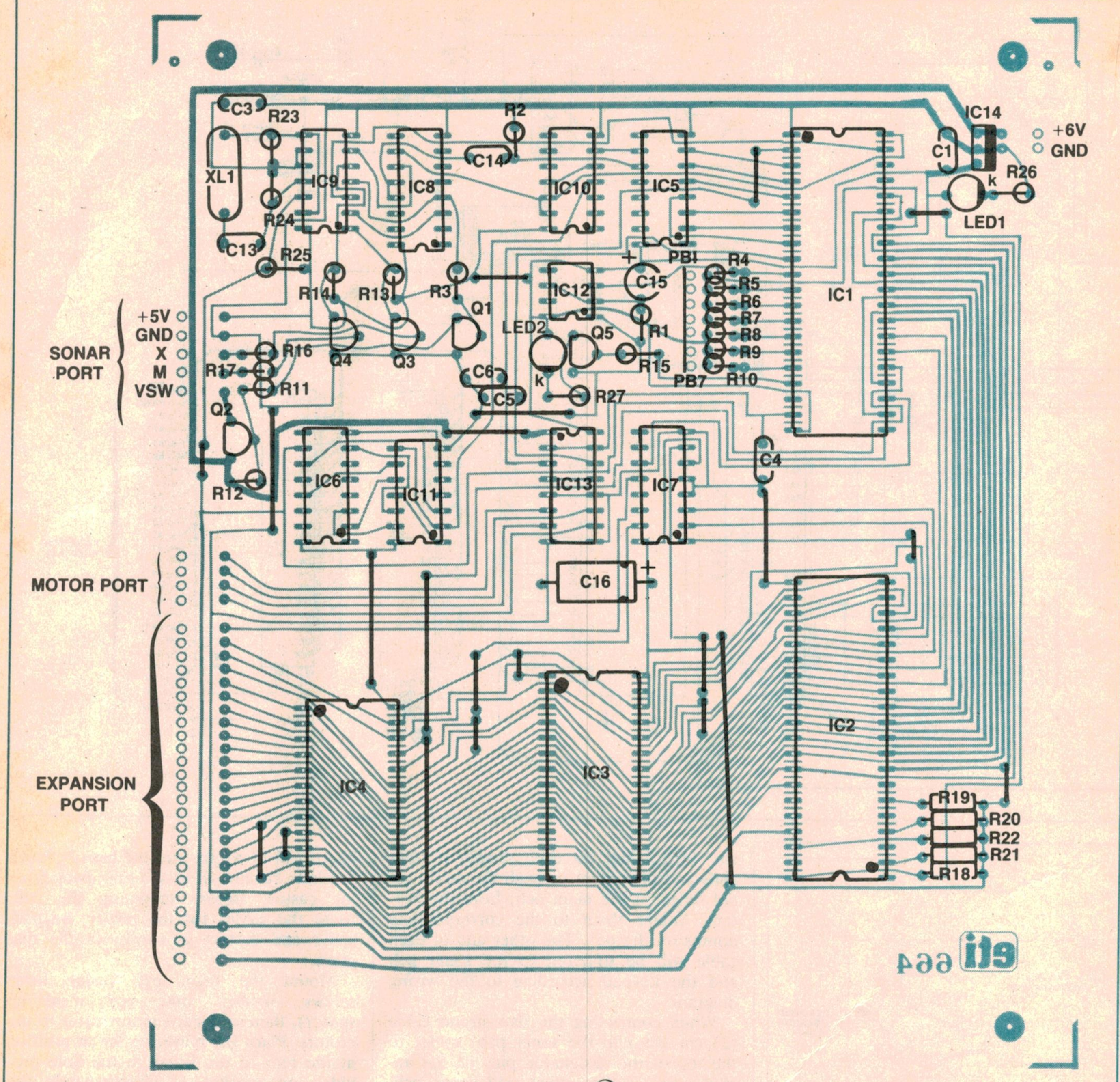
You should now have the main pcb ready to mount on the robot frame. The board will fit neatly into the base between brackets 1a and 1b at the end away from the castor. Before mounting the pcb, route the cables for the power, keypad, sonar and motors as shown in the diagram.

Mount the main pcb (using three screws, washer, nuts and insulating spacer), then solder the motor wires to the motors. Place the power switch in position at the rear of the frame in the hole provided on bracket 4. Unfortunately the sonar pc board comes as a package with the transducer and has only one decent mounting hole. Enlarge the small hole near the connector on the sonar board and mount the board on plastic standoffs near the robot's left hand gearbox.

Use the Velcro to attach your keypad to a convenient place on the robot's top frame and label the keys using the keypad cut-outs. Finally, connect the sensor to the sonar pcb and the power leads to the battery.

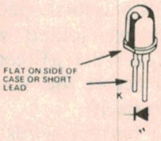
Test and start-up

By now the main pcb should have four cables emanating from each of the power, keypad, motor and sonar ports. The main pc board and sonar pc board should be separated from the aluminium frame by ▶



NOTES: C2 IS SOLDERED ON TO SONAR BOARD OUTPUT

C7,8,9,10,11,12 ARE SOLDERED ON TO THE MOTORS AND GEARBOXES



For a guide to components and kits for projects, see SHOPAROUND this issue.

four insulating spacers. The shielded cable should be connected securely between the sensor and the sonar pcb. The power leads should be correctly oriented, with the positive (+) lead going from the battery to the switch to the main pcb.

When you are sure these details are taken care of, you are ready to try it out. Remove each of the four main semi-conductors from their sockets. Turn on the power switch — the red LED1 should glow instantly. If not, check the power leads to the board and ensure your batteries are not discharged. If the green LED2 came on, the red LED1 is probably in the wrong way.

If all is well, turn the power off and replace the semiconductors. Turn on the power again. This time after the red LED1 goes on, the robot should jump forward a short distance then the green LED2 should light. Your robot is now ready to test. If the green LED2 does not come on, you probably have a fault on the main pcb since this LED is driven from software.

Press the manual commands (F, B, L, R, Stop) to see the robot move. If the directions and responses don't match, you have connected the motor wires incorrect-

CHASSIS PARTS

Brackets 1a, 1b
2 pieces × 460 mm long
To fix to gearbox:
2 short screws
2 flat washers
2 star washers
2 nuts

Brackets 2a, 2b
2 pieces × 460 mm long
To fix to gearbox:
2 long screws
4 flat washers
2 star washers
2 nuts

Brackets 3a, 3b
2 pieces × 317 mm long
To fix to brackets 1a, 1b:
4 screws
4 flat washers
4 star washers
4 nuts

To attach castor:
2 screws
2 flat washers
2 star washers
2 nuts

Bracket 4a, 4b
2 pieces × 317 mm long
To fix to brackets 5a, 5b, 5c, 5d:
4 screws
4 flat washers
4 star washers
4 nuts
To fix to brackets 2a, 2b:
4 screws
4 flat washers
4 star washers
4 nuts

Brackets 5a, 5b, 5c, 5d
4 pieces × 106 mm long
To fix to brackets 3a, 3b:
4 screws
4 flat washers
4 star washers
4 nuts

Brackets 6a, 6b
2 pieces × 382 mm long
To fix to brackets 2a, 2b:
4 screws
4 flat washers
4 star washers
4 nuts

Bracket 7
1 piece × 366 mm long
To fix to brackets 6a, 6b:
2 screws
2 flat washers
2 star washers
2 nuts

Bracket 8
1 piece × 70 mm
To fix to bracket 7:
2 screws
2 flat washers
2 star washers
2 nuts

PARTS LIST — ETI-664

Resistors.................all ¼ W, 5% unless noted
R1, 2......................47k
R3..........................15k
R4-15......................4k7
R16, 17....................2k7
R18-22.....................2k2
R23-25.....................1k
R26, 27....................220R

Capacitors
C1, 2......................100n ceramic
C3-12......................10n ceramic
C13, 14....................150p ceramic
C15........................4μ7 electro
C16........................100μ electro

Semiconductors
LED1.......................red 5 mm
LED2.......................green 5 mm
Q1, 3, 4, 5................BC547
Q2.........................BC328
IC1........................6821 PIA
IC2........................6502 microprocessor
IC3........................2764 EPROM
IC4........................6116 static RAM
IC5, 6.....................4040
IC7........................74LS138
IC8........................4044
IC9........................74LS04
IC10.......................74LS00
IC11.......................74LS08
IC12.......................LM555
IC13.......................UDN 2993B
IC14.......................7805
XL1........................1 MHz crystal

Miscellaneous
SW1........................SPST toggle
Frame......................4 x 460 mm, 2 x 382 mm, 1 x 366 mm, 4 x 317 mm, 4 x 106 mm, 1 x 70 mm — aluminium angle
Cable......................1 m 12 strand ribbon
500 mm powerflex
200 mm single shielded flex
Sockets....................2 x 40 pin sockets
1 x 28 pin sockets
1 x 24 pin sockets
Screws, etc................26 x ½″ x ⅛″
8 x ¾″ x ⅛″
38 x flat washers
34 x star washers
4 x spacers

TI sonar pc board; ETI-664 main pc board; sonar sensor; keypad; 2 wheels; castor; 3 cm Velcro; 8 cm x 5 mm copper strip; 2 gearboxes.

Price estimate: $337

ly. Now press LEARN 1. The green light should go out indicating that the robot is in learn mode. Press F2, B2 then press COMM. (COMM is a 2ND key-function and you need to press the 2ND button then the COMM button. This is similar to a shift function except after the COMM button is pressed, the keypad is back to the 1ST key-functions again.)

When COMM is pressed, the green light should come back on. Now press RUN 1. Your simple program F2, B2 should be executing.

If at any time the green LED2 starts to flash you have made a keypad error and need to press CLEAR before continuing (remember 2ND then CLEAR).

Your Hobbybot is now ready for you to program fully. Watch out for next month's ETI for complete details of the software! ●