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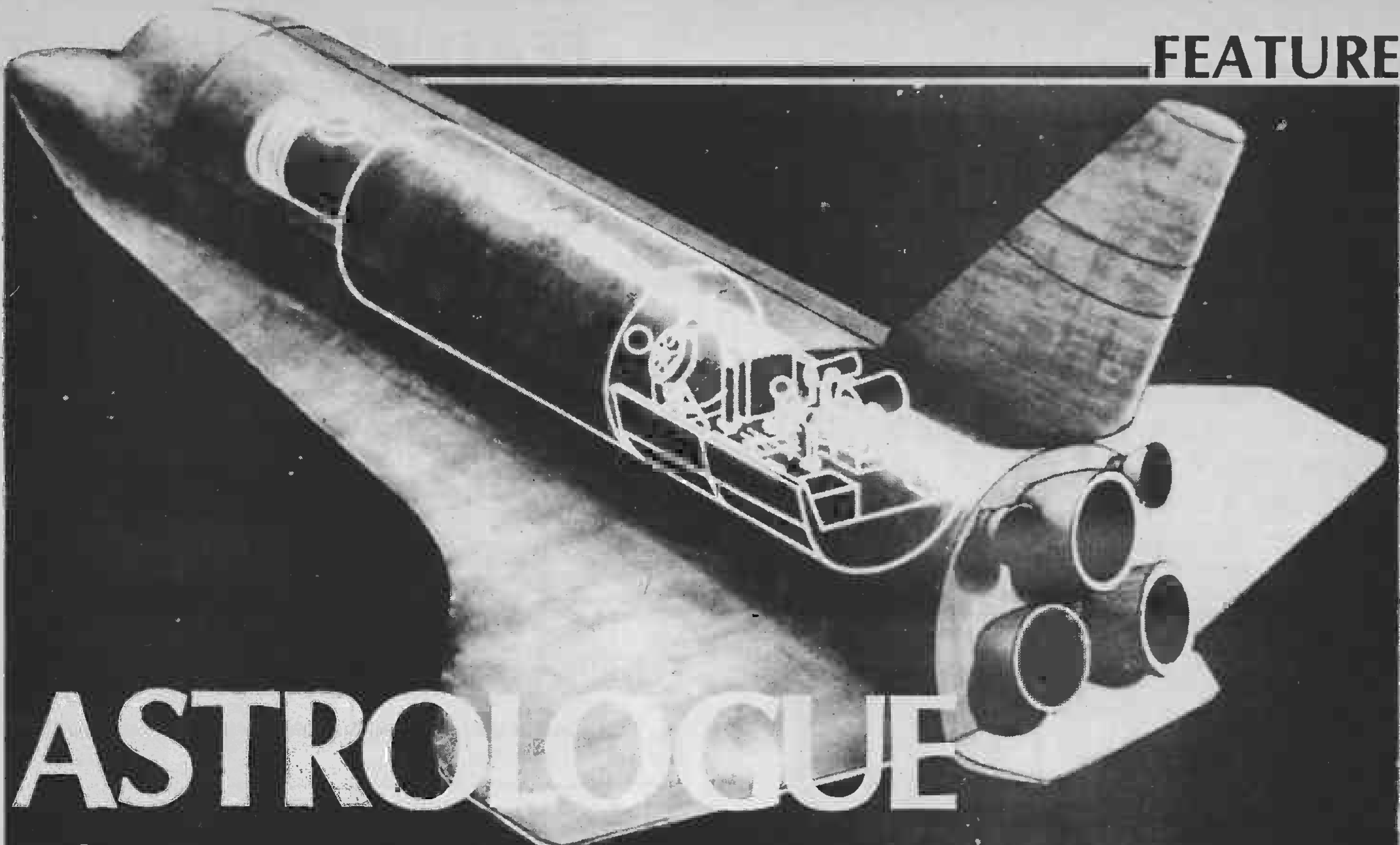


ASTROLOGUE

As the European Space Agency prepares to send its first astronauts aloft, Ian Graham explains how they were selected.

In March 1977 2,000 hopefuls replied to an Announcement of Opportunity from the European Space Agency (ESA). They were approaching the first hurdle in the selection procedure to find the first European astronauts. By September 1977, ESA's member states had eliminated all but 53 of the applicants, who then went on for scientific and medical screening.

ESA was looking for Spacelab Payload Specialists — men and women up to 47 years old, between 150 and 190 cm tall (that's about 4′ 11″ to 6′ 3″ in bushels, furlongs and farthings), sound in mind and body (not loonies) and with considerable engineering and scientific ability.

The Lucky Few

Of the 53 nominees, the Selection Board recommended four preferred candidates, who were subsequently approved by NASA. After six months of initial training, three were finally selected in May 1978 to join the Payload Specialist Training Programme. The three are:

Claude Nicollier, a Swiss astronomer;
Ulf Merbold, a German material scientist;
Wubbo Ockels, a Dutch nuclear physicist.

Further Education

Because of delays in the Space Shuttle project, Spacelab has also been delayed. While the Payload Specialists wait for their first flight, NASA has agreed to train two of them (who meet the necessary medical criteria) as Mission Specialists. The training programme began in July 1980 at the Johnson Space Centre and consists of lectures on aerospace technology and projects, T-38 flying, use of Space Shuttle simulators, water survival techniques, parachute landing and tours of NASA facilities.

After a year the candidates (Nicollier and Ockels) become fully fledged astronauts and enter the Shuttle training scheme for assignment to Shuttle flights. So, a future Space Shuttle/Spacelab flight may well carry European Mission Specialists *and* Payload Specialists. The third Payload Specialist, Ulf Merbold, is still a firm candidate for a place on the first Spacelab mission, now scheduled for June 1983.

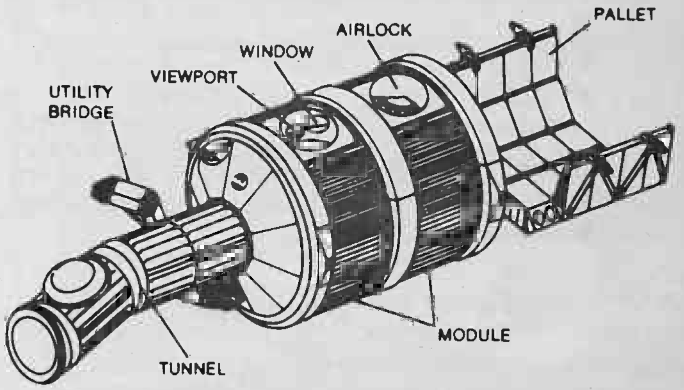


Fig. 1 One configuration of Spacelab — two pallets, a short pressurised module and the tunnel adaptor.

A Flexible Space Station

Spacelab will permit scientists and engineers, who are not trained as astronauts, to work on experiments in space. The lab itself is based on a modular design. There are three basic configurations:- module only, module plus pallet or pallet only. Fully loaded, Spacelab weighs in at 14.5 tonnes in its heaviest configuration, including a payload of 4.6 tonnes (long module only) to 9 tonnes (pallet only).

Mission costs are reduced by being able to use Spacelab again and again. For the first mission, it will consist of a long pressurised module plus one segment of pallet. The pallet, which is open to space during the mission, is made up from one to five segments, each 4 m wide, 3 m long and capable of carrying 3 tonnes of payload.

Scale Modelling

An engineering model of the space station was delivered to NASA in November 1980. The engineering model is a prototype of the station, not intended for flight. NASA will use it to check out interfaces with the Space Shuttle Orbiter. The first flight unit will be delivered this year and a second in 1982/3.

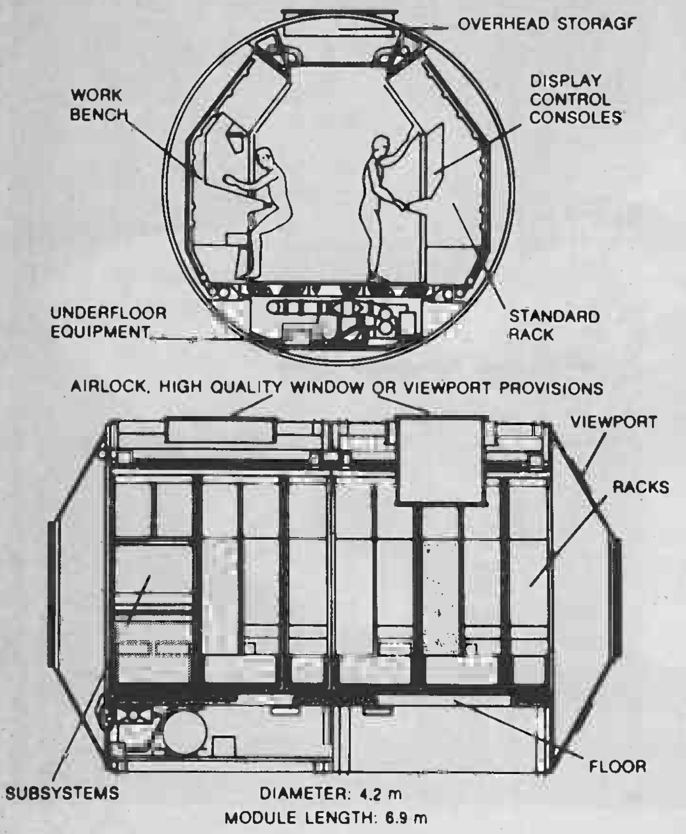


Fig. 2 Cross-sections through Spacelab's pressurised module.

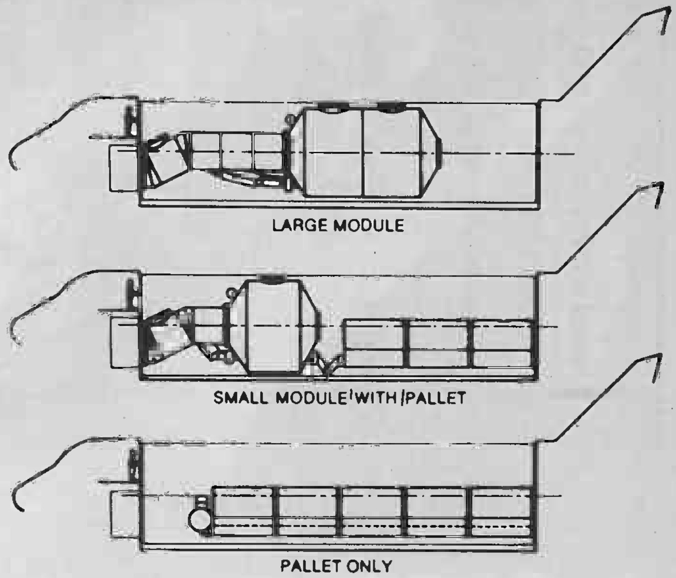


Fig. 3 Three typical Spacelab flight configurations in the Orbiter's cargo bay.

Although the engineering model pallets supplied to NASA were never intended for flight, NASA has determined that they are of sufficiently high quality to be approved for flight. The first pallet is due to fly in the second Space Shuttle mission scheduled for later this year.

Applications

Spacelab will carry instruments to look far out into space (unhindered by the Earth's distorting atmosphere) and back towards Earth. There are plans for zero-g experiments on plants and cell tissue, vaccine purification, antibody concentration, alloy production, atmospheric physics, astronomy, etc, etc. Man himself and his reaction to extended stays in space will be the subject of some studies.

Throughout its mission Spacelab will remain connected to the Shuttle Orbiter's payload bay. However, looking further into the future, Spacelab may be cast adrift for periods on its own, while the Orbiter returns to Earth.

The most important aspect of the Spacelab project is that it establishes a place for Europe in manned spaceflight for years to come.

