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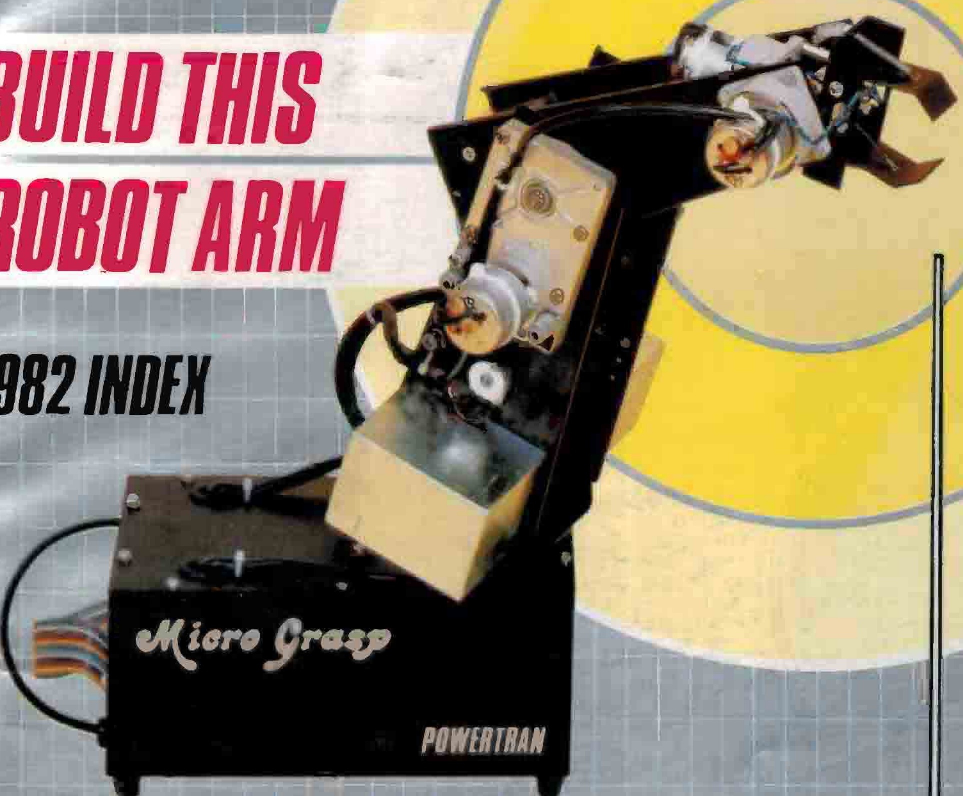
HI-FI SEVEN LIGHTWEIGHT HEADPHONES REVIEWED

BUILD THIS ROBOT ARM

1982 INDEX



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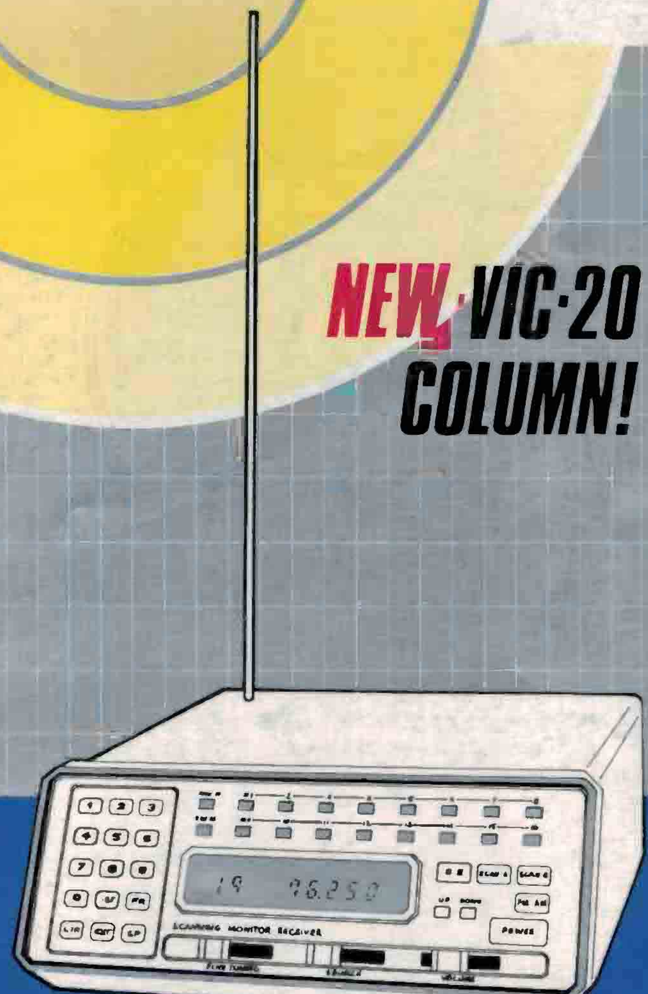


HP-75 Portable Computer Reviewed

Radioteletype Converter for the MicroBee

How to Use DVM Modules

Motor Speed Controller for Drills, Blenders etc.

This will grab you — the Micro-Grasp robot arm

Having obtained a computer and learned how to 'drive' it, the next step for a thinking computerist is robotics. No matter if computing is just a hobby or if it's your workaday job, robotics is an important step forward. Here is a low cost, down to earth way of learning what robotics is about — build this robot arm.

Richard Becker

Powertran, Andover, Hants, U.K.

THE MICRO-GRASP was designed as a low cost 'introduction to robotics' machine, priced as low as possible yet including everything to have it running immediately assembly is completed — i.e: inclusive of power supply and interface — no 'hidden extras'. Despite this major restriction, the Micro-Grasp has some powerful features.

It can be driven from any computer, even the humble ZX81, that has an expansion connector giving access to the data and address buss lines, plus the memory write and memory request lines.

The Micro-Grasp is an articulated arm jointed at shoulder, elbow and wrist positions. The entire arm rotates about the base and there is a motor-driven gripper. Each of the arm movements is servo controlled i.e: there are position sensors feeding back information to the interface board where the current position of an axis is compared with the programmed-in intended position and the servo circuit automatically takes corrective action.

This servo action is independent of the computer, greatly simplifying the software to drive the robot. All programming is carried out with a small number of BASIC commands.

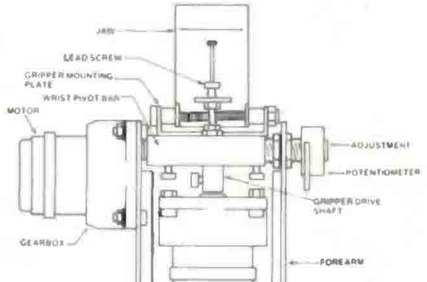
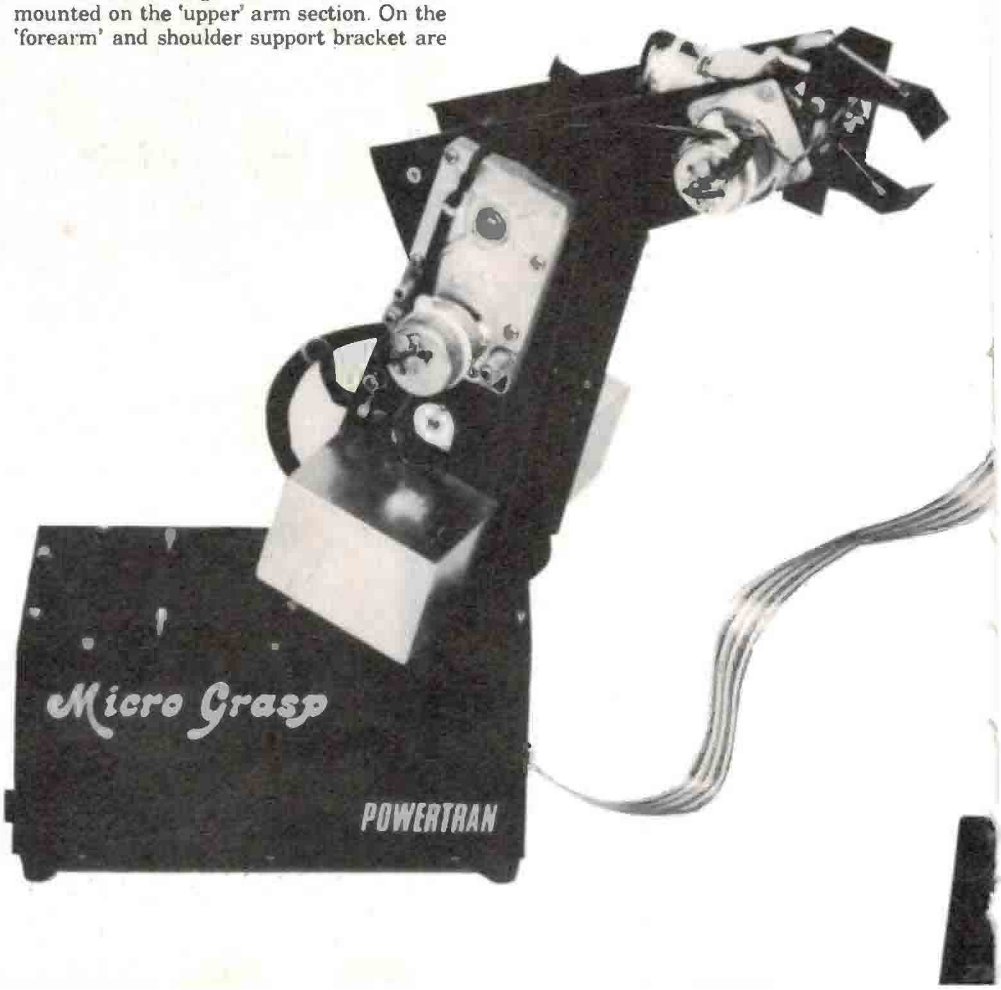


Figure 1. View of the wrist and gripper, showing the various components.

Mechanical design

Each of the four axes plus the gripper is driven by a small dc motor with integral gearbox. For the wrist and gripper motors, small in-line gearboxes are used. The three remaining axes use more powerful gearboxes housed in heavy duty zinc alloy castings. The shoulder and elbow joints are driven directly from their motor's gearboxes with both axes mounted on the 'upper' arm section. On the 'forearm' and shoulder support bracket are steel bushes clamping the gearbox shaft so that when the motors are driven, there is relative movement between the upper arm and forearm and the support bracket. The gripper is driven by a leadscrew which either pulls the jaws shut or pushes them open.

Position sensing potentiometers for the



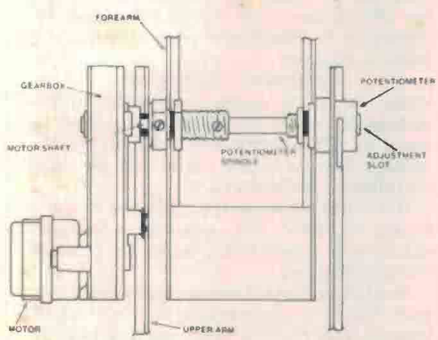


Figure 2. View of the elbow, showing how the motor drives the forearm assembly, plus the coupling to the position pot.

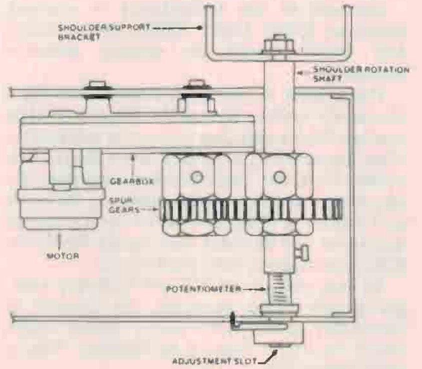


Figure 3. Simplified view of the rotation drive assembly. Note that the gearbox drive shaft comes out on the same side as the motor, unlike the shoulder and elbow drives.

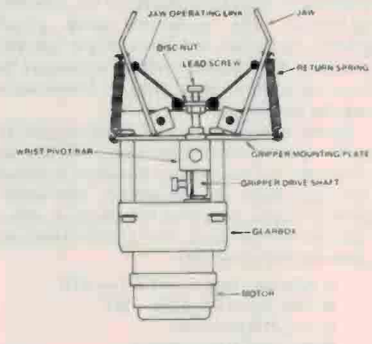


Figure 4. Side view of the gripper, showing how the lead screw, driven by the motor, operates the gripper jaws.

shoulder and elbow axes are also mounted on the upper arm. The joints rotate about plastic bearings mounted on the bushes of these pots. The shaft of each pot is held in a steel bush fitted to the forearm or support bracket.

The rotation axis has a more complex arrangement as it was not possible to arrange the gearbox shaft, the potentiometer and shoulder support bracket all in line. Drive is taken from the gearbox via a pair of spur gears. These have a 2:1 reduction ratio, resulting in a doubling of torque for the rotation axis. For this axis, the gearbox shaft is taken out from the motor side of the gearbox, rather than opposite as is the case with the shoulder and elbow gearboxes.

This arrangement is not perfect and some backlash is evident in the gears, but some compromise has to be accepted in order to keep costs down.

For raising and lowering the wrist, the gearbox shaft rotates a bar to which the position pot. and gripper assembly mounting plate are fitted. The drive shaft for the gripper leadscrew passes through this bar. When the leadscrew turns clockwise, the disc nut is moved toward the motor, pulling the jaws closed. When the leadscrew turns anticlockwise, the disc nut moves away from the motor and the jaws are pulled apart.

The forearm and upper arm each have counterbalance weights fitted so that no voltage needs to be applied to the motors to hold the arm in a desired position, improving accuracy of the servo action. Without this balancing, an error signal would always be required for the arm to be motionless and a considerable torque would also have to be provided by the gearboxes, unduly straining them. ▶

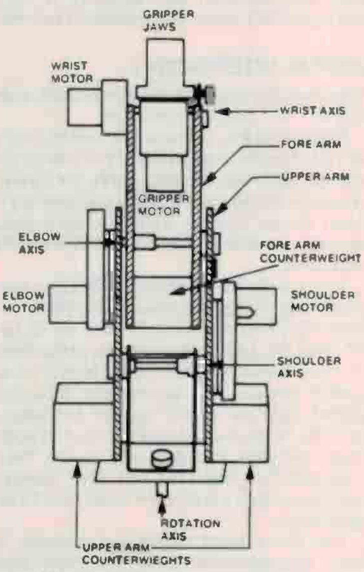
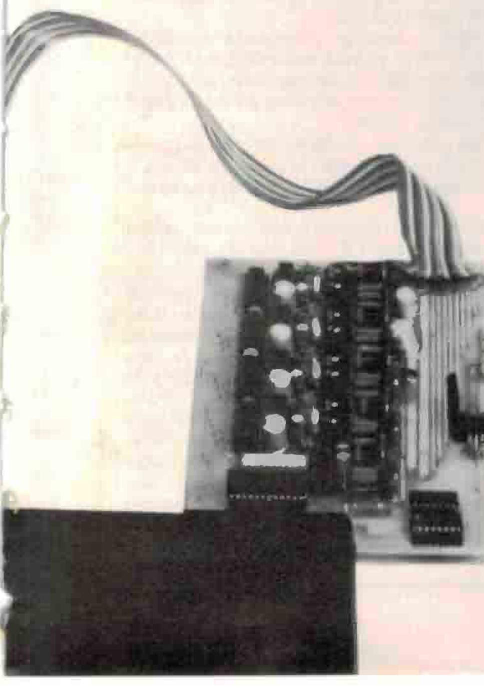


Figure 5. Overall view of the arm (simplified) showing each axis, the motors and counterweights. Note the 'sandwich' arrangement of the forearm and upper arm sidepieces and shoulder bracket.



FEATURES ETI-648 MICROGRASP

- Employs 'revolute coordinate' system with four degrees of freedom (four axes of movement).
  1. rotation about base
  2. shoulder bend
  3. elbow bend
  4. wrist bend
- Gripper mechanism on wrist.
- Each movement axis servo controlled (independant of programming).
- 'Universal' interface board permits interfacing the arm to virtually any computer.
- Interface acts as a memory-mapped peripheral, simplifying software for commanding the arm.
- Interface board is isolated from the mains.
- Straightforward mechanical assembly, requires no special tools or mechanical skills to set it up.

HOW IT WORKS — INTERFACE BOARD — ETI-648

The interface board contains both servo control and motor drive circuitry for the arm's motors, plus interface logic so that this can be 'commanded' from a computer. The whole interface board is designed to operate as a memory-mapped peripheral of the controlling computer. The on-board servo circuitry greatly simplifies the work of the computer, avoiding the requirement for extensive software specific to each type of computer that may be employed.

Some computers have input/output (I/O) ports by which data could be sent to the robot. However, the majority of personal computers available have an 'expansion' connector or buss giving access to all the address, data and internal control lines. The signals required to operate this robot are:

- Address buss lines A0 — A15
- Data buss lines D0 — D7
- Read/Write line
- Memory Request line

Although the interface connector choice could have been arbitrary, a keyed 23-way double-sided edge connector was chosen as they are common and because it fits the low-cost ZX81 computer expansion connector.

DIGITAL INTERFACING

This circuitry involves the 10-bank DIL switch, IC2, IC3, IC4, ICs 5A-D and IC9.

By setting the 10-bank DIL switch, any one of 1024 blocks of 64 bytes of the memory area can be selected. Actually, only six bytes are required, but to narrow down the memory area used would call for extra circuitry and, as memory is cheap, such extra complexity is pointless.

IC2 is a ten-bit comparator. Data on the ten most significant address lines (A6 — A15 inclusive) is compared with data set up by the 10-bank DIL switch. A closed switch puts a low (0 V) on the appropriate input of IC2, an open switch permits the appropriate input to be pulled high via a 4k7 resistor (resistors R1 to R10). When the data on the A6-A15 address lines matches the data set up on the DIL switches (i.e: when the computer selects an address within the 64 byte block) pin 13 of IC2 goes high.

The three least significant address lines from the computer drive the three primary inputs of IC3, a three-into-eight line decoder (sometimes also called a 1-of-8 decoder as only one out of the eight outputs is active at any one time). An output of the decoder can only be enabled (or activated) when the RW (write) and MREQ (memory request) lines are low and pin 6 is high. Now pin 6 is driven by the output of IC2 (pin 13). Thus, when a match occurs between the DIL switch data and the 10 most significant address lines, and RW and MREQ are low, an output of IC4 will be activated, which one depending on the data on the three least significant address lines.

The first four outputs (pins 15, 14, 13, 12 in that order) drive the four axis servo circuits A, B, C, D. If A0, A1 and A2 are all low, servo circuit A will be selected (rotation motor). If A0 is high and A1 and A2 low, servo circuit B will be selected (shoulder motor), and so on.

Thus, the computer addresses a chosen axis as if it were a memory location into which data is to be written. For example, if the top of the computer's address space is to be used, all the switches in the DIL switch bank would be set open, allocating addresses 65472-65535 to the robot. To move the rotation axis, (servo circuit A, remember) to the centre position the command would be POKE 65472,128 (128 being the centre of the range of positions, defined as 0 to 255. Each axis has 256 separate positions within its range of movement as you only have an 8-bit data buss).

Because of the redundancy in address selection 65480, 65488, 65504, 65512, 65520 and 65528 would be equally effective addresses.

The gripper is driven by a motor turning a leadscrew which either pulls the jaws shut or pushes them open. Jaw closure is initiated by IC9a, jaw opening by IC9b. IC9 is a dual monostable flip-flop. Each flip-flop operates for about two seconds, determined by R25/C14 and R28/C15. IC9a is enabled by the pin 10 output of the decoder, IC3, being activated. IC9b is activated by the pin 9 output.

As the outputs of IC3 are normally high, going low when activated, an inverter is necessary to drive the servo circuit inputs which require a high to be enabled. This is provided by IC4.

ANALOGUE CIRCUITRY

Servo circuits A to D are all identical, hence only servo circuit A is shown. Using the example given under 'Digital Interfacing', when the command POKE 65472,128 is received, pin 15 of the decoder (IC3) will go low and pin 2 of IC4a will go high, driving pin 11 of IC5A high. Now, IC5A is a 74LS373 8-bit latch. The data on the computer's data buss (128) appears on its inputs (pins 3, 4, 7, 8, 13, 14, 17, 18). When pin 11 ('latch enable') goes high, the data on the data buss lines is transferred to the outputs (pins 2, 5, 6, 9, 12, 15, 16, 19) which 'latch', holding the data there until the next time pin 11 is toggled high when another data value can be provided.

The outputs of IC5A drive the inputs of a digital-to-analogue (D-to-A) converter, IC6A (a DAC0808). The data written to IC5A is converted to a current output, from pin 4, the value of which is directly proportional to the value of the data. If 128 is the data value, the DAC0808 output will be halfway between 0 and its maximum value.

Pin 4 of IC6A drives the inverting input of IC7Aa, half of a 1458 dual op-amp. This converts the D-to-A converter's output into a voltage with a transfer ratio of 1 V/mA. The output of IC7Aa (pin 1) provides the 'desired position voltage' (DPV) to the motor drive circuitry.

A dual power amplifier, IC8A, arranged in a bridge configuration, drives the rotation motor. The position of the rotation axis shaft is sensed by a pot., RV101A, coupled to the shaft. A reference voltage of about 2 V is supplied to the pot. from 'Vp', derived from a voltage divider off the regulated +5 V rail (R11 and R12). When the rotation axis shaft is at its 'zero' position, the pot. wiper is near the 0 V end of the track. At the shaft mid-way position, about 1 V appears on the pot. wiper.

This 'measured position voltage' (MPV) is applied to one input of the motor drive bridge amp, IC8A, via a buffer, IC7Ab. RV2A permits varying the range of movement by restricting the range of the MPV variation.

IC8A compares the programmed-in desired position voltage (DPV) with the measured position voltage (MPV) and drives the motor backwards or forwards by applying a voltage that depends on how far away from the desired position the axis happens to be.

The DPV is applied directly to pin 8 of IC8A. Feedback via R22A makes the non-inverting input of this amp (pin 7) a virtual earth point elevated above 0 V by the voltage on pin 8 (the non-inverting input). The MPV forces a current into pin 7 via R21, resulting in a voltage at pin 10 which is equal to

R22A (DPV — MPV)/R21A

Similarly, the MPV drives the non-inverting input (pin 4) of the 'opposite' power amp and the DPV forces a current into the inverting input (pin 5), resulting in an output at pin 2 which is equal to

R20A(MPV — DPV)/R19A,

which is in the opposite direction to the voltage out of pin 10. These voltages will be equal as R20A=R22A and R19A=R21A. The voltage applied to the motor will be twice R22A(DPV — MPV)/R21A.

The motor will move the shaft until the MPV equals the DPV. The components selected result in a servo action which is close to critically damped.

An offset voltage is applied to pin 3 of IC7Aa, from RV1A, to compensate for the residual voltage from RV101A when the axis is at its zero position.

The RC networks on the outputs of IC8A a and b are the 'Zobel' networks almost universally used to stop power amplifiers from oscillating in the MHz region.

Capacitors C12A and C13A are for local decoupling and C105A, C106A are suppression capacitors fitted as close as possible to the motor. Without these the interference from the motor brushes is sufficient to make the computer abort its program.

Only four of the five axes are servo controlled as the gripper needs only to be either holding or releasing.

As explained under 'Digital Interfacing', the gripper motor is activated by triggering IC9a to close the jaws, IC9b to open them.

As with the axis drive circuits, a 2877 dual power amp (IC10) is used in a bridge configuration to drive the gripper motor. When IC9a is triggered, its Q output (pin 13) goes high for about two seconds. About 0.5 V appears across R27, owing to the voltage division provided by R26-R27. This will cause the output of IC10b (pin 10) to swing toward the +9 V rail and the output of IC10a to swing toward the −9 V rail. The motor will then drive the gripper jaws shut.

When an object is siezed, the motor will stall but the amplifier is fully protected and, as the stall period is less than two seconds, no motor overheating occurs.

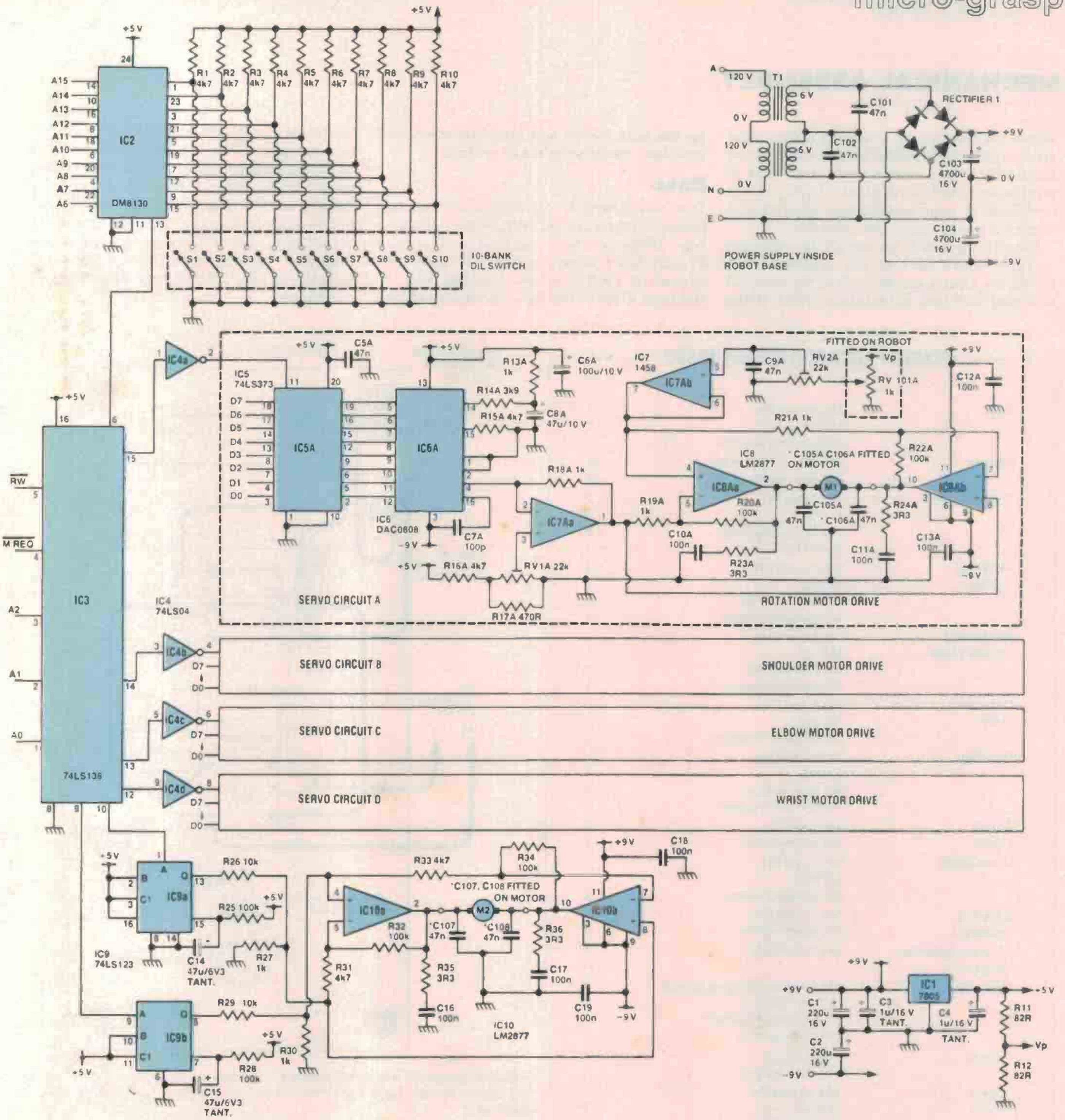
On triggering IC9b, the motor is driven in the opposite direction until it stalls with the jaws in the fully open position.

Gripper operating commands could be POKE 65477,0 to hold and POKE 65478,0 to release, though this data as indicated by 0 is quite irrelevant and anything between 0 and 255 could be written.

If the address allocated to axis 0 (servo circuit A) is A then axis 1 is A + 1, axis 2 is A + 2, axis 3 is A + 3, grip is A + 5 and release is A + 6.

The rotation shoulder and elbow motors take up to about 1 A each and the other two motors up to about 0.5 A each.

The reference voltage for the DAC and the position sensing potentiometers comes from IC1 (a 7805) which provides excellent stability. The amplifiers' requirements however are non-critical and an unstabilised supply is entirely adequate. The power supply circuit provides ± approximately 9 V. The supply is sited in the robot base where, as well as providing useful ballast at the rear of the base the mains connections are fully enclosed. The interface board is therefore free of mains and is safely operated whilst unenclosed and closely connected to the computer.



Electronic design

Despite the size of the interface board, the electronics is relatively simple. Four identical servo circuits are employed to drive the four axes motors. The gripper motor is driven from a slightly different circuit. Servo circuit *A* controls the *rotation axis*, servo circuit B controls the *shoulder axis*, *C* controls the *elbow axis* and *D* controls the *wrist axis*.

A 10-bank DIL switch sets the base address of the arm. The ten most significant bits of the computer's address lines (A6 — A15) are compared to the address set on the DIL switch. When these match, a three-to-eight line decoder is enabled, providing the memory write and memory request lines are low at the same time (they are *active low*).

The three least significant bits of the computer's address buss (A0, A1 and A2) are then used to select which axis is to be moved. Data is written to the appropriate address and the value on the data buss is then converted to an analogue voltage to drive the selected axis' motor. The servo circuitry then sets the position of that axis. As the address buss is eight bits wide, each axis can be positioned at any of 256 locations.

For example, as the wrist can move through an angle of 180° it can theoretically be positioned anywhere in its semi-circle of movement to an accuracy of 180/256, or about 0.7°. Mechanical tolerances will decrease this.

The elbow and shoulder axes have greater range of movement and could theoretically be positioned to an accuracy of about 1°, but again, mechanical tolerances will decrease this.

The gripper only has two positions — open and shut! The electronics is only toggled one way or the other to set the jaws as required.

Complete details of the circuit operation are given in the 'How It Works' panel accompanying the circuit diagram. ▶

MECHANICAL ASSEMBLY

While the mechanical assembly of this robot arm is relatively straightforward, constructors should be aware that a certain amount of mechanical skill is required. If you are not confident of your mechanical abilities, get someone else to tackle the assembly.

First thing to do is lay out all the parts and identify which part of the assembly they belong to. Take a careful look at the pieces of stamped and bent aluminium which make up the arm pieces and familiarise yourself with how the other parts fit to them.

Base

The base assembly consists of six stamped pieces of metal which fit together to make a box. These are held together with special Philips head screws which roll their own thread. A good assembly starting point is the base plate of the base on which is fitted the power supply and the rotation axis position sensing pot. (RV101A). The accompanying assembly diagram (Figure 6) shows the general construction. Bolt on the potentiometer and bridge rectifier first. Make sure you identify the rectifier terminals correctly and orient it accordingly (see the bridge rectifier pinout diagram). You can mark the base plate with something like 'Whiteout' or 'Liquid Paper' to help you.

FIXING PARTS FOR MICRO-GRASP

Feet	M4 16 mm PH	4
	M4 nut	4
	M4 serrated washer	4
Panels	M3 10 mm PH Taptite	24
	M3 plain washers	24
Transformer	M4 8 mm PH	2
	M4 nut	2
	M4 serrated washer	4
	solder tag	1
Terminal blocks	M3 16 mm PH	4
	M3 nut	4
	M3 plain washer	4
	M3 serrated washer	4
Solder tag on end plate	M3 8 mm PH	1
	M3 nut	1
	M3 plain washer	1
	M3 serrated washer	1
Capacitor clips	M4 6 mm PH	2
	M4 nut	2
	M4 serrated washers	2
Rectifier	M3 16 mm PH	1
	M3 nut	1
	M3 plain washer	1
	M3 serrated washer	1
Axis 0 motor	M4 6 mm PH	4
	M4 plain washer	4
Drive Shaft	M3 6 mm PH	1
	M6 nut	1
	M6 serrated washer	2
Axis 1, 2 motors	M4 10 mm CSK	8
	M5 plain washer	8
Counter balance weights	M4 10 mm CSK	8
Motor Bushes	M4 6 mm socket grub screws	4
	½" UNF half nut	2
	M12 serrated washers	4
	M8 nylon washer	2
Tie rod	M5 nylok nut	2
	M5 plain washer	2
Axis 3 motor	M3 12 mm PH	4
	M3 nut	4
	M3 plain washer	4
	M3 serrated washer	4
Square shaft of wrist	M3 6 mm PH	4
	M3 serrated washer	5
	M3 nylon washer	2
Axis 4 motor	M3 25 mm tapped spacer	4
	M3 8 mm PH	8
	M3 serrated washer	4
	M3 plain washer	4
Gripper Drive shaft	M3 6 mm PH	1
	M3 16 mm PH nylon	1
	M3 nut	1
	M3 nylon washer	1
Gripper plates	M4 50 mm PH	2
	M4 nylok nut	2
	M4 6 mm spacer	4

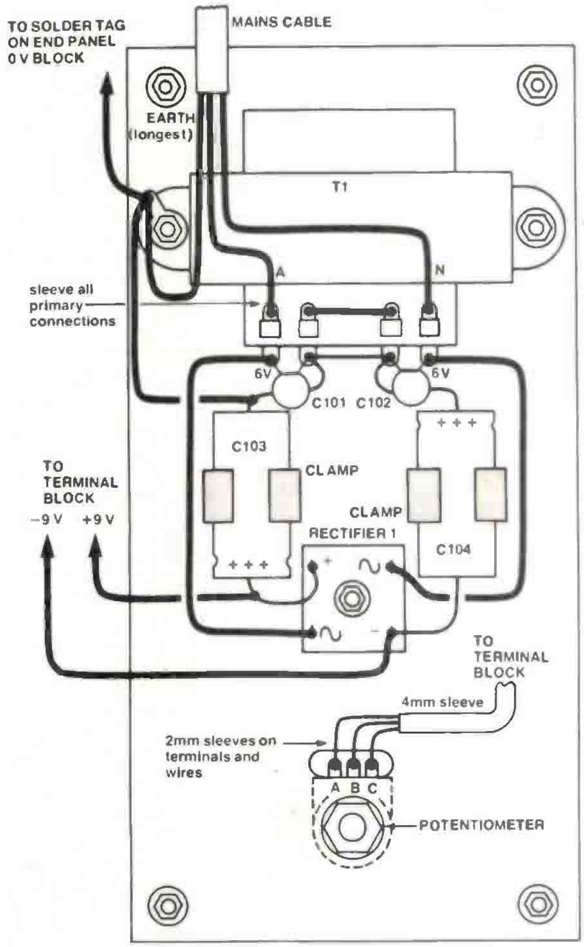
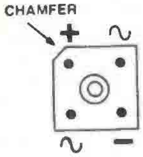


Figure 6. Assembly and wiring diagram of the power supply. Make sure the solder lug under the left hand transformer mounting bolt is securely earthed to the base plate.



Top view of the bridge rectifier showing pin connections.

PARTS LIST — ETI-648 ARM ASSEMBLY

Resistors
RV101A-D .... 1k linear pots

Capacitors
C101, 102, 105A-D, 106A-D, 107, 108 .. 47n ceramic (12 off)
C103, 104 .... 4700u/16 V axial electros (2 off)

Semiconductors
RECT.1 .... 6 A bridge rectifier

Miscellaneous
T1 .... 2 x 120 V pri./2 x 6 V sec.
Motors, mechanical parts, fixings, etc.

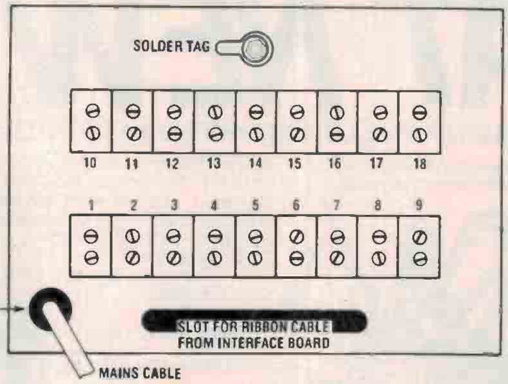


Figure 7. End plate assembly from the base (viewed from the inside) showing terminal block numbering. Make sure the bolt securing the solder tag gets a good 'bite' into the metal.

TERMINAL BLOCK	DESTINATION	WIRE COLOUR	PC BOARD CONNECTION POINT
1	rotation motor-red	grey	1
2	rotation motor-black	orange	2
3	shoulder motor-black	blue (left)	3
4	shoulder motor-red	black (left)	4
5	elbow motor-black	orange (right)	5
6	elbow motor-red	grey (right)	6
7	wrist motor-black	brown (right)	7
8	wrist motor-red	green (right)	8
9	gripper motor-black	black (right)	9
10	gripper motor-red	blue (right)	10
11	+ve, power supply	red	11, 12
12	−ve, power supply	blue	13, 14
tag	solder tag, base plate	black	15
13	RV101D, tag B	white (left)	16
14	RV101C, tag B	yellow (left)	17
15	RV101B, tag B	violet (right)	18
16	RV101A, tag B	green/yellow	19
17	0 V (anlg), RV101A, tag C	pink	20
	0 V (anlg), RV101B, tag A	pink (right)	
	0 V (anlg), RV101C, tag A	pink (left)	
	0 V (anlg), RV101D, tag A	pink (left)	
18	Vp RV101A, tag A	red	21
	Vp RV101B, tag C	red (right)	
	RV101C, tag C	red (left)	
	Vp RV101D, tag C	red (left)	

TABLE 1

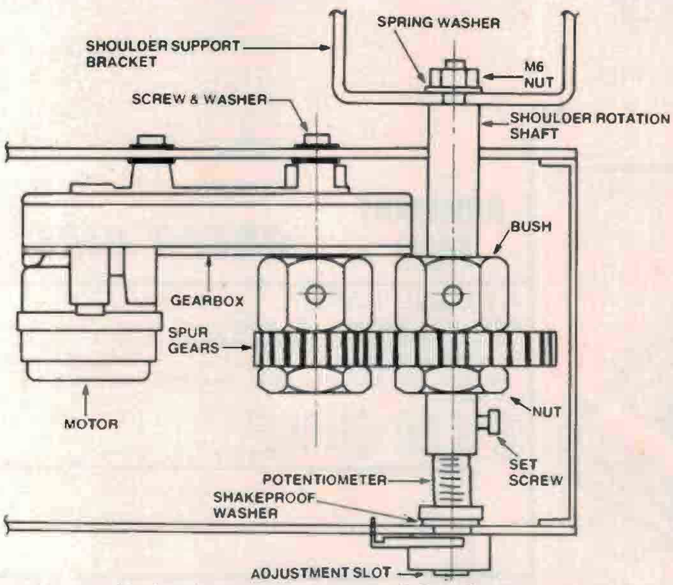


Figure 8. Rotation drive assembly. Install suppression capacitors C105A, C106A, as described later under the heading 'Wiring Looms', before mounting the motor.

NOTES FOR CONSTRUCTORS

To put this project together you'll need a heavy duty soldering iron, apart from an ordinary iron for electronic work, a medium-sized Philips head screwdriver, a small shifting spanner or set of small spanners, and perhaps a small hole reamer or fine rat-tail file — apart from your usual tools.

Bolt the transformer on next and then solder the two electrolytic capacitors in place, making sure you get them the right way round. Then solder C101 and C102 in place directly on the terminals of the 6 V secondaries. Bridge the two inner terminals of the 6 V secondaries. Also bridge the inner two terminals of the 120 V sections of the primaries.

Then wire the bridge rectifier to the transformer secondary and the earth tag to the connection bridging the two inner terminals of the secondaries (i.e: the centre tap).

Now assemble the end plate of the base (Figure 7). Bolt on the two terminal blocks and the solder tag. Attach the mains cord with a clamp grommet but make sure you leave about 15-200 mm of lead length so that it can be wired in easily.

Mark terminals 1, 9, 10 and 18 on the end plate using Whiteout or Liquid Paper so that you can readily identify the terminals. Then wire RV101A and the rectifier to the appropriate terminals, as per Table 1.

Now you can wire up the mains lead. Make sure the earth wire is the longest so that it's the last to break in the event of an accident. Don't attach a plug to the end of the mains cord yet, for safety's sake.

The power supply and rotation potentiometer can now be wired to the terminal block. Make up two looms as shown in the 'wiring looms' diagram, then wire them in place as per table 1 and Figure 6. When making up the looms, use a ruler to get exact wire lengths as only just enough wire is supplied.

Tackle the rotation drive assembly next. First take one of the motor-and-gearbox assemblies. What you have to do is turn the shaft over so that it comes out on the same side as the motor.

The gearbox has a cover plate held on by four Philips head screws and an aluminium rivet (located adjacent to the motor, at one end). The turnover on the rivet can be gently prised up using side cutters and the rivet slipped out. Then undo the four screws. Carefully take off the cover plate and examine the drive shaft and associated gears. By examining it, you will see how to slip out the drive shaft and turn it over so that it faces the opposite direction — it's easier to do than describe!

With the drive shaft now correctly oriented and the gears meshed, put the cover plate back on and slip the rivet back in place, turning over the end to secure it.

Take a look at the rotation drive assembly drawing (Figure 8). Attach the small spur gear to the gearbox shaft with the bush and nut, as shown. Fit the motor loosely to the top plate of the base assembly. Screw the side panels to the base (use washers under all screw heads) and then screw the top plate in place.

Assemble the shoulder rotation shaft, large spur gear, bush and nut to the potentiometer shaft, align the gears and secure in place. Position the motor so that the spur gears are firmly meshed without binding and tighten the motor mounting screws. At this stage, you can apply 9-12 V to the motor to see that the rotation shaft turns without the spur gears binding. If not, readjust the motor mount so that it does. ▶

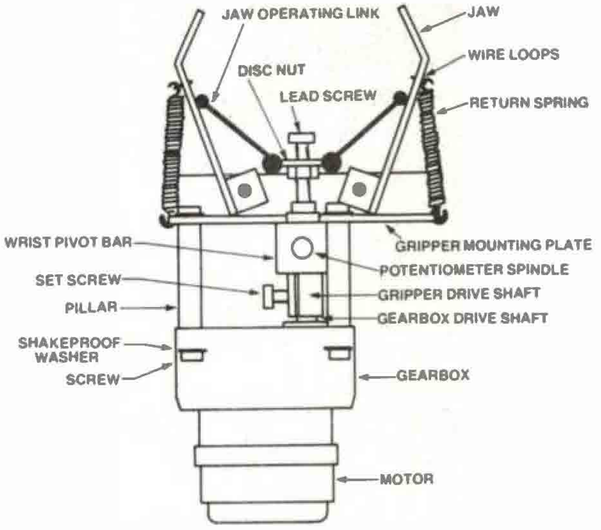


Figure 9. The gripper assembly showing motor mounting, jaw components and pivot bar, etc.

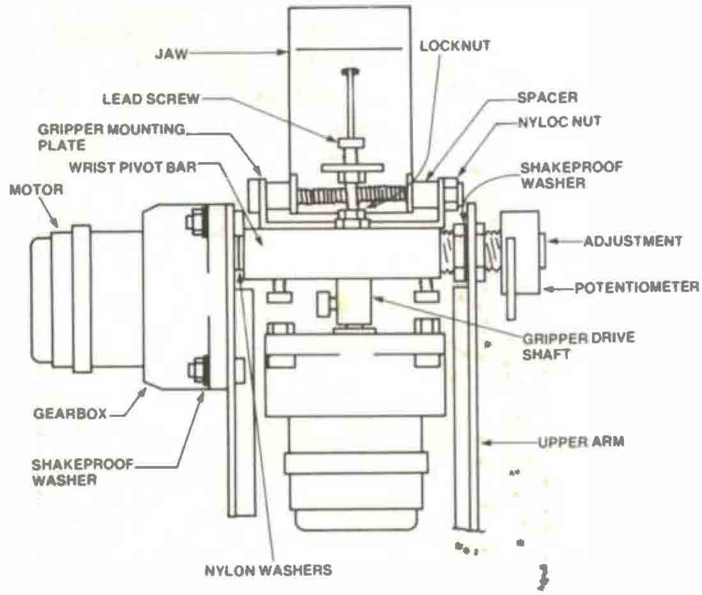


Figure 10. The wrist and gripper assembly, showing how the gripper fits to the wrist drive shaft.

Don't tighten the set screw to the pot shaft at this stage, otherwise you're liable to damage the rotation potentiometer through moving the rotation shaft at some stage of construction.

The end plates for the base are not screwed in place yet, that comes much later.

Gripper

The gripper assembly should be tackled next. The motor marked 'gripper' attaches to the gripper mounting plate, as shown in Figure 9, via four hexagonal pillars. The mounting plate is U-shaped and should have the open side of the U facing away from the motor.

The motor shaft should line up with the large hole in the plate. The wrist pivot bar (see Figure 10), fits flat against the hexagonal pillars and the gripper mounting plate. It only fits correctly one way round.

Two screws pass through the mounting plate into the pivot bar. The gripper drive shaft should pass through the pivot bar and over the gearbox drive shaft, where a set screw is used.

At this stage, apply about 12 V or so to the gripper motor and make sure the gripper drive shaft rotates freely. If not, re-check the orientation of the pivot bar. We found that some filing with a fine rat-tail file was necessary to obtain proper rotation.

The jaws are spaced between the U of the mounting plate by four cylindrical spacers, each about 5 mm long. Tighten the screws onto the lock nuts, but make sure the jaws can still move with only light pressure applied. The screw heads should be on the side where the pivot bar sticks out furthest.

The nylon leadscrew passes through a flat plate about 15 x 50 mm and into the end of the gripper drive shaft. Fit the jaw operating links to the flat plate and return springs with small wire loops. Apply power to the gripper motor once again and observe the action.

The leadscrew will require some adjustment to get the jaws to open and close completely. Once you have mastered the adjustment procedure, you may fix the leadscrew to the drive shaft with a drop of 'Loctite' or similar compound. DO NOT use epoxy or you'll never be able to adjust it again.

Forearm

Sort out the pieces for this assembly. This is the section that goes between the elbow and the wrist (naturally!). Note that the lips on the side plates face inwards.

Fit the couterweight between the two side pieces and loosely mount it with the four countersunk screws. Fit the wrist motor and potentiometer to the *outside* of the side pieces, as shown in Figure 10.

Fit the shaft securing bush (Figure 11) near the counterweight on the same side piece as the wrist motor is mounted on. Tighten it. The gripper may now be placed between the wrist motor and the wrist potentiometer, as per Figure 10.

Tighten the counterweight screws and the set screw on the motor end of the wrist pivot bar. The wrist pot. position should be adjusted by moving the shaft nuts to get the arm side pieces near parallel, but, more importantly, to allow the gripper assembly to rotate freely.

Upper arm

Sort out the pieces for this assembly. Note that the two side pieces assemble with the lips facing outwards.

The two motors and two position pots mount diagonally opposite one another on the two halves. Study the accompanying photographs to get the orientation right.

The potentiometers mount with plastic spacers and bushes to form a sort of floating bearing through the upper arm and shoulder support bracket. Because of this, the upper arm must be assembled through the other pieces so must be done last.

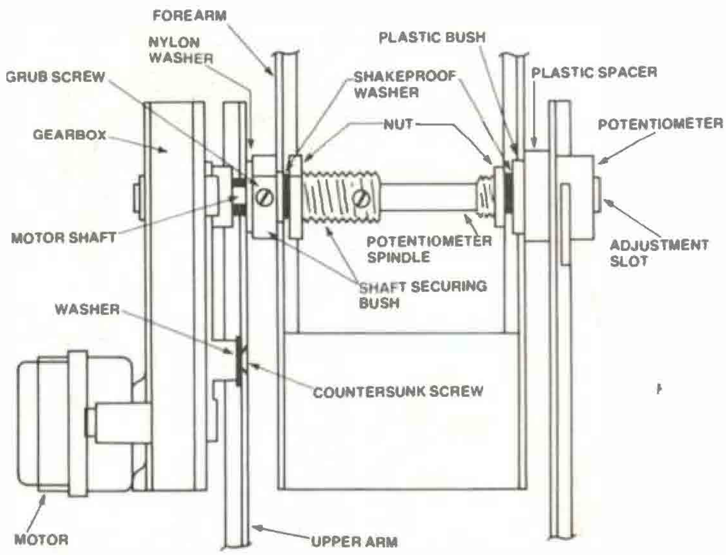
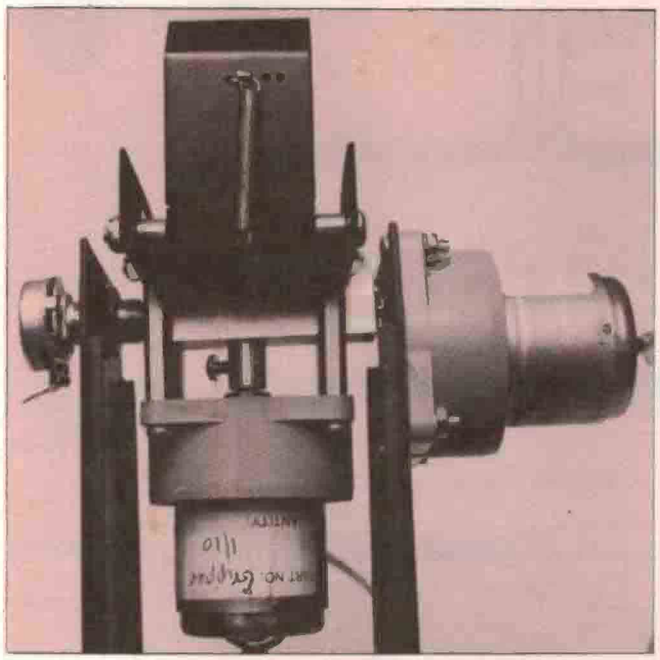
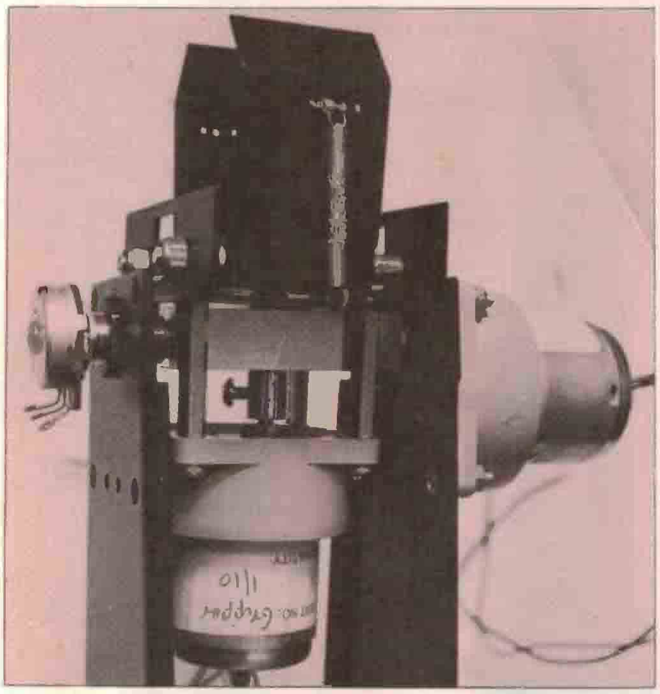


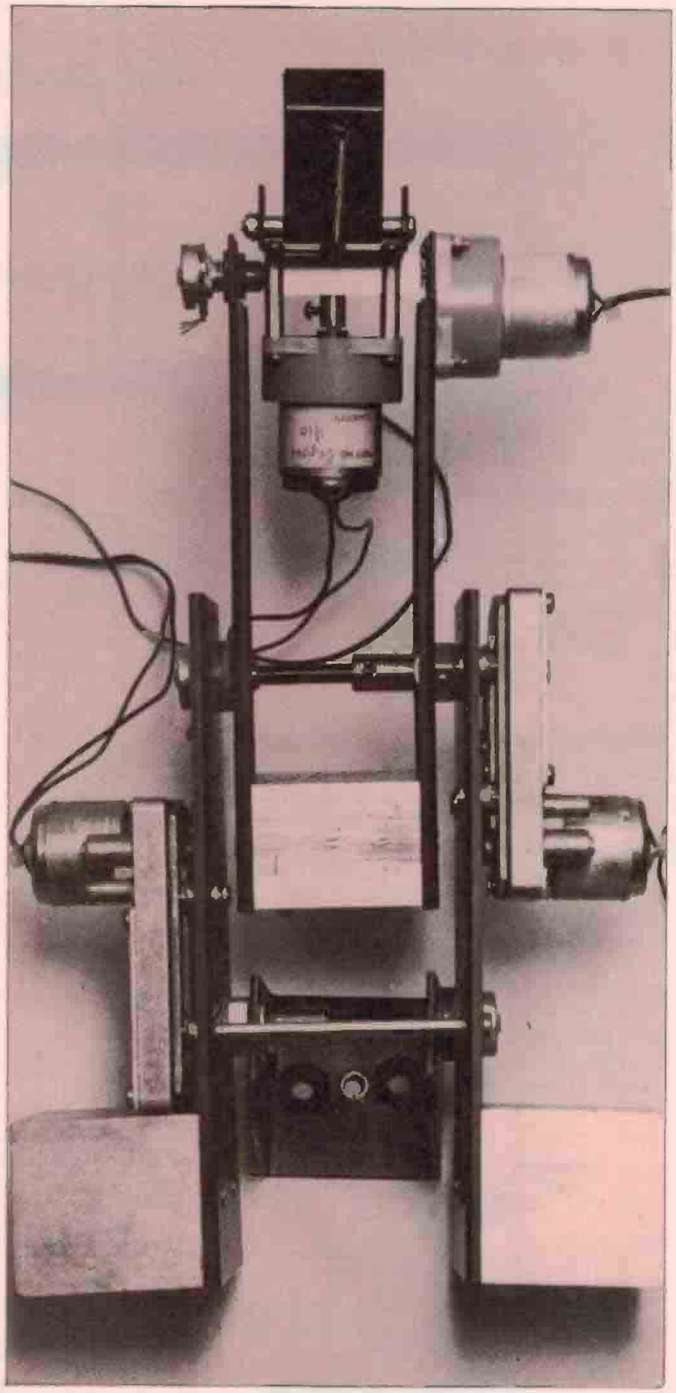
Figure 11. How the elbow is assembled.



The end. View of the wrist and gripper assembly.



Twisted. Angled view of the wrist and gripper assembly.



Assembled. Overall view of the completed arm assembly prior to mounting it on the rotation shaft and attaching the wiring looms.

Fit the two counterweights to the lower ends of the side pieces, on the outside. We found that the two pots on this arm section had to have 5 mm cut off their shafts. Check the fit by trial and error, assembling the upper arm before you chop off the pot. shafts!

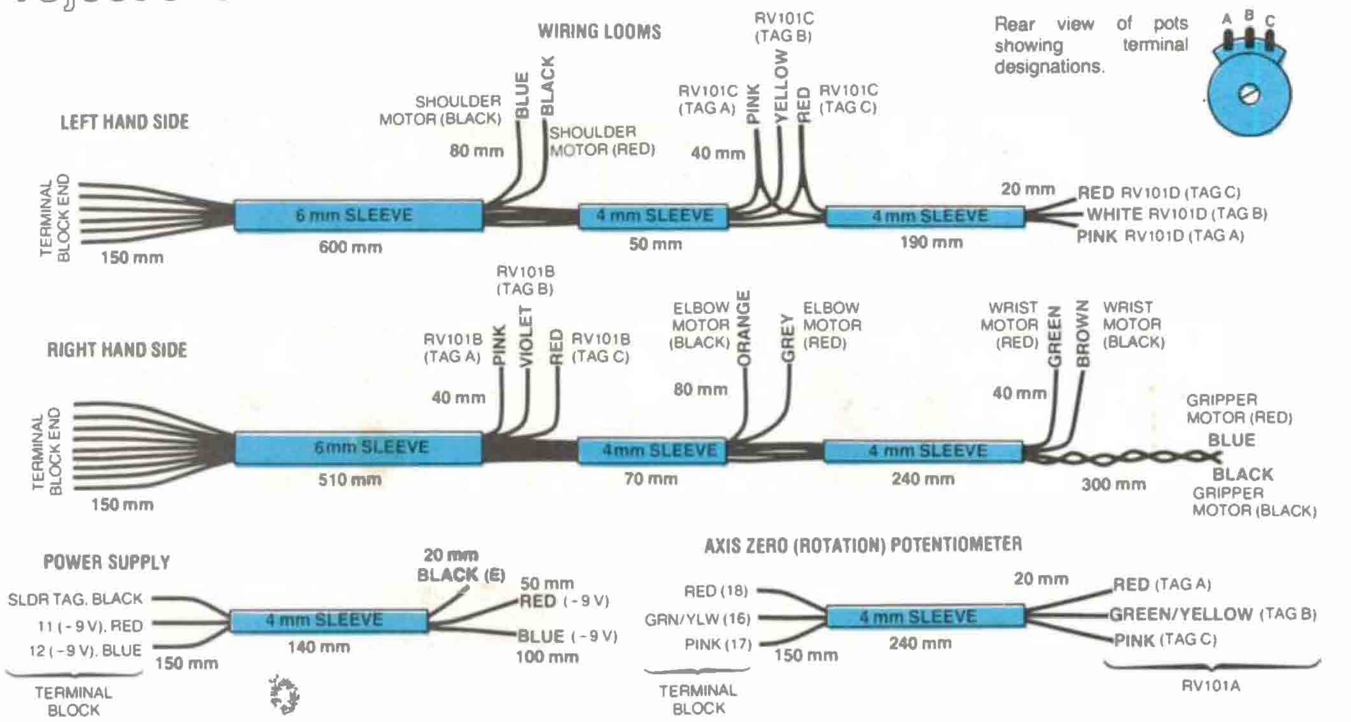
A metal rod with threaded ends is used to stabilise the upper arm near the counterweights and to limit the angle through which the arm can move relative to the shoulder support bracket. This rod passes through the outermost holes on the upper arm side pieces and when the arm is assembled, the rod fits on the side of the shoulder bracket that has the corners cut off. Two nyloc nuts secure this rod. Refer to the accompanying photographs. Don't forget the two rubber grommets in the base of the shoulder bracket.

Final

Place the shoulder bracket onto the rotation drive shaft, orienting the arm so that, from the power cord end of the base, the wrist motor is on the right. Tighten it.

Now secure all the gearbox drive shaft set screws, but not the potentiometer shaft set screws. Move each axis to the centre of its travel — gripper, forearm and upper arm all in line about 60° above the horizontal, with the arm pointing forwards.

Set each potentiometer to its centre position, i.e: equal resistance between the centre tag and each of the outer ones, by using a screwdriver in the adjustment slot. Then secure all the pot. shafts. ▶

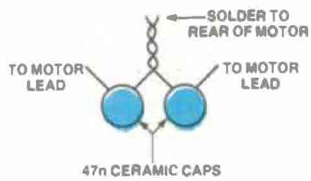


Wiring looms

Now for the wiring looms. Make up the left and right looms as per the Wiring Looms diagram. Use a ruler to cut the wires accurately as only just enough is supplied.

With each loom completed, wire them in place and then route them as shown in Figure 12, securing the looms with cable ties and stick-on cable grips, as shown.

The hash suppression capacitors are mounted on the rear of each motor as follows: take two 47n ceramic capacitors and twist two adjacent leads together, as shown in the accompanying illustration. Cut all leads to a length of about 10 mm.



Solder the joined leads to a convenient spot on the rear of each motor using a heavy duty iron. It is best to lay a blob of solder on the motor case first (i.e: 'tin' a small area), then solder the twisted leads to the blob. Make sure you get a secure connection.

Having done that, cut the motor leads short and solder each to a remaining capacitor lead.

The two looms pass through the grommetted holes in the base of the shoulder bracket, then towards the rear of the base and through the two grommetted holes on the top of the base. Don't wire them to the base end plate terminal blocks yet. Make sure to leave a generous loop near each axis of the arm. Only apply the cable ties loosely at this stage as you will undoubtedly need to adjust them. You can do this by applying power to each motor in turn and seeing that each has enough freedom of movement without fouling on the cable. The rotation shaft needs 180° of movement, so take care here.

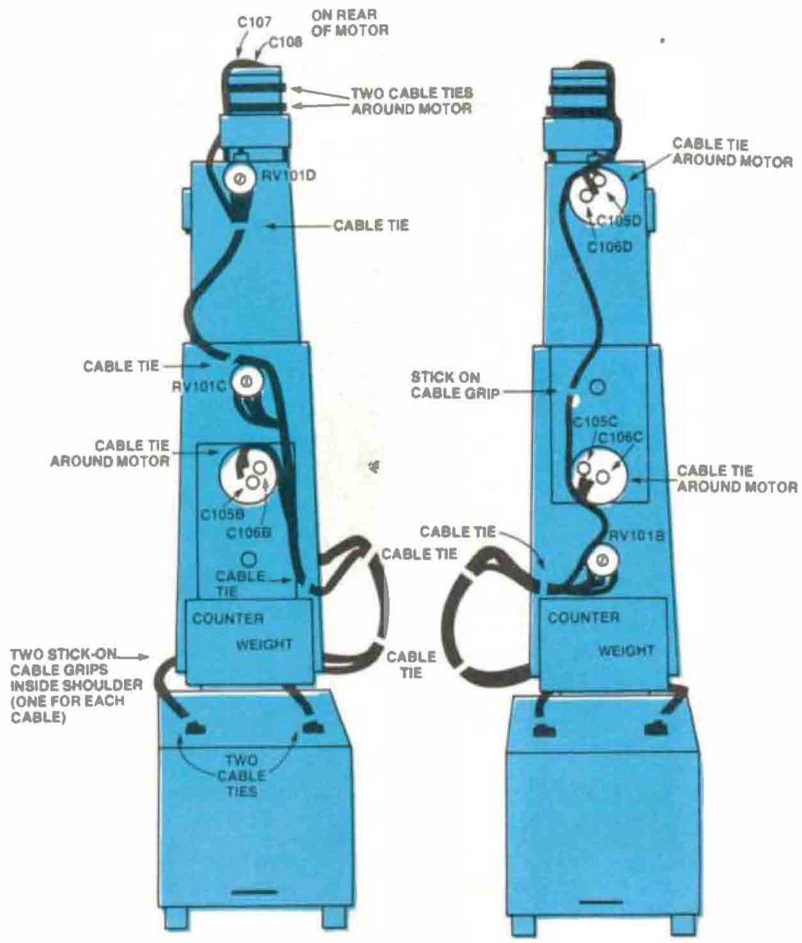


Figure 12. Attaching the wiring looms.

Now you can wire the looms to the terminal blocks, as per Table 1.

Check everything.

The Micro-Grasp robot arm

Part 2

This part covers construction of the interface electronics board, which completes the project.

Richard Becker

Powertran, Andover, Hants U.K.

ALL THAT REMAINS to complete the Micro-Grasp project is the assembly of the interface board, wiring it to the mechanical assembly and arranging the interface connections.

ELECTRONIC ASSEMBLY

Many of the components on the interface board are closely spaced and you'll find assembly easiest if you follow the order detailed here.

Sockets are used for all the dual-in-line (DIL) ICs. These should be soldered in place first. Identify which is required for each IC position and solder them in place one by one taking care to orientate them correctly.

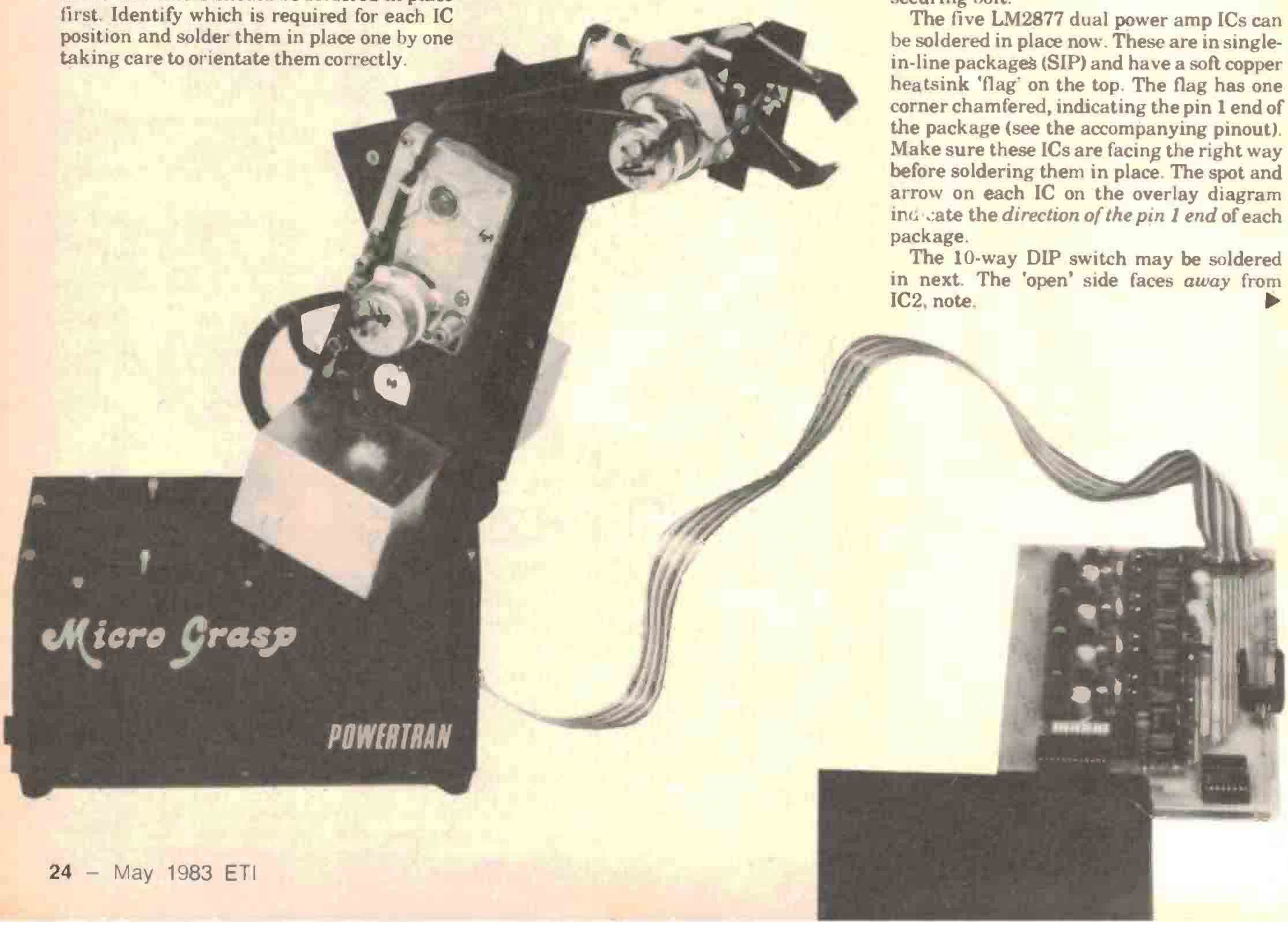
The single-in-line resistor pack, R3-R10, should be soldered in place next, making sure you place the end marked with a spot towards the outer edge of the board, as indicated on the component overlay.

All the resistors should be soldered in place next. Note that four are stood vertically from the board: R26, R27, R29 and R30. Solder the disc ceramic capacitors in place next, then the polyester capacitors (the colour-coded ones). The four 47n capacitors are located between the row of trimpots and the row of IC6s (A, B, C, D). The 100n capacitors are all located between the row of trimpots and the line of LM2877s (ICs 8A-D and 10). Finish off this stage of the construction by soldering the electrolytic and tantalum capacitors in place. Take care they are each orientated correctly.

Now you can mount the eight trimpots. Follow by assembling the 7805 regulator, IC1, and its heatsink to the board, carefully bending the leads to fit into the holes provided. Solder the leads *after* tightening the securing bolt.

The five LM2877 dual power amp ICs can be soldered in place now. These are in single-in-line packages (SIP) and have a soft copper heatsink 'flag' on the top. The flag has one corner chamfered, indicating the pin 1 end of the package (see the accompanying pinout). Make sure these ICs are facing the right way before soldering them in place. The spot and arrow on each IC on the overlay diagram indicate the *direction of the pin 1 end* of each package.

The 10-way DIP switch may be soldered in next. The 'open' side faces *away* from IC2, note. ▶



INTERFACE BOARD

Resistors all ½W, 5%

R1, 2, 15A-D, 16A-D, 31, 33	4k7 (12 off)
R3-10	4k7 8-up SIP network
R11	82R
R12	68R
R13A-D, 18A-D, 19A-D, 21A-D, 27, 30	1k (18 off)
R14A-D	3k9 (4 off)
R17A-D	470R (4 off)
R20A-D, 22A-D, 25, 28, 32, 34	100k (12 off)
R23A-D, 24A-D, 35, 36	3R3 (10 off)
R26, R29	10k (2 off)
RV1A-D, RV2A-D	22k trim pots (8 off)

Capacitors

C1, C2	220u/16 V RB electro. (2 off)
C3, C4	1u/16 V tant. (2 off)
C5A-D	47n ceramic (4 off)
C6A-D	100u/10 V RB electro. (4 off)
C7A-D	100p ceramic (4 off)
C8A-D	47u/10 V RB electro. (4 off)
C9A-D	47n polyester (4 off)
C10A-D, 11A-D, 12A-D, 13A-D, 16, 19	100n polyester (20 off)
C14, C15	47u/6V3 tant. (2 off)

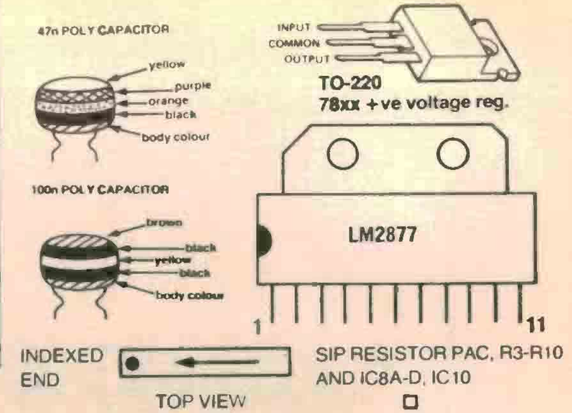
Semiconductors

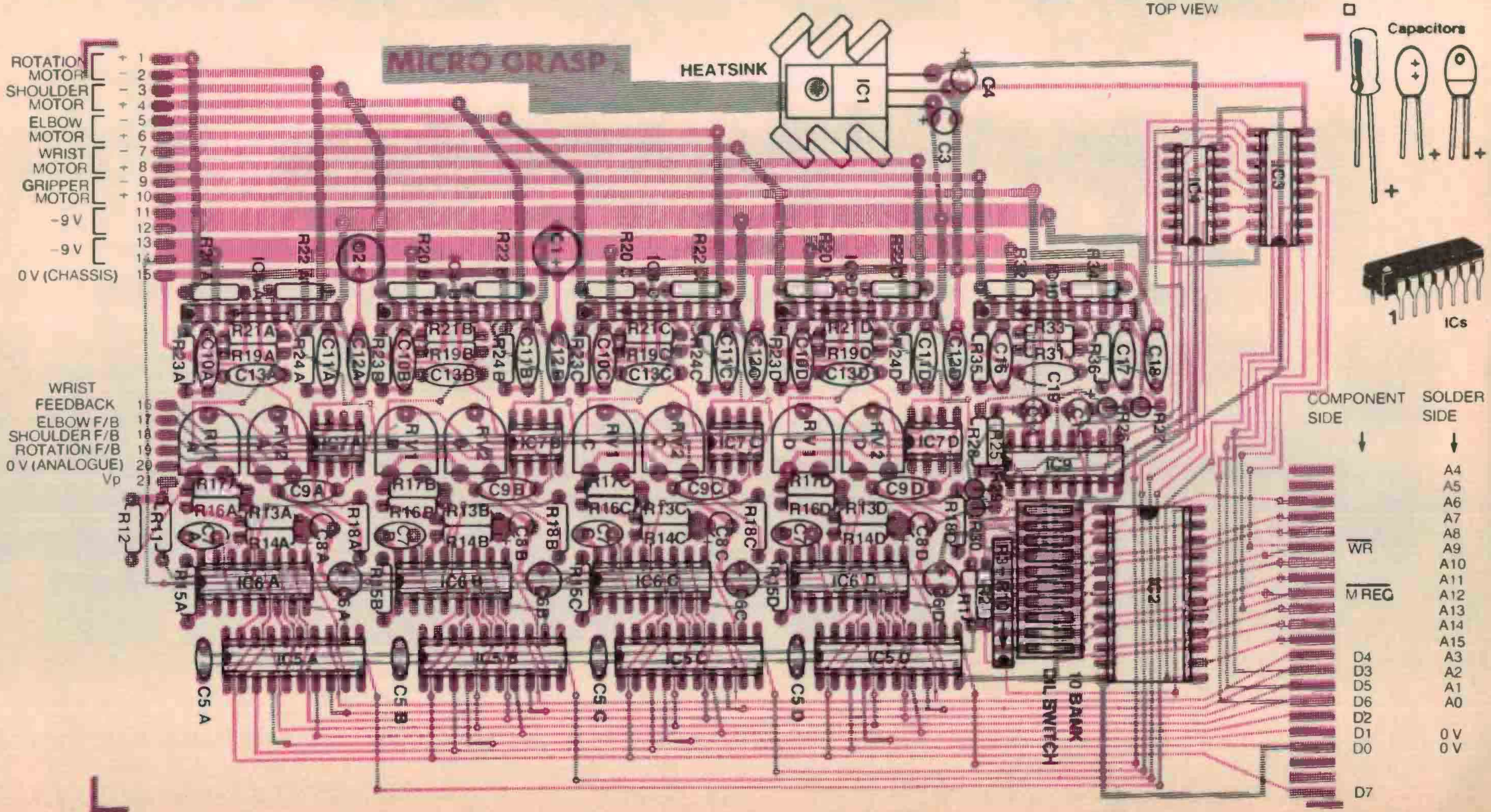
IC1	7805
IC2	DM8130
IC3	74LS138
IC4	74LS04
IC5A-D	74LS373 (4 off)
IC6A-D	DAC0808 (4 off)
IC7A-D	1458 (4 off)
IC8A-D, IC10	LM2877 (5 off)
IC9	74LS123

Miscellaneous

S1-S10 .... SPST 10-band DIL switch

Printed circuit board; flatpack heatsink; 4 x 8-pin IC sockets; 1 x 14-pin IC socket; 6 x 16-pin IC sockets; 4x20-pin IC sockets; 1x24-pin IC sockets.





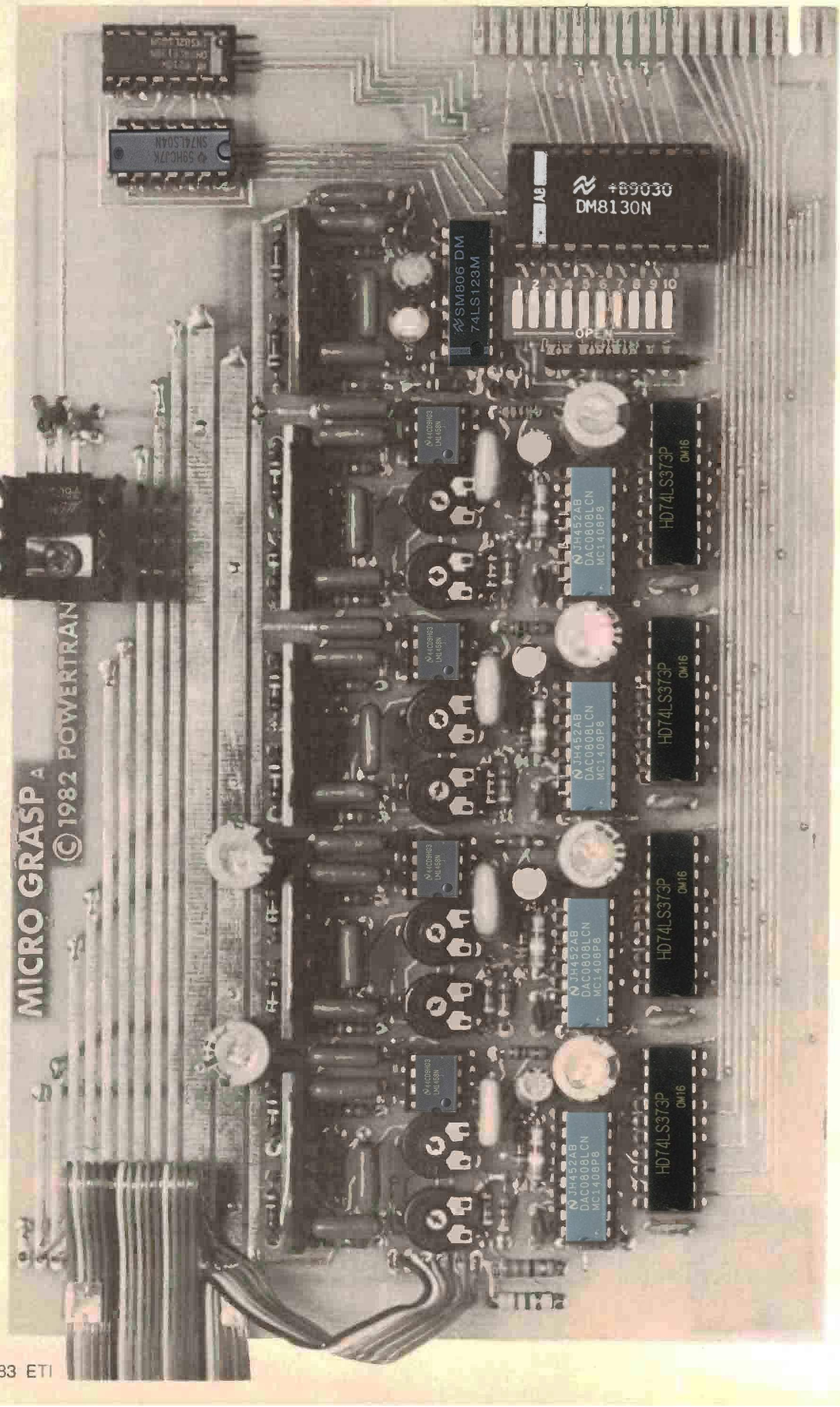

MICRO GRASP A
© 1982 POWERTRAN
DM8130N
SM806 DM
74LS123M
OPEN
JH452AB
DAC0808LCN
MC1408P8
HD74LS373P

TABLE 2.

PC BOARD CONNECTION POINT	TERMINAL BLOCK	DESTINATION
1	1	rotation motor +ve
2	2	rotation motor −ve
3	3	shoulder motor −ve
4	4	shoulder motor +ve
5	5	elbow motor −ve
6	6	elbow motor +ve
7	7	wrist motor −ve
8	8	wrist motor +ve
9	9	gripper motor −ve
10	10	gripper motor +ve
11, 12	11	+9 V
13, 14	12	−9 V
15	tag	0 V (solder tag on chassis)
16	13	wrist feedback (RV101D, tag B)
17	14	elbow feedback (RV101C, tag B)
18	15	shoulder feedback (RV101B, tag B)
19	16	rotation feedback (RV101A, tag B)
20	17	0 V, analogue
21	18	Vp

That completes the component assembly. A careful check at this stage may obviate problems later on.

The 21-wire flat ribbon cable can now be prepared for connecting between the interface board and the arm assembly. Separate the wires at one end and strip and tin the wires. A group of six on one side is pared back from the rest to go to connection points 16-21 (see the overlay and photograph).

The other end of the ribbon cable connects to the terminal blocks on the end plate of the arm assembly according to Table 2 (which is related to Table 1). Temporarily leave off the wires to terminals 2, 4, 6, 8 and 10.

Check everything, once again.

Don't plug in the remaining ICs yet.

All that remains now is to arrange the interface connections according to your computer's expansion socket pinout.

The edge connector at the right hand end of the board plugs into a 44-way keyed socket. This is British-made, UECL part CS 1692F 1585 8237, and suits the Sinclair ZX81 expansion connector. To interface the board to your computer, you'll need one of these sockets, a short length of 28-way ribbon cable and a plug or socket to suit your computer's expansion connector.

Testing and calibration

Power up the robot and interface board without the computer connected and with all the ICs unplugged and check the power rails for ±9 V approximately and ±5 V from the regulator. Assuming all is well, switch off and plug in the ICs. Check again and switch off.

Connect the computer, switch on the robot followed by the computer and check the computer's operation is unaffected by the interface board. If it is, then there is probably a short across the address or data lines on the board.

Set all the DIL switches to open, rotate RV1 A-B-C-D fully anticlockwise and enter POKE 65472,0. Each output of IC5a will now be low and IC7a pin 1 will be close to 0 V. Enter POKE 65472,255 and each output will change to high and IC7a pin 1 will change to close to +1 V. Enter POKE 65472,128 and IC7a pin 1 will change to 0.5 V.

Similar results will be obtained on servo circuits B, C, D using addresses 65473, 65474, 65475 respectively.

Address the monostables with POKE 65477,0 and POKE 65478,0 and IC9 pins 13 and 5 respectively will go high for about two seconds and then return to low.

Connect the rotation motor (terminal block 2) whilst the robot is switched off, turn each preset to its midway position and switch on. The arm will move to some extent and come to rest peaceably i.e: without being held back by its cables.

Turning RV1A will result in the arm changing its position.

Return RV1A to its midway position, successively enter data of 0 and 255 (i.e: minimum) and maximum codes and adjust RV1A-RV2A for 180° of movement symmetrical about the forward facing position.

Repeat this procedure one axis at a time for the other three servo-controlled axes, adjusting for the shoulder to move between almost touching the end stop and about 10 below horizontal and for the elbow and wrist joints to have 180 movement.

Finally, connect and check the gripper motor circuit and after fitting the end panels the robot is ready for use.

We hope to follow up this project description with some general software details plus interfacing to some popular micros and a few programs. ●