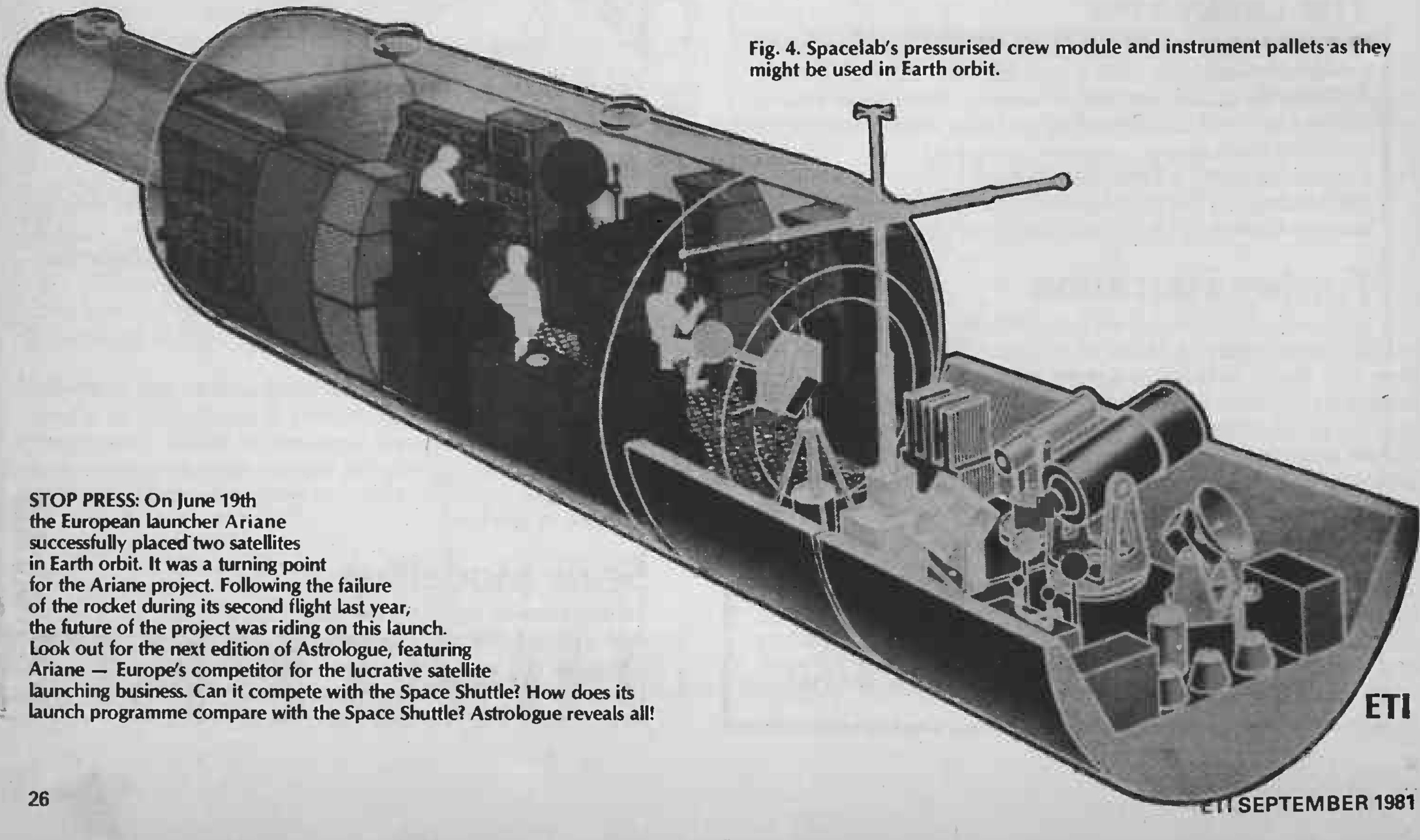


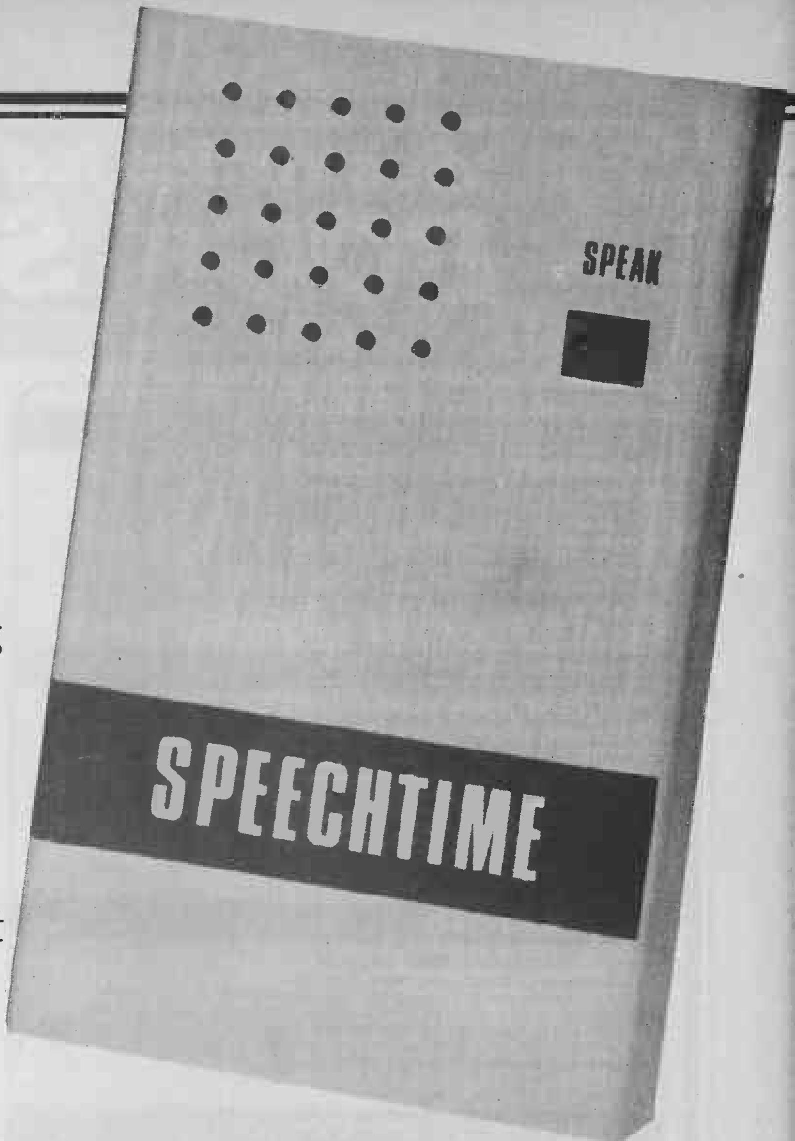
Fig. 4. Spacelab's pressurised crew module and instrument pallets as they might be used in Earth orbit.

STOP PRESS: On June 19th the European launcher Ariane successfully placed two satellites in Earth orbit. It was a turning point for the Ariane project. Following the failure of the rocket during its second flight last year, the future of the project was riding on this launch. Look out for the next edition of Astrologue, featuring Ariane — Europe's competitor for the lucrative satellite launching business. Can it compete with the Space Shuttle? How does its launch programme compare with the Space Shuttle? Astrologue reveals all!

ETI

SPEAKING CLOCK

There's been a lot of talk in hobby magazines about speaking chips, but the chips themselves haven't been saying much. Forget application notes, forget 'development systems'... ETI brings you a tried and tested project. Design and development by Silicon Speech Systems.



Speechtime is a hand-held talking clock. There is no visible display of the time; instead, a speech synthesiser 'talks' the time. If the time was 7.30, then the device would say 'SEVEN THIRTY'. Speech is generated a few milliseconds after the SPEAK button is pressed and will only continue while the button is depressed. The unit runs from a standard PP3 battery and is a mere 66 x 122 x 20 mm in size, small enough to fit into a pocket. Speechtime was partly designed as an aid for blind persons (this is the International Year of Disabled Persons) but it is just as useful for sighted persons.

Construction

All of the components are mounted on the single PCB, making construction extremely easy. For compactness, many of the resistors are the hard-to-obtain ⅛ W types; but since the only way to get hold of the chips for this project is to buy the complete kit of parts from the designers, this isn't a problem. With everything soldered in place, including the leads to the battery and speaker, the PCB can be fastened into the bottom of the case with a sheet of thin plastic beneath it to prevent shorts to the metal case. The miniature speaker is stuck into the circular cut-out in the board using a double-sided sticky pad, and there should be sufficient clearance at the other end of the case for the PP3 battery; sticky cable clamps on the 40-pin ICs hold the battery leads neatly in place (see the photograph). The case lid simply snaps into place.

Testing

Check that the power supply current is about 10 uA with SW3 off, and about 25 mA with the unit talking. With SW3 pressed, the output voltage at IC3 pin 5 should be half of $+V_{cc}$. Check that IC4 generates +5 V.

The clock chip outputs vary very slowly and are only present when SW3 is pressed. However, they can be made to oscillate at about 2 Hz when SW1 and SW2 are operated. IC1 pins 1, 2, 3, 4, 7, 8, 10, 12, 13, 16, 17, 18, 21 and 22 will slowly oscillate between 0 V and $+V_{cc}$ when SW3 *and* SW2 or SW1 are pressed. Check that PR1 alters the pitch of the voice, and adjust the preset to give a male-sounding voice.

General Use

Switch SW1 sets the minutes of the clock. Press this switch and the minutes counter of the clock will advance at 2 Hz. There is, however, a 1 s delay after pressing before this 2 Hz advance occurs. Press SW3 (speak) to monitor the new time. SW2 sets the hours in the same way. Do not set both at once.

When the battery gets flat the output will become distorted and the pitch may change. It is then time to change the battery. C1 forms a short-term reservoir of power so that if you are quick at changing the battery (less than 30 s) then the clock will continue to operate, and will not need to be re-timeset. The 9 uA current drain of IC1 discharges C1 at a mere 90 mV per second!

If the clock is running fast or slow it can be corrected as follows. CV1 is a trimmer capacitor that is used to slightly vary the crystal oscillator frequency, and is composed of two plates A and B (see Fig.2). Plate B has a continuous 360° rotation. When plate B completely overlaps A, the effective capacitance is maximum and so the oscillator runs slower. When the two plates have no overlap, the capacitance is minimum and so the oscillator runs faster. Therefore, if the clock runs fast increase the area of overlap of the two plates and vice versa.

HOW IT WORKS

The speech synthesiser (IC2) is basically a very large digital memory that contains data to generate the speech waveforms of a small fixed vocabulary. It is a sort of solid state 'digital tape recording'. Its vocabulary contains the following words; 0 (oh), 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 30, 40, 50. With these words it is possible to 'speak' any time in hours and minutes. The data for the time comes from IC1, a standard digital clock chip. The output data is encoded in a form suitable to drive normal seven-segment displays. The speech chip decodes this data so as to determine the time, which it then uses to address its memory and extract the correct speech waveforms. The clock chip consumes very little current from the battery (about 9 uA), so it is possible to run it from a PP3 for several years. It is also very insensitive to the supply voltage, so battery droop is not a problem.

The speech chip and the audio amplifier (IC3) consume about 25 mA and this would give a battery life measured in hours! Clearly the solution is to only power up this section when the unit is speaking. The speech chip is very sensitive to supply voltage and so a voltage regulator is used to power it. Q2 and Q3 form a short time delay circuit; about 20 ms after power up the collector of Q2 goes high and initiates the speak mode of the speech chip (Fig.3). The output waveform from IC2 is rather 'crunchy' and is filtered by C4,5 and R25,26 to remove the high frequency harmonics (Fig.4). This signal is then amplified by a low power amplifier which drives a miniature loudspeaker.

The clock chip is timed by a 32,768 Hz standard watch crystal. A trimmer capacitor allows a ±1 Hz variation of this frequency. PR1 sets the play speed of the speech, which of course determines the pitch (just like slowing down a record). The pitch of the voice is higher for PM outputs, to distinguish between AM or PM. This is achieved by voltage-controlling the pitch from the PM output via resistor R29. If you remove this resistor then the pitch remains invariant.

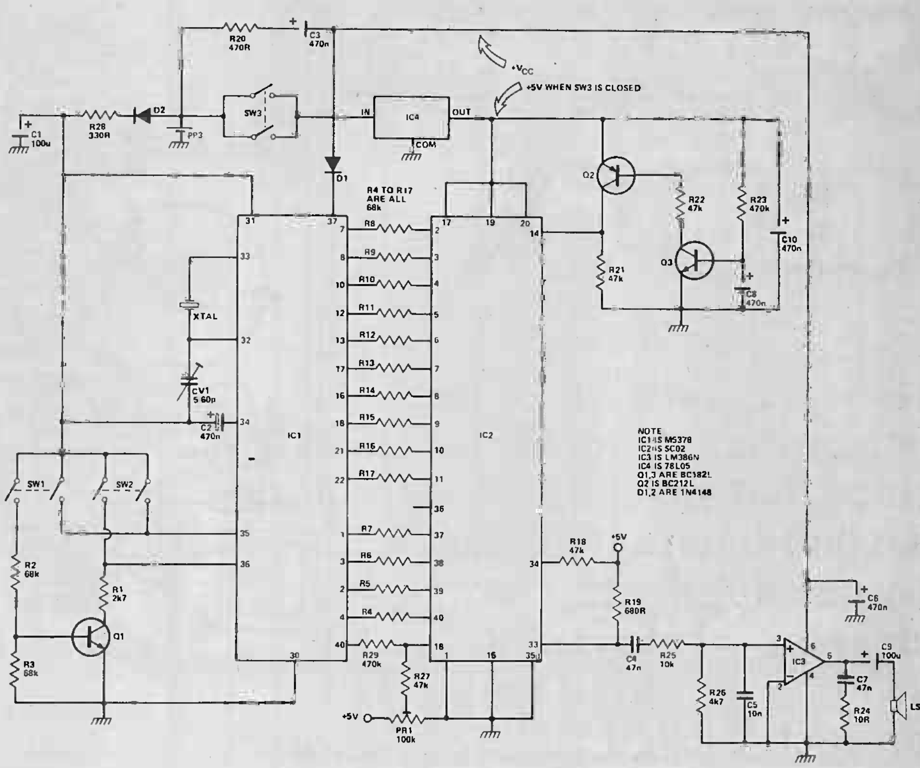


Fig. 1 The complete circuit diagram of the Speechtime talking clock.

BUYLINES

A complete kit of parts for this project including fully finished stainless steel case, nuts, bolts etc is available from Silicon Speech Systems for £29.50 inclusive of VAT and postage. Silicon Speech Systems, Portway Industrial Estate, Andover, Hampshire SP10 3NM

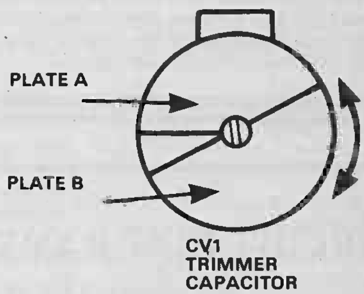


Fig. 2 Construction of the trimmer capacitor.

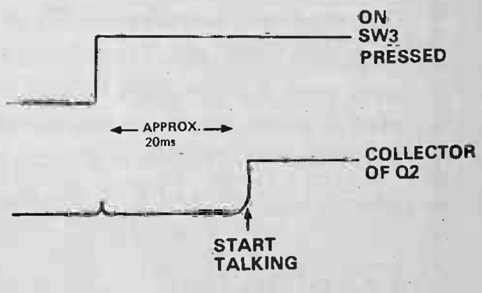


Fig.3 The time delay associated with Q2 and Q3 allows the supply lines to become stable before speaking commences.

It's a tight squeeze but you can fit everything in! Cable clamps stuck on top of the ICs keep the battery wiring neat, and the loudspeaker sits on the hole cut in the PCB.

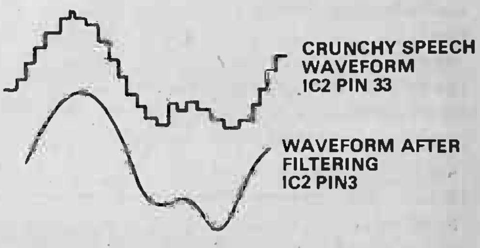


Fig.4 The digitally-generated speech waveforms before and after filtering.

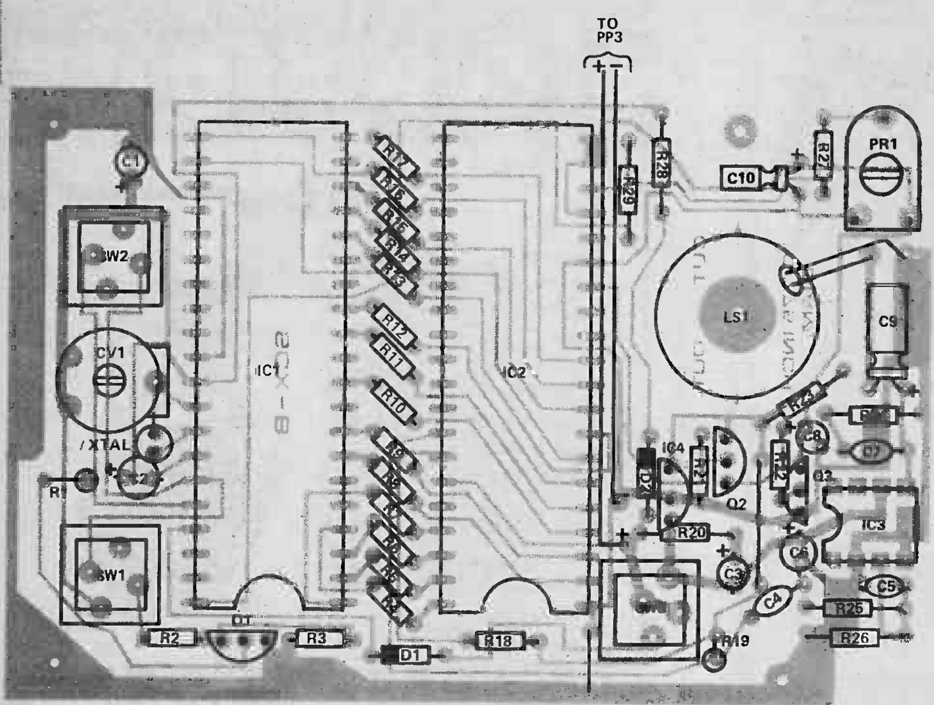


Fig. 5 Component overlay for the Speechtime project. Two of the capacitors, C9 and C10, must have their leads bent at right angles before soldering so that they lie flat against the board — this gives enough clearance for the loudspeaker to fit above them when the case is closed. Also make sure that you get the switches in the right positions: SW1 and SW2 are low profile so as to fit inside the case (avoiding accidental alteration of the clock settings), while SW3 is larger and lies flush with the cut-out in the case lid.

PARTS LIST

Resistors (all ¼ W, 5% except where stated)

R1	2k7
R2-17	68k ⅛ W
R18,21,22,27	47k ⅛ W
R19	680R
R20	470R
R23,29	470k
R24	10R
R25	10k
R26	4k7
R28	330R

Potentiometer

PR1	100k miniature horizontal preset

Capacitors

C1,9	100uF 10 V radial electrolytic
C2,3,6,8,10	470n 35 V tantalum
C4,7	47n mylar
C5	10n mylar
CV1	5-60p trimmer

Semiconductors

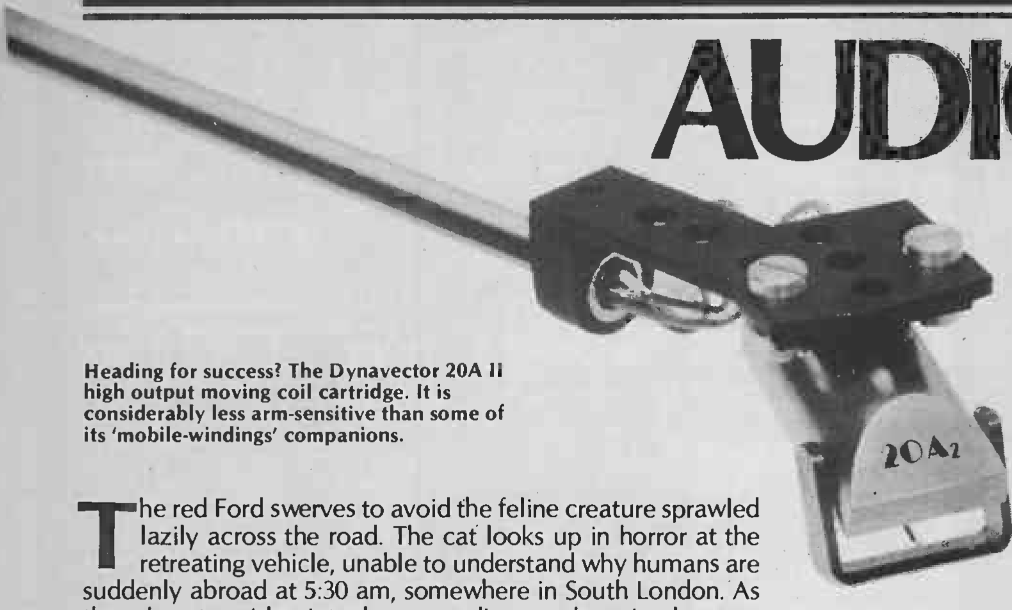
IC1	M5378
IC2	SC02
IC3	LM386N
IC4	78L05
Q1,3	BC182L
Q2	BC212L
D1,2	1N4148

Miscellaneous

SW1,2	push-button low profile two-pole on/off
SW3	push-button two-pole on/off

PCB, IC sockets, 1½" diameter 8R speaker, 32,768 Hz crystal, battery, connector, case, nuts, bolts, wire etc.

AUDIOPHILE



Heading for success? The Dynavector 20A II high output moving coil cartridge. It is considerably less arm-sensitive than some of its 'mobile-windings' companions.

An adrenalin-soaked Audiophile this month, as Ron Harris gets angry about duff accessories and enthusiastic about two new pickups.

The red Ford swerves to avoid the feline creature sprawled lazily across the road. The cat looks up in horror at the retreating vehicle, unable to understand why humans are suddenly abroad at 5:30 am, somewhere in South London. As the exhaust vanishes into the empty distance the animal returns to its meal certain that the morning's car parade is still hours away and one Granada doth not a rush hour make.

Meanwhile ETI's editor continues to pursue the dawn along the South Circular Road, bound for Sunbury-upon-Thames and the morning rite of the digital disc. Why do these Japanese companies still insist upon the virgin at dawn (instead of a civilised alcoholic hour at high noon) to announce their new Technology? Note the capital.

I haven't been up that early in years. Even my car refuses to start that early. If I'd gotten out of bed any sooner I'd have been leaving it before I got in. Anyway, more on the future hi-fi revolution in a later issue. For this month it will suffice to consider the extremes of the moment. Extremes that run from the satisfaction of discovering a new pair of cartridges that offer good performance at a good price, to the all-consuming anger and frustration involved with the quality control failures of a major accessory manufacturer.

On the basis of saving the best until last, I shall deal with the darker side of life first. Before I go any further let me say now that I'm not going to name the firm concerned — yet. This is simply because I could not guarantee to remain less than subjective in my presentation.

In all probability a large percentage of my readership will work out for themselves the name of those of whom I speak.

So be it.

Connecting Shorts

It began, actually, in the middle of preparing a speaker comparison for Audiophile two months back. There arose the need, due to everything running late as usual, for a quick method of comparing three pairs of loudspeakers. Never having bought a comparator box in my life — I can still use a soldering iron, however advanced my senility — and always having preferred to make my own, I suppose I was a little too trusting in expecting it to work first time.

We obtained a three-way switching 'box' from this 'well known company' and half an hour of 15 A cabling later sat back to listen, resplendent in the convenience of armchair control. First time we switched in Speakers '3' the amp fuses blew. Speakers '2' appeared to be suffering from loss of definition and bass, with no stereo image to speak of. Something wrong here too. . . .

All in all we found that:-

1. Speakers '2' were wired out of phase with each other.
2. Speakers '3' did not actually select Speakers '3'. Instead it contented itself with shorting the amplifier channels to earth.
3. Two screws were missing from the connecting blocks (non-standard size of course).
4. Very small gauge wire was employed in the unit, and a dry joint was present on one of the switch contacts.

In fact the *only* thing correct in the whole box was the little sticker assuring us that it had passed quality control. . . .

Repeated Rage

Well, we all have off-days and had that been that, I doubt if anyone would have thought more of it. One bad sample, just our luck and so on.

However, in the last month one of my lab testers bought a tape selector unit from the same company, only to find that Output 'A' became connected to Output 'B' upon change-over. . . . One failed output stage later he rewired the unit correctly, just as I had had to do earlier.

Even *that* isn't the last of it. I have since been shown, by a suitably irate reader, another speaker control on which both ends of the volume control went to earth. . . and so, eventually, did the slider.

Did wonders for the amplifier that did, I can tell you. Same company, of course. Probably got shares in a repair business.

Someone, somewhere, is obviously spending too much time putting little stickers on and too *little* time actually testing the equipment they sell.

I have written to the company concerned — twice. The first letter remains unanswered, and the second left today. If they choose to ignore *that* one, then I shall send a third — registered mail — and print a copy in Audiophile. It will, of course, contain the company name and address.

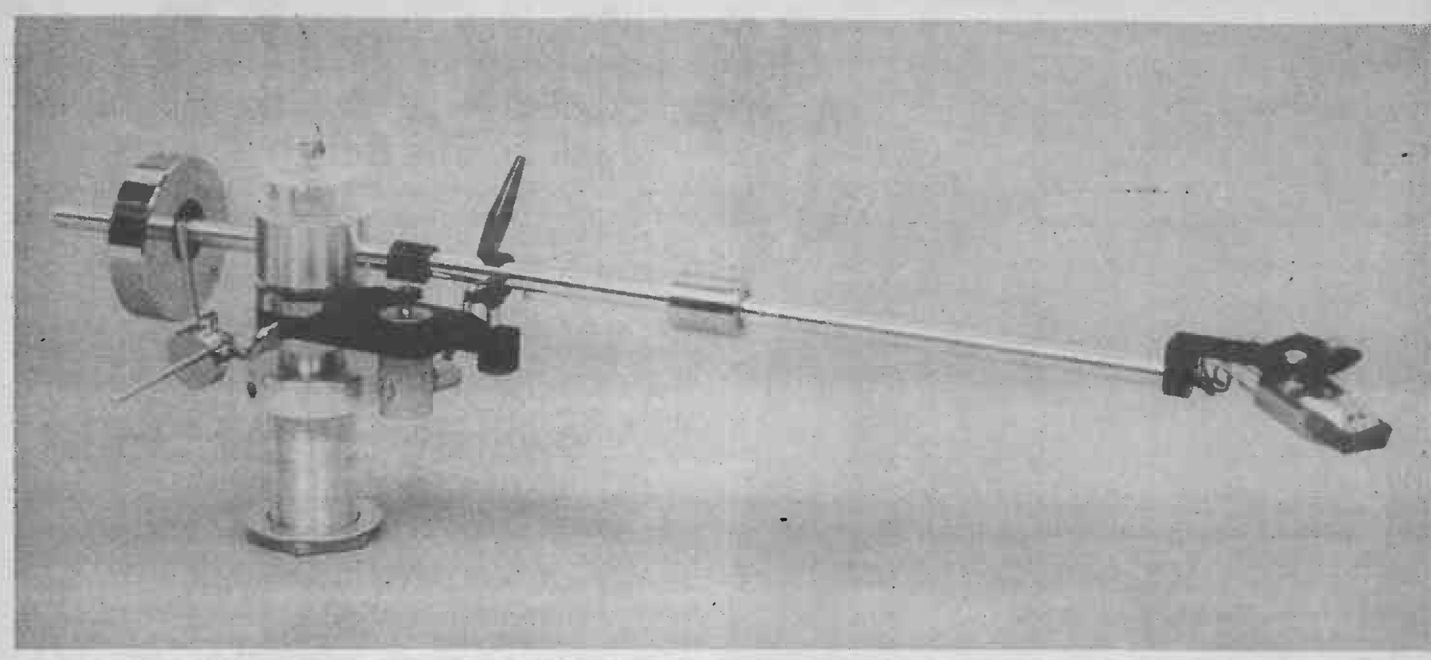
In the meantime the moral would seem to be "If you can do it yourself — DO IT". For anyone who can wire up a switch or two into a case, buying ready-made connection machines can not only prove very expensive, it can also prove a total waste of time. . . .

If I ever *do* get a reply, what odds that that too contains a quality assurance sticker?

●

A Life Of Stylus

Pickup cartridges continue to fascinate me. Of late there has been such rapid development in the field, especially with moving coils, that it is difficult to keep up. In addition, cartridges remain the cheapest major upgrade, barring accessories. From



Above: the Dynavector 20A II in the Mayware Mark III pickup arm. This is no longer termed the 'Formula 4' due to an international agreement. The 20A worked well in this arm, as indeed it did in the SME Series III.

talking to hi-fi users lately, I wonder how manufacturers ever sell *any* replacement styli at all. From what I can gather people change the cartridge when the time comes, not the stylus! It makes good sense whilst still climbing the 'upgrade' slope, I suppose.

I mention this because an increasing number of high-output moving coils do not have a user-replaceable stylus. At first I wondered what effect this might have upon their acceptability. In the light of subsequent conversations, none whatsoever it would appear. Dynavector also offer that exchange scheme of theirs, in which the user can trade in his present unit for a better one at a huge discount.

The days of the disposable cartridge would appear to be with us already. Not a bad thing I think — after all, once the original 'Stylus' is changed, how many companies guarantee performance to original levels?

I ramble thus because both of the cartridges to be described herein are of this type, namely the Dynavector DV20A II and the Coral MC88E. Long standing readers — for God's sake sit down you'll get flat feet — will remember that the Coral MC81 is one of my favourite pickups and will thus be less than surprised to see me review this new offspring.

Dynavector DV20A II

The 20A II is designed as a low-mass, high output, moving coil pickup which can be safely employed in low-mass arms without the need for a step-up device.

To achieve these ends, Dynavector have employed a glass fibre frame, reinforced with polyester, instead of the usual aluminium, winding onto it a far greater number of turns than before. Rare-earth magnets are also used to reduce mass still further.

The result is a weight of around 5.3 g — ideal for an SME arm when taken with the compliance figure of 25 — and an output of some 3.7 mV per channel at 5 cm/s (1 kHz). That compliance is remarkably high for a moving coil, too.

Testing For Flats

On test the DV20A II gave a sound account of itself. Frequency response was well controlled and extended, with no sign of major excursions from a straight line. In numbers: 20 Hz-20 kHz ±1.5 dB.

Channel separation was in excess of 25 dB below 2 kHz and never less than 18 dB right up to 25 kHz. Balance between the channels was excellent at 0.5 dB.

Tracking ability reached its peak at 1.7 g playing weight, at which point it would track HFS 75 cleanly — just! Again a good result for its class. For the listening tests, both an SME 3009 Series III and a Mayware 'Formula 4' were used with good results.

In the SME damping proved beneficial, but only the smallest amount was required. The unit is totally insensitive to load capacitance and anything between 5k and 50k will do for resistance.

Listening For What?

As always with hi-fi components, ultimately you should go listen for yourselves to a couple of units and decide between them. If you include the DV20A II on your shopping list, I fancy it will be an easy decision.

The cartridge gives a vivid rendering of any material presented to it, with an excellent feel for detail. Bass response is well and truly extended and it is good to hear the detailed reproduction being maintained in the lower registers. Stereo imaging is precise and steady. All types of music were replayed with equal ease and quality, a true sign of a high class unit.

The more I listen to this cartridge, the more I am impressed by it. I can find nothing to criticise in its sound at all — save that some may find it a little 'live', if it is incorrectly matched to a bright speaker system.

Overall a component which it is easy to recommend wholeheartedly, and at around £70-£80 it is sensibly priced.

•

Coral MC88E

At the other end of the moving coil market (in terms of price) lies the MC88E. This is Coral's competitor to such as Dynavector's 10X II and Mayware's MC3L, recently considered in these pages.

It will sell at just under £40, and thus has a significant price advantage over its proposed rivals. Again the output is high enough to need no boosting when operated with a standard preamp.

Physically it appears identical to the MC81, except that it is grey in colour, rather than black. It weighs only 5 g and can be

The Coral as it will arrive in your life. Readers who note more than a passing physical resemblance between this and the MC81 are not wrong!

employed in either low or medium mass arms, with the latter being preferred. Here is a unit clearly intended to be an 'upgrading' step and perhaps even a user's first foray into moving coil music.

Back To The Bench

The audible range was covered with a mere ±2 dB deviation from a ruler-straight line, and the channel separation remained above 15 dB at all times. At 1 kHz, where most manufacturers specify their product, the MC88E could muster 23 dB. Creditable.

The two channels were matched within 1.5 dB, and optimum tracking was reached at around 1.9 g in a selection of decks/arms.

A Sound Deal

So what does it sound like? In a word — good. Taking the price into account, which you have to, I think, the MC88E is a good unit. The sound is clean and has a good mid-range to it. Bass response is well defined, but could be better extended. Treble is never hard and *is* well extended! An easy cartridge to listen to, then, and one which shows the advantages of moving coils, if not fully exploiting them.

My only doubt, having heard it at length, is whether or not it will stand up to the competition from such excellent moving magnet units as the Shure M97HE or the new Goldring IGC variations.

It will be interesting to watch the progress of this one. Meantime, a definite recommendation for a good value-for-money product which is ideal to discover the differences inherent in moving coil sounds.

Arm-ful Variations?

Odyssey RP1 tone-arm. That's what it's called. What it actually *is* will be entirely up to you. This is a design which allows the buyer to choose his/her own finish and is then individually assembled to meet that buyer's requirement.

At a basic price of £80 — some finishes (ie gold!) cost more — the RP1 appears to have a lot to offer. Features include the aluminium headshell (fixed) and the 10 mm diameter aluminium arm tube which is treated internally to reduce acoustic and structural resonances. The arm/counterweight support has precision ball races situated at stylus level to improve tracking and 'twisting movement' behaviour.

The counterweight is positioned to optimise the centre of gravity placement and the sleeve and weight are machined from brass. The main pillar and bearing housing are in brass, with provision for a damping assembly acting in the vertical plane only. The base is again brass with the main pillar offset, for overhang adjustment.

The RP1 is available with three arm tube and headshell assemblies of low, medium and high effective mass, and the arm can be specified in a variety of surface finishes to customer requirements, ranging from a basic painted finish to polished brass and aluminium, chrome plate or even real gold (at a lot more than £80).

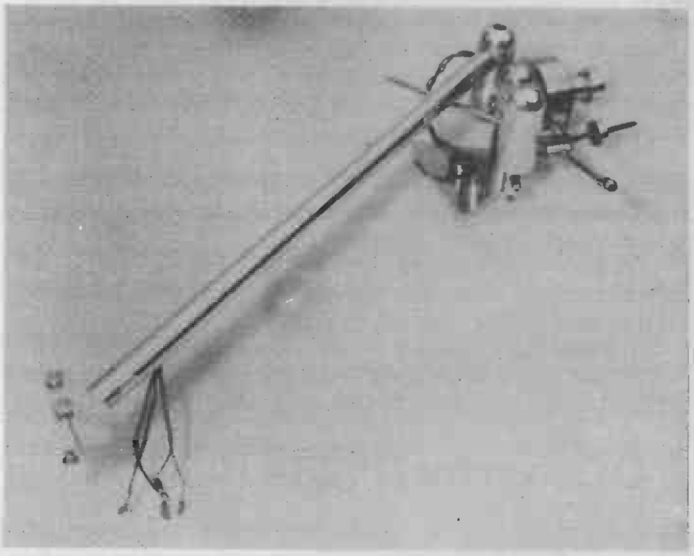
I've written to them, requesting a play with one, and if it arrives Audiophile will report on it in detail at a later date.

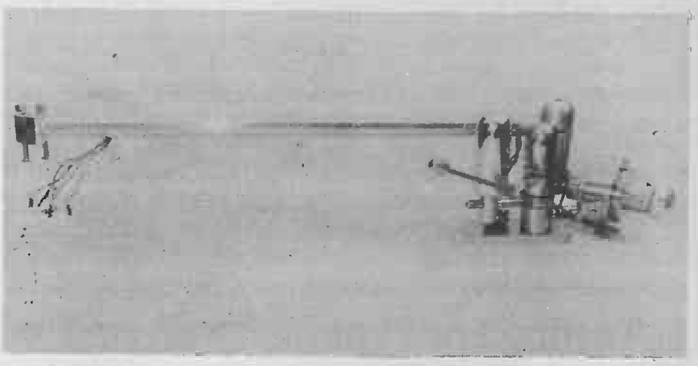
In the meantime Odyssey can be found at 35 High Barholm, Kilbarchan, Renfrewshire, Scotland.

Next Month

And for my next trick . . .

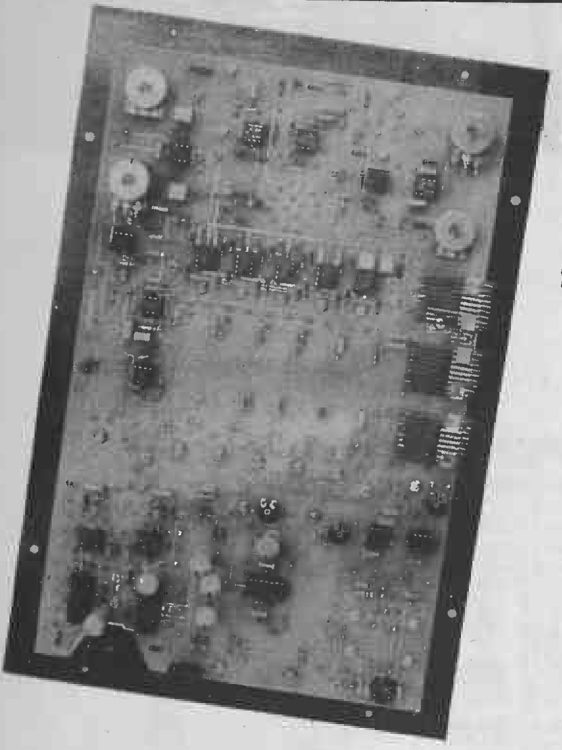
In the next issue I'll be going through a new range of cassette decks — entitled Alpage — distributed by Shure Electronics. Launched at the Cunard show recently they have a number of unique features that make them worthy of consideration. Worth a read or two, methinks.





The Odyssey Engineering pickup arm. This can be produced to any finish desired by the purchaser, basic price £80. If you're one of those people who are never satisfied with the 'commercial compromises' it could be that this is for you.

ETI



DISCO MIXER

Part 3 of the DJ90 Stereo Mixer finishes the series with the final constructional details. Design and development by Tim Orr.

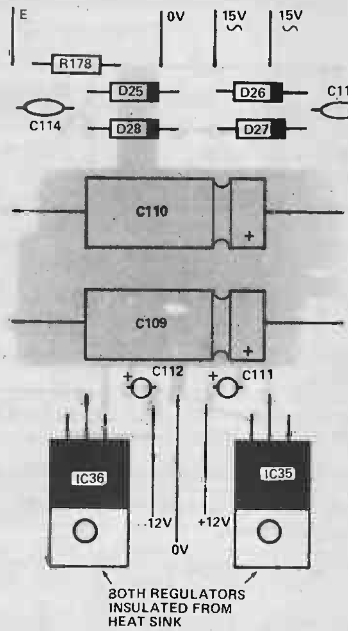
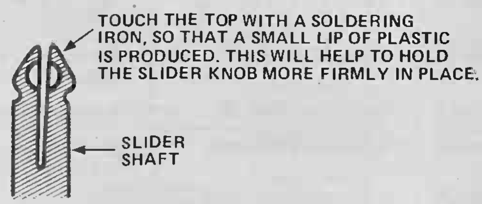


Fig.1 (Left) Component overlay for the power supply for this project, which can be obtained from Powertran Electronics. Alternatively any suitable 12-0-12 supply that you have may be used. Note that the regulators must be mounted on, but insulated from, a small heatsink.

Fig.2 (Right) Component overlay for the panel board. Molex connector 'A' (MA) connects to the input board.

Fig.3 (Below) The knobs on the slider pots will be a bit loose unless this heat-treatment is used!



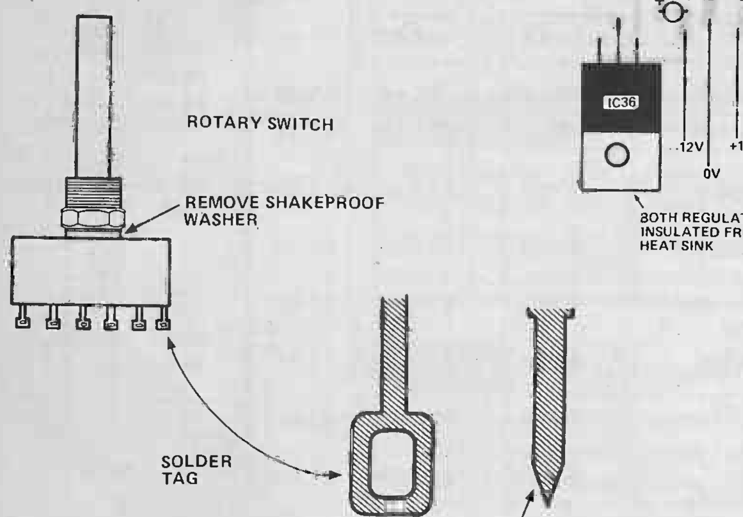
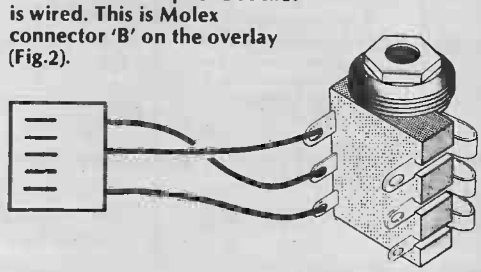


Fig.4 (Above) Converting the rotary switches so that they become PCB-mounting.

Fig.5 (Below) How the Molex lead for the headphone socket is wired. This is Molex connector 'B' on the overlay (Fig.2).



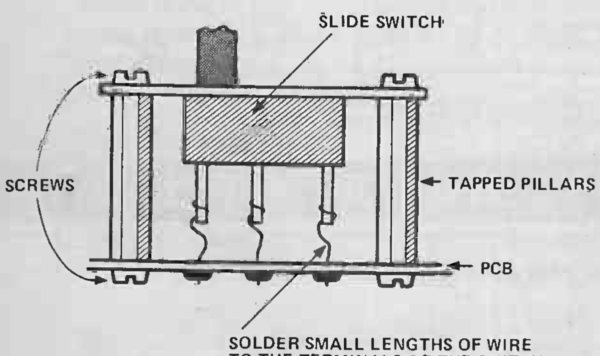


Fig.6 The slide switches are mounted on pillars so as to pass the front panel. Connection to the PCB is made by means of tinned copper wire.

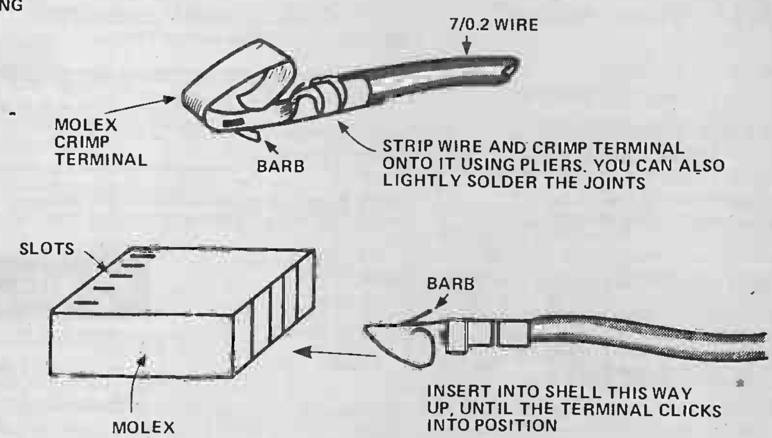
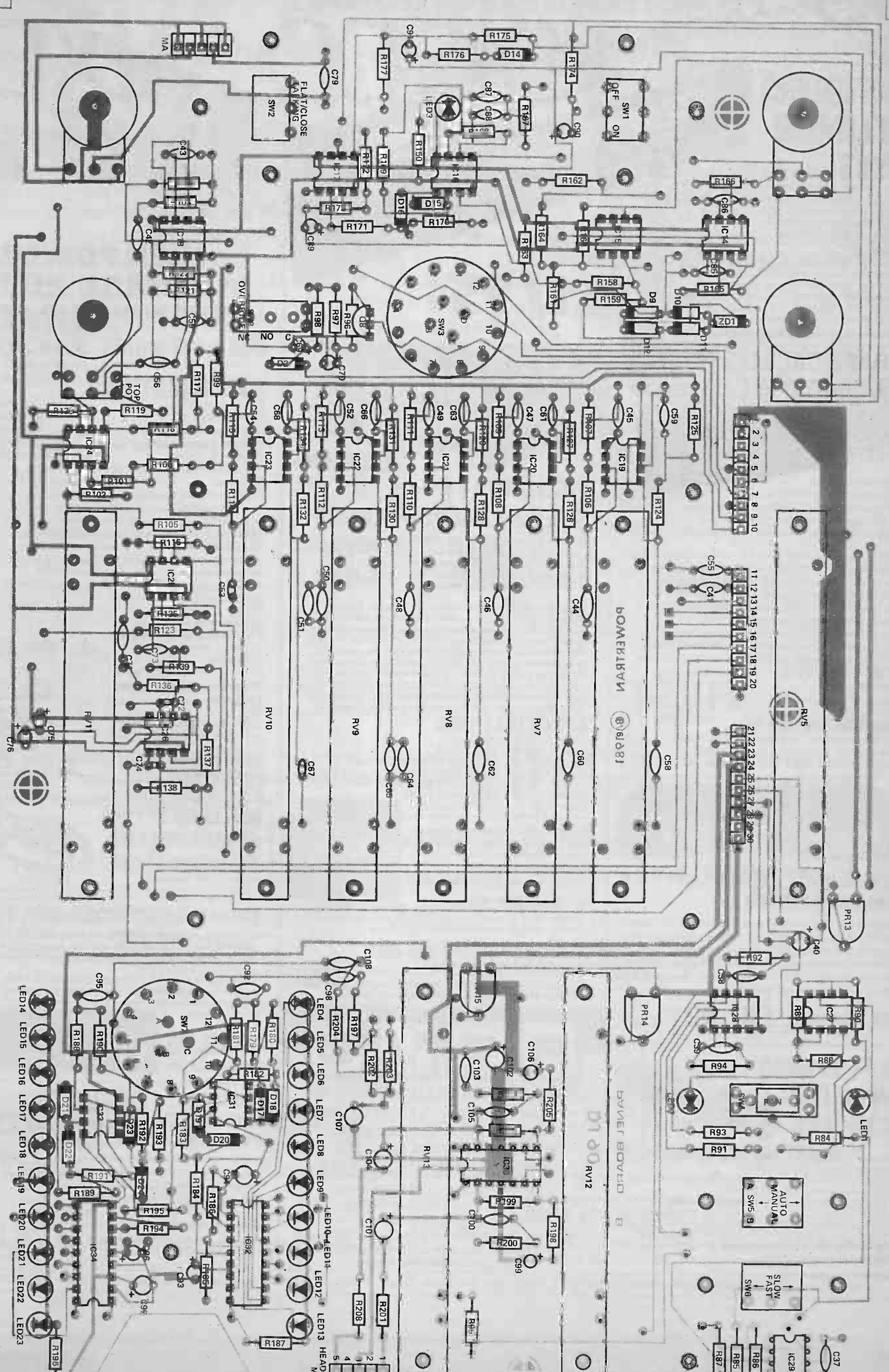
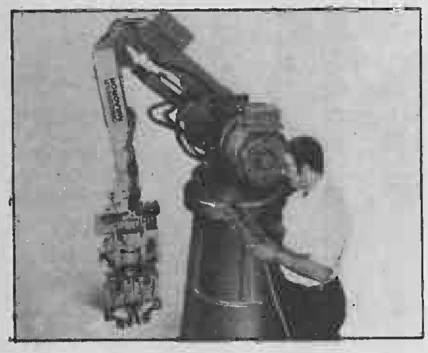


Fig.7 If you've never used Molex connectors before, this is the way it's done. Simple really.



The Robot Age is here p.50



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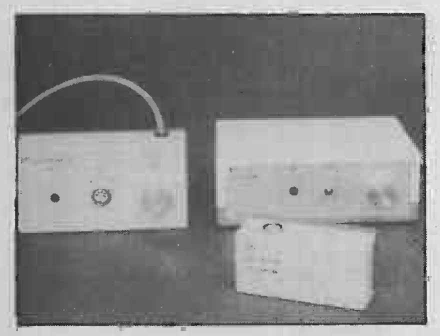

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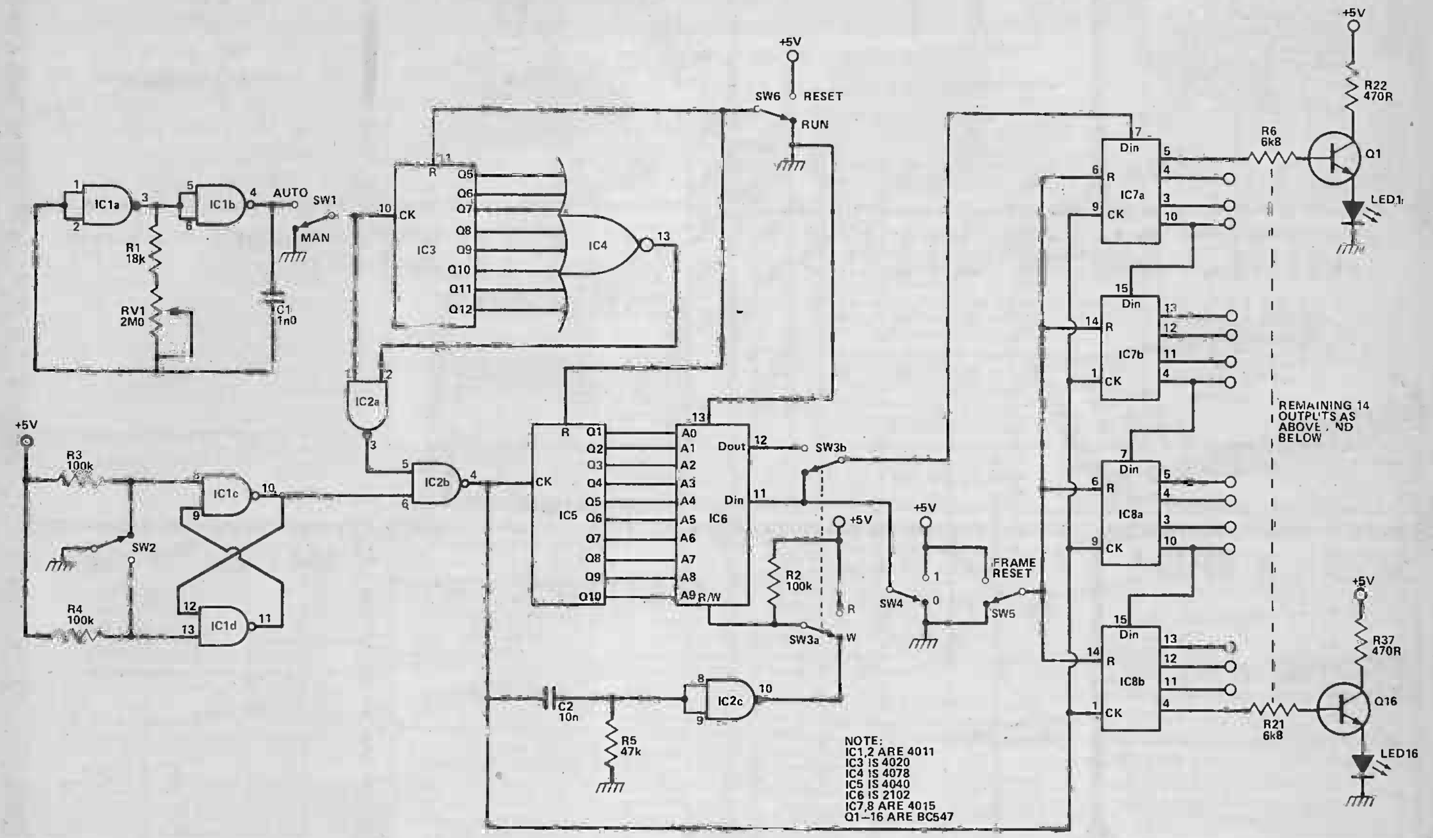
TECH TIPS

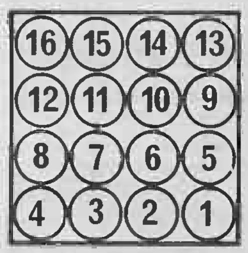


Video Sequencer

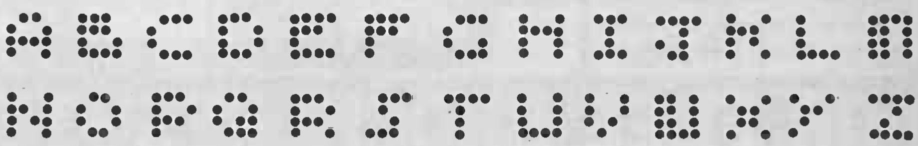
R. T. Gain, London

This design uses a 2102 RAM (1024 x 1) controlling a square array of 16 LEDs to display up to 64 preprogrammed patterns. Data is fed into the RAM manually using the data switch, SW4, and the step switch, SW2, and can be played automatically using an internal clock and counter. The display rate can be varied from 10 frames a second to one frame every 10 s. When SW1 is set to manual and SW2 is pressed, a write pulse is fed to the R/W input of the 2102 and the data on SW4 is stored in the first memory location. On releasing SW2 the negative-going edge clocks the 4040 on to the next address location. Subsequent locations are programmed in the same way, setting SW4 to the correct position and pressing SW2 momentarily.

To replay the pictures SW1 is set to auto, SW3 to read and SW6 is switched to reset and then back to run. The first 16 clock pulses are relayed to IC3 and IC5, filling the four-bit shift registers with the first 16 bits of data and lighting the appropriate LEDs. At the 17th pulse pin 13 of IC4 goes low, inhibiting the address counter IC5 for the next 4080 counts. The clock rate should therefore be variable from roughly 400 hz to 40 hz using RV1. This cycle then repeats, displaying each frame in turn until SW1 is switched to manual. SW5 allows the frame to be cleared after entering each group of 16 bits to avoid confusion. Any 5 V, 200 mA supply can be used to power the circuit. Current requirements vary between 30 and 140 mA, depending on the number of LEDs alight.



Arrangement of the LED matrix (above) and a suggested alphabet. (below).



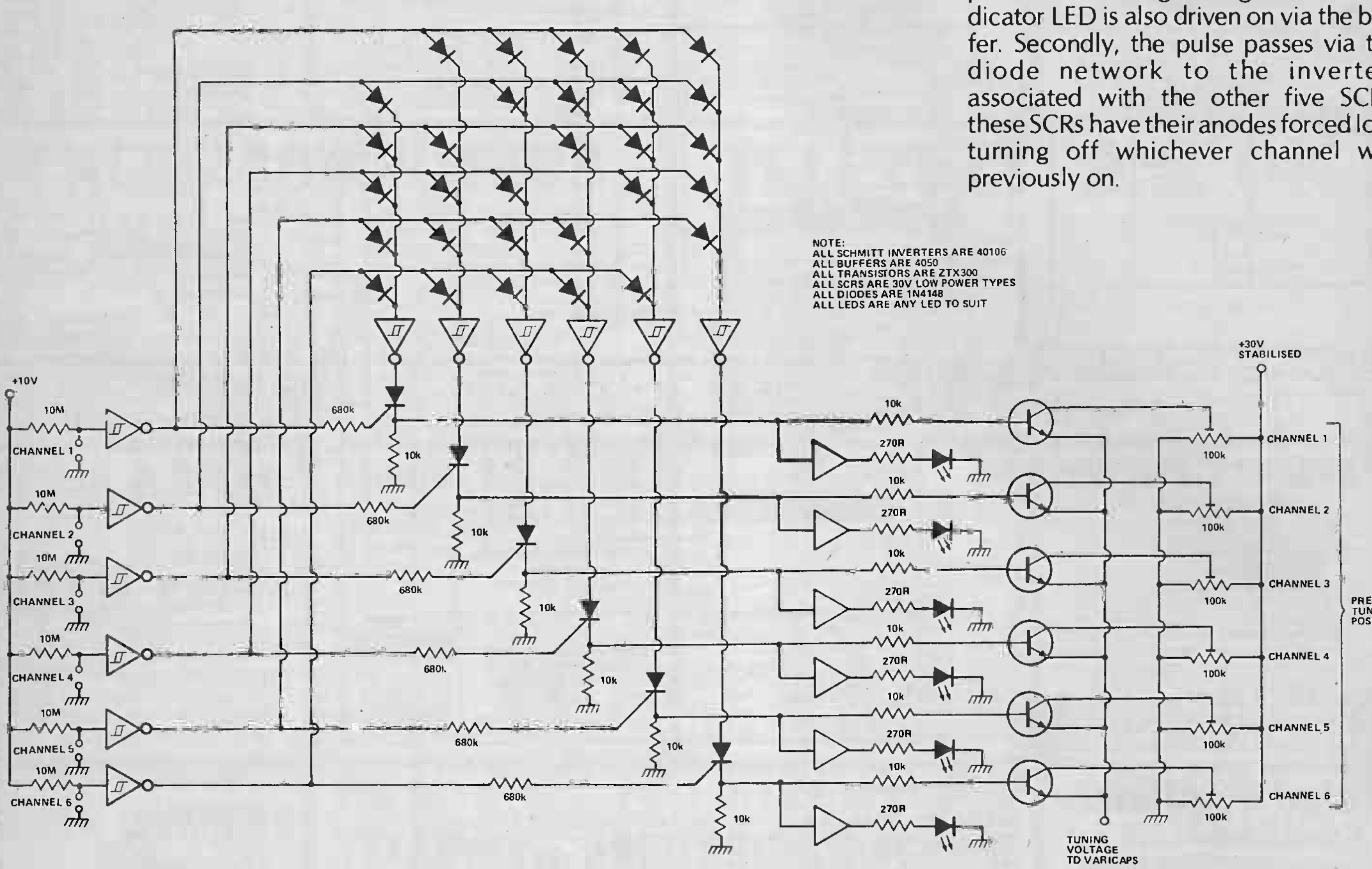
Tech-Tips is an ideas forum and is not aimed at the beginner. We regret we cannot answer queries on these items. ETI is prepared to consider circuits or ideas submitted by readers for this page. All items used will be paid for. Drawings should be as clear as possible and the text should preferably be typed. Circuits must not be subject to copyright. Items for consideration should be sent to ETI TECH-TIPS, Electronics Today International, 145 Charing Cross Road, London WC2H 0EE.

FM Touch Selector

S.C. Vestuti, Llanelli

The circuit shown here is a six-channel touch station selector, suitable for use with the FM tuner in the January '81 ETI or other varicap tuners.

The required channel is selected by bridging the appropriate touch contacts with your finger; this causes the output of the associated inverter to switch high for the duration of the touch. This high pulse fires the gate of the corresponding SCR; the high at the cathode turns on the transistor and connects the preset tuning pot to the tuning voltage rail. An indicator LED is also driven on via the buffer. Secondly, the pulse passes via the diode network to the inverters associated with the other five SCRs; these SCRs have their anodes forced low, turning off whichever channel was previously on.

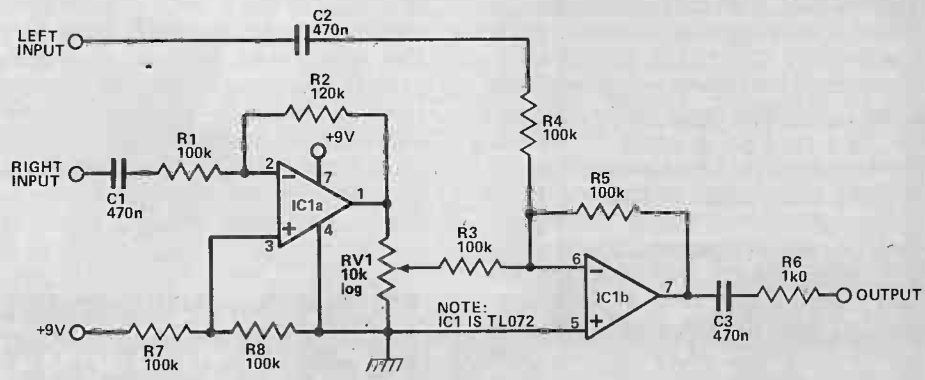


Vocal Canceller

S. P. Giles, London

If you want to lower the level of the vocal on a record, then this circuit does the trick very easily. It very often happens that during the mixing of the multichannel recording to give a stereo image, the vocal is positioned in the middle with the other instruments on the left and right. If we therefore invert the right channel and mix it with the left, any signals which were originally equal on both channels will cancel out (or at worst become very much reduced in level).

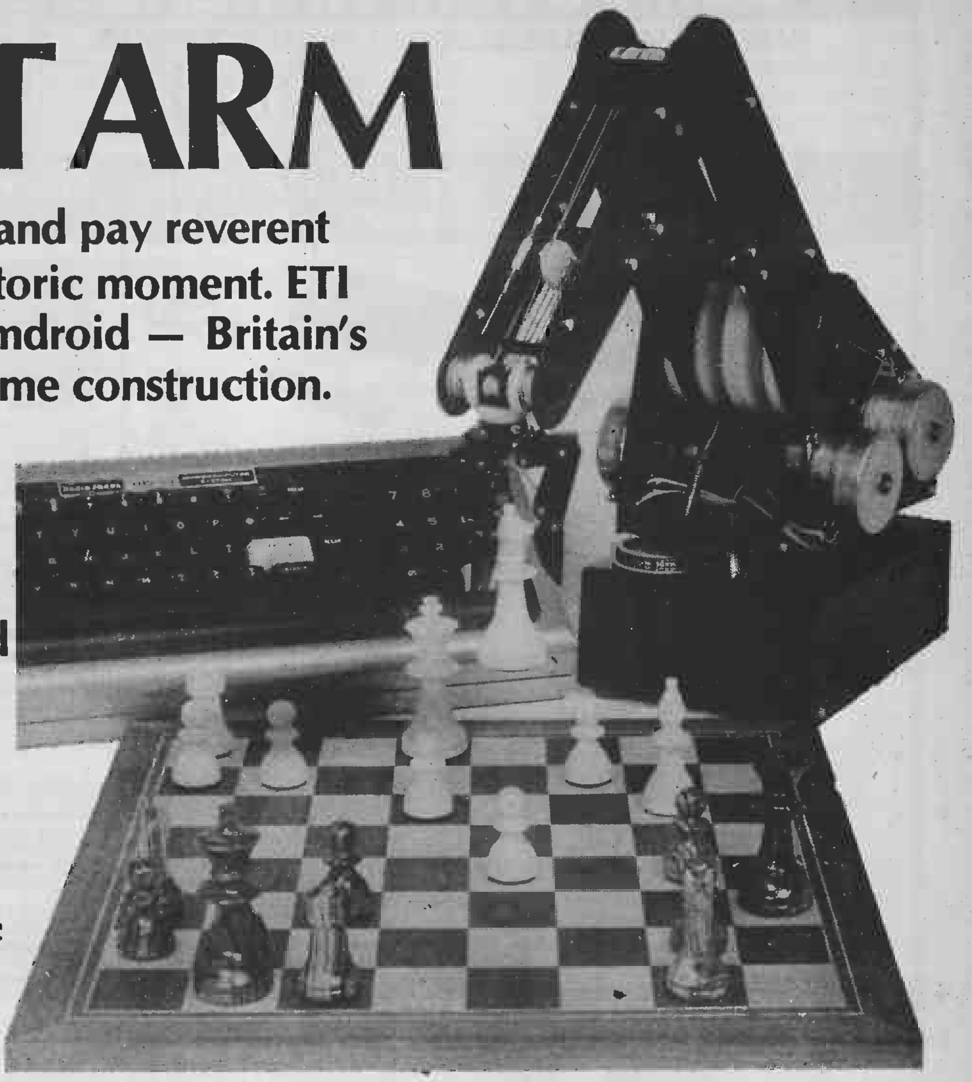
In the circuit shown here the right channel is inverted by IC1a and given a small gain. The output is attenuated by RV1 and mixed with the left channel by IC1b. To set up the circuit, listen to the output and adjust RV1 for best cancellation.



The circuit works very well with Led Zeppelin II, and many Shadows records where poor Hank Marvin gets the chop!

ROBOT ARM

Stop what you're doing and pay reverent attention — this is a historic moment. ETI proudly presents the Armdroid — Britain's first serious robot for home construction. It can be operated manually or taught movement sequences under computer control, and is really only limited in its applications by your imagination. System concept by Ron Harris. Realisation and development by Agit Channe, Nick Ouroussof and Andrew Lennard.



Welcome to the Robot Age. With the publication of this project ETI shepherds in a new era in our hobby. Robotics is the logical extension of electronics and modern manufacturing methods. We already have all the necessary technology to produce viable robots: cheap memory; cheap processing; mass produced computers; comprehensive I/O electronics; accurate and versatile metalwork machinery — automated, of course.

Any civilised country wishing to survive as an economic power in the 1990s and beyond will have to have a large and operative robot population in its industries. Read the article elsewhere in this issue for an assessment of Britain's chances, based on today's figures.

Know The Robot

One of the greatest obstacles to industrial robots is the lack of freely available information on the subject for the engineer and technician, who will be expected to use and control the dreaded 'mechanical men'.

The Armdroid is the first in a line of ETI robotic projects, all of which can be built and used by *anyone* who can solder! The arm can lift loads in excess of any commercial equivalent we know of up to £1,000 in price.

As such it is designed to fulfill the needs of the small industrial user who is searching for a small programmable manipulative machine; the educational establishment interested in research and adaptation; and finally the hobbyist at home who just wants to build a good project.

We hope that it will stimulate interest in the field and serve to illustrate the accessibility of this new branch of technology. Although originally configured to run from a Tandy TRS-80 Model I home computer, the bus structure is such that it can be instantly set up to run from any other machine with this (standard) input.

In order to encourage this level of involvement we are offering a £100 prize to the author(s) of the most ingenious piece of software to run the Armdroid — on any machine *except* the Tandy! (See end of article for details.)

Establishments who do not yet own a computer need not despair, as a control box is available to operate the arm without recourse to a processor. The circuit details are given herein.

Capabilities

Built along the lines of the prototype described here, and with a Tandy computer, the Armdroid can be used under direct keyboard control or 'taught' a sequence of actions, which it will then repeat either once or forever (in theory!) to a very high degree of accuracy.

It is a 'continuous path' robot, which means that more than one motor can be operating at any given time, making possible very complex motions. Many commercial machines are what is termed 'point-to-point', in that each motor/driver operates in sequence, moving the robot from one point to another in a series of steps.

The 'claw' or 'grabber' on the Armdroid is of a totally new design and is the subject of patent applications.

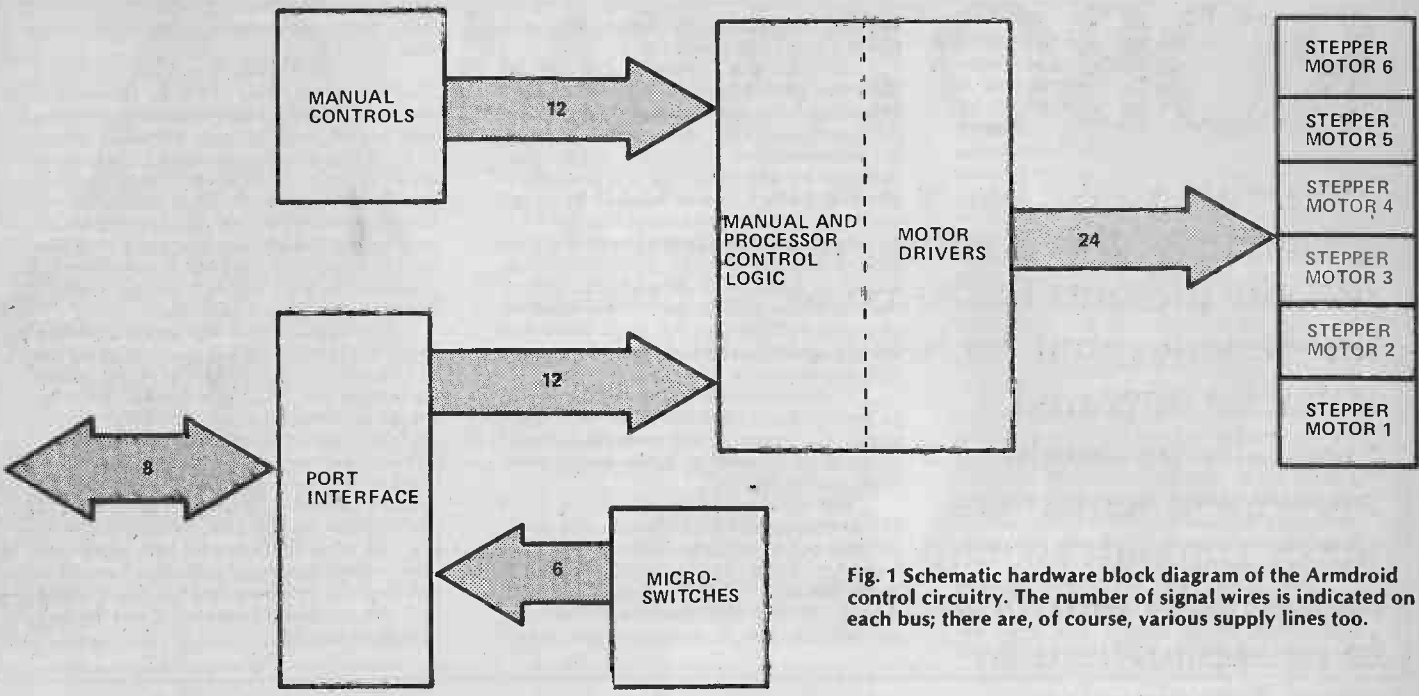


Fig. 1 Schematic hardware block diagram of the Armdroid control circuitry. The number of signal wires is indicated on each bus; there are, of course, various supply lines too.

OUTPUT FROM MICRO		INPUT TO MICRO
X2	D8	MS6
X1	D7	MS5
CCLK	D6	MS4
CDIR	D5	MS3
A3	D4	MS2
A2	D3	MS1
A1	D2	U1
$\overline{\text{OUT}}$	D1	IN

OUTPUT BITS
X1,X2: Unused (could be used with CCLK, CDIR for direct stepper drive)
CCLK: Clocks driver circuitry
CDIR: Gives motor direction
A1,A2,A3: Motor address
$\overline{\text{OUT}}$: Low indicates data out from microprocessor
INPUT BITS
MS1-MS6: Microswitch inputs (if used)
U1: For personal use
IN: High indicates data in to microprocessor

Fig. 2 Interface port specification. This will help readers who wish to write their own software routines.

Software

A program tape containing the 'tutor' program, to enable the Armdroid to be programmed for repetitive actions, is available for the TRS-80. At a later date, routines for the other major machines may well become available if the demand warrants it.

The interface port specification is given in Fig. 2, to enable programmers to write routines to drive the machinery in the meantime.

A block diagram of the required program is also given, though not a full flowchart. A full (machine code) listing of the TRS-80 tutor program is available from our Charing Cross Road offices, in exchange for an SAE for us to send it in! As it runs to some 700 lines we though it inappropriate to publish it all here. However, we've included a hex dump for those people who want to be able to load and use the program without necessarily understanding it.

Anyone rewriting the software for other machines should take note of the following points. First, the TRS-80 uses the Z-80 microprocessor so any machine with a different micro will require a complete rewrite of the machine code. Line 46AE contains a jump address which in the published listing (Fig. 3) simply points back to the start of the program. If you want the facility to quit the tutor program and jump back into the system monitor, this is the address to change (what you change it to naturally depends on your machine). Lines 4921-4926 contain the port address, which should also be changed to suit.

The next few lines contain calls to a delay routine; this sets the torque of the motors by controlling the clock delay. Two delay routines are provided in the program, DELS (46BD) which gives a delay of about 0.001 s and DELT (46C5) for a delay of about 0.01 s.

Manual Metalwork

In order to make construction of the Armdroid possible for the home constructor, we have arranged for a kit of parts to be supplied, somewhat in the manner of a Meccano set! All the drilling and cutting is done for you; all you have to do is slot it all together.

And to make *that* easy, a comprehensive assembly manual is to be supplied free with each kit.

The arm is also to be made available in fully assembled form, albeit at a higher price, for those users who wish only to experiment with the finished item.

Because of the existence of the excellent metalwork manual, we are not going to deal with the building of that side of the project here at all. It would simply duplicate information which is being supplied anyway and we do not have the space to do it thoroughly.

Have a good look at the detailed photographs within the article if you're in any doubt as to its assembly. Follow the manual through carefully and no problems should occur.

Construction

Anyone who has ever built an ETI project before — or even one from the other, lesser, electronics magazines — will be quite capable of wiring up the interface and PSU required. Follow the basic rules — and check everything at each stage before proceeding any further.

Build and test the PSU first, and make sure you obtain the correct voltages of 12 V and 5 V *before* connecting circuits to the PSU output.

Assemble and test each motor drive circuit individually. It will be much simpler to de-bug each channel

HOW IT WORKS

THE INTERFACE

In order to enable the robot arm to function with as broad a range of microprocessor equipment as possible, the interface is designed around a standard eight bit, bidirectional port. This may be a latched or non-latched port; in a non-latched situation the interface circuitry will normally be in an 'input-to-micro' configuration.

The port is configured as follows. The eight output lines are defined as four data bits (D8-D5), three address bits (D4-D2) and one bit (D1) which defines the direction of data travel on the port. Four data lines are provided for the user, who at a later stage may wish to directly control the stepper motor coils from the computer instead of via the stepper control logic.

When the motors are being operated via the stepper control logic, only two of the data lines are used. Data bit six is used as a clock bit to step the motor; the delay on this bit will relate to the speed of the step, and hence the speed and flow of movement. Data bit five is used to indicate the direction the motor will step in.

The address bits are used to channel the selected clock and direction bit to the appropriate motor output. The three address bits can define eight states; states 1-6 are used to select any of the six motors, with states 0 and 7 not allocated.

Data bit one is used to indicate the direction of data travel. When this bit is low, data is being transferred to the arm joints and when high, data can be read from the microswitches, if installed. On the transistion of bit one from high to low a pulse is generated which causes the data to be latched into the addressed output latch.

In the input mode the lines D8-D3 are used to read any of the six microswitches installed on the arm. These are in the form of reed switches and magnets, and indicate one specific position of each joint and hence enable the arm to be reset before any learning sequence takes place.

A spare input bit (D2) exists which can be buffered and used for some extra input sensor. For example, this spare input could be used to connect a 'home brew' transducer to the system.

The interface circuitry consists of 12 TTL components which decode and route the data out to the appropriate motor control/driver logic. Two 74LS125 ICs (IC1,2) buffer the data out to the decoder and latches. A 74LS138 (IC6) decodes the three input address bits to provide eight select lines, six of which are for the 74LS175 latches (IC7-12).

Data bit D1 is buffered and fed into a 74LS123 monostable (IC4) to generate a clock pulse. This causes the decoder to provide a latch pulse for approximately 500 ns to the addressed motor control latch. Data bit D1 is tied to a pull-up resistor (R1) so that this line is high, except when data is output from the processor. The 74LS125 buffers are enabled by the buffered output of bit 1 so data is only fed to the latch inputs when bit 1 is low. The bit 1 buffer is always enabled because its enable is tied low.

The microswitch inputs are buffered by a 74LS366 (IC5) which is enabled by the complemented output of bit 1, hence when bit 1 is high the 74LS366 is enabled. Thus for a large portion of the time this buffer will be enabled and the contents of the microswitches will be input to the micro. This allows users to operate the arm under bit interrupt control, allowing instant response to a microswitch change and avoiding the 'polling' of the microswitches. The six microswitch inputs are pulled up, hence the switches can be connected to the arm using only one return lead per switch and the arm chassis as ground.

Fig. 3 Hex dump of the TRS-80 Model I tutor program. The memory following this program is designated ARST, the ARm STorage area that holds the numerical data defining a learned sequence of moves.

```
4400  CD D6 46 21 6B 49 CD A7 28 CD C5 46 21 84 49 CD
4410  A7 28 CD 49 00 CD 33 00 CD 5D 49 FE 4C CA 51 44
4420  FE 52 CA 85 44 FE 57 CA 35 45 FE 43 CA D7 44 FE
4430  47 CA 8C 45 FE 44 CA 26 46 FE 42 CA 00 44 FE 4D
4440  CA 9F 46 FE 51 CA B1 46 21 DE 49 CD A7 28 C3 09
4450  44 21 E5 49 CD A7 28 CD 49 00 CD 33 00 CD 5D 49
4460  FE 53 20 05 CD D6 46 18 0C FE 43 20 E4 2A 8A 4A
4470  7D B4 CA 38 46 AF 32 8E 4A CD 53 47 47 78 B7 C2
4480  79 44 C3 09 44 21 C4 49 CD A7 28 CD 49 00 CD 5D
4490  49 AF CD 12 02 CD BD 46 CD 96 02 CD 35 02 47 CD
44A0  35 02 4F B0 CA 38 46 ED 43 8A 4A 21 AE 4A C5 1E
44B0  00 06 06 CD 35 02 77 83 5F 23 10 F7 C1 CD 35 02
44C0  BB 20 0B 0B 78 B1 20 E6 CD F8 01 C3 2C 45 21 75
44D0  4A CD A7 28 C3 09 44 ED 4B 8A 4A 78 B1 CA 38 46
44E0  21 C4 49 CD A7 28 CD 49 00 CD 5D 49 AF CD 12 02
44F0  CD 96 02 ED 4B 8A 4A CD 35 02 B8 20 D1 CD 35 02
4500  B9 20 CB B0 CA 38 46 21 AE 4A C5 1E 00 06 06 CD
4510  35 02 BE C2 CE 44 83 5F 23 10 F4 C1 CD 35 02 BB
4520  C2 CE 44 0B 78 B1 C2 0A 45 CD F8 01 21 81 4A CD
4530  A7 28 C3 09 44 ED 4B 8A 4A 78 B1 CA 38 46 21 C4
4540  49 CD A7 28 CD 49 00 CD 5D 49 AF CD 12 02 CD C5
4550  46 CD 87 02 CD C5 46 ED 4B 8A 4A 78 CD 64 02 79
4560  CD C5 46 CD 64 02 21 AE 4A C5 1E 00 06 06 7E CD
4570  BD 46 CD 64 02 CD BD 46 83 5F 23 10 F1 CD 64 02
4580  C1 0B 78 B1 20 E3 CD F8 01 C3 09 44 CD 5D 49 AF
4590  32 91 4A 21 B2 49 CD A7 28 CD 49 00 CD 33 00 CD
45A0  5D 49 FE 4F 28 09 FE 46 20 E2 3E 01 32 91 4A 3E
45B0  2E CD 33 00 CD C6 45 3A 91 4A B7 20 F2 21 61 4A
45C0  CD A7 28 C3 09 44 ED 4B 8A 4A 78 B1 28 19 21 AE
45D0  4A 11 9C 4A C5 01 06 00 ED B0 E5 CD F2 45 CD 65
45E0  49 E1 C1 FF 53 20 05 AF 32 91 4A C9 0B 78 B1 20
45F0  E0 C9 0E 00 06 06 11 AD 4A 21 A1 4A 7E FE 00 28
4600  0F FA 0A 46 3E 03 12 35 18 08 3E 01 12 34 18 02
4610  AF 12 1B 2B 10 E6 3E 01 32 90 4A CD 89 48 0D C2
4620  F4 45 C9 C3 09 44 21 09 4A CD A7 28 21 AE 4A ED
4630  4B 8A 4A 78 B1 C2 41 46 21 21 4A CD A7 28 C3 09
4640  44 01 00 00 C5 E5 60 69 23 DD 21 92 4A CD 00 47
4650  21 92 4A CD 97 28 3E 3A CD 33 00 E1 06 06 7E E5
4660  C5 CB 7F 28 04 26 FF 18 02 26 00 6F DD 21 92 4A
4670  CD 00 47 21 92 4A CD A7 28 3A 10 38 CB 47 28 03
4680  CD 49 00 C1 E1 23 CD 55 49 10 D3 CD 5D 49 C1 03
4690  3A 8A 4A B9 20 AE 3A 8B 4A B8 20 A8 C3 09 44 3E
46A0  01 32 8E 4A CD 53 47 C2 A4 46 AF 32 8E 4A C3 09
46B0  44 CD 5D 49 21 7F 49 CD 97 28 C3 86 43 C5 06 14
46C0  CD CD 46 C1 C9 C5 06 00 CD CD 46 C1 C9 C5 C5 00
46D0  00 C1 10 FA C1 C9 21 00 00 22 8A 4A AF 32 8E 4A
46E0  21 AE 4A 22 8C 4A CD EA 46 C9 21 9C 4A 11 9D 4A
46F0  36 00 01 11 00 ED B0 C9 F5 D5 CD 33 00 D1 F1 C9
4700  F5 E5 D5 CB 7C 28 10 7C 2F 67 7D 2F 6F 23 3E 2D
4710  DD 77 00 DD 23 18 04 3E 20 18 F5 FD E5 FD 21 49
4720  47 3E 30 FD 5E 00 FD 56 01 B7 FD 52 DA 32 47 3C
4730  19 57 19 DD 77 00 DD 23 FD 23 FD 23 1D 20 E2 FD
4740  E1 D1 E1 AF DD 77 00 F1 C9 10 27 E8 03 64 00 0A
4750  00 01 00 CD 41 49 39 40 38 CB 7F 28 06 CD C5 46
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4760  CD C5 46 AF 32 90 4A 3A 10 38 CB 47 CA 72 47 C3
4770  F3 47 01 00 00 CB 1F CA 7D 47 CD FC 47 03 CB 57
4780  CA 86 47 CD FC 47 03 CB 5F CA 8F 47 CD FC 47 03
4790  CB 67 CA 98 47 CD FC 47 03 CB 6F CA A1 47 CD FC
47A0  47 03 CB 77 CA AA 47 CD FC 47 01 00 00 3A 04 38
47B0  CB 4F CA B8 47 CD 00 48 03 CB 7F CA C1 47 CD 00
47C0  48 03 3A 01 38 CB 6F 28 03 CD 00 48 03 3A 04 38
47D0  CB 57 CA D8 47 CD 00 48 03 CB 67 CA E1 47 CD 00
47E0  48 3A 08 38 03 CB 1F CA ED 47 CD 00 48 CD 17 48
47F0  F6 01 C9 3A 8E 4A B7 CC AF 48 AF C9 1E 03 18 02
4800  1E 01 21 A8 4A 09 F5 7E B7 28 04 AF 77 F1 C9 73
4810  3E 01 32 90 4A F1 C9 3A 8E 4A B7 C2 89 48 32 8F
4820  4A 06 06 DD 21 A8 4A FD 21 AE 4A 21 A2 4A FD 2B
4830  DD 2B 2B FD 7E 00 B7 28 1F FE 01 28 27 DD 7E 00
4840  FE 01 20 09 CD 81 48 FD 36 00 00 18 0B 34 7E FE
4850  7F CC 81 48 DD 36 00 03 10 D4 CD 99 48 3A 8F 4A
4860  B7 20 4C C9 DD 7E 00 FE 03 20 09 CD 81 48 FD 36
4870  00 00 18 E4 35 7E FE 80 CC 81 48 DD 36 00 01 18
4880  D7 F5 3E 01 32 8F 4A F1 C9 F5 E5 C5 21 A8 4A 06
4890  06 7E B7 20 07 23 10 F9 C1 E1 F1 C9 C1 E1 3E 01
48A0  CD FC 48 CD C5 46 AF CD FC 48 CD C5 46 F1 C9 C5
48B0  E5 DD 36 00 00 2A 8A 4A 23 7C FE 01 D2 D8 48 22
48C0  8A 4A ED 5B 8C 4A 21 9C 4A 01 06 00 ED B0 ED 53
48D0  8C 4A CD EA 46 E1 C1 C9 21 38 4A CD A7 28 CD 49
48E0  00 CD 33 00 CD 5D 49 FE 14 CA F3 48 FE 53 CA D5
48F0  48 18 E5 CD D6 46 E1 C1 C1 C3 09 44 F5 C5 E5 4F
4900  06 06 21 AD 4A 7E E6 03 B7 20 02 18 29 CB 27 CB
4910  27 CB 27 E6 F0 C5 CB 20 00 CB 41 28 20 CB EF CB
4920  87 32 E8 37 E6 F0 32 E8 37 CD BD 46 CD BD 46 CD
4930  BD 46 CD BD 46 C1 2B 10 CC F1 C1 F1 C9 CB AF 18
4940  DE E5 D5 C5 21 A8 4A 11 A9 4A 01 05 00 36 00 ED
4950  B0 C1 D1 E1 C9 F5 3E 29 CD F8 46 F1 C9 F5 3E 0D
4960  CD F8 46 F1 C9 D5 CD 2B 00 D1 C9 41 52 4D 20 43
4970  4F 4E 54 52 4F 4C 4C 45 52 20 4D 4B 31 0D 00 43
4980  53 45 0D 00 4C 45 41 52 4E 2C 52 45 41 44 2C 43
4990  48 45 43 4B 2C 57 52 49 54 45 2C 47 4F 2C 44 49
49A0  53 50 2C 42 4F 4F 54 2C 4D 41 4E 2C 51 55 49 54
49B0  0D 00 46 4F 52 45 56 45 52 20 4F 52 20 4F 4E 43
49C0  45 3F 0D 00 54 59 50 45 20 53 50 41 43 45 20 42
49D0  41 52 20 57 48 45 4E 20 52 45 41 44 59 00 53 4F
49E0  52 52 59 0D 00 53 54 41 52 54 20 41 47 41 49 4E
49F0  2C 20 4F 52 20 43 4F 4E 54 20 46 52 4F 4D 20 43
4A00  55 52 52 20 50 4F 53 0D 00 4D 4F 56 45 4D 45 4E
4A10  54 20 41 52 52 41 59 20 44 49 53 50 4C 41 59 0D
4A20  00 0D 4E 4F 20 53 45 51 55 45 4E 43 45 20 49 4E
4A30  20 53 54 4F 52 45 0D 00 4E 4F 20 4D 4F 52 45 20
4A40  41 52 4D 20 53 54 4F 52 45 20 4C 45 46 54 2C 44
4A50  45 4C 45 54 45 20 4F 52 20 53 41 56 45 3F 20 0D
4A60  00 0D 53 45 51 55 45 4E 43 45 20 43 4F 4D 50 4C
4A70  45 54 45 0D 00 52 45 41 44 20 45 52 52 4F 52 0D
4A80  00 54 41 50 45 20 4F 4B 0D 00 00 00 AE 4A 00 00
4A90  00 00 20 30 30 30 37 34 00 01 42 7F 00 00 00 00
4AA0  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
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separately since if you have all six in operation at any given moment, horrendously complex gyrations of the robot arm are possible and it will not always be easy to see exactly what the faults are or even in which channel they lie.

Note that the parts list and overlay for the drive board are a little peculiar, with some parts apparently labelled the same. This is because the drive circuit is repeated six times, but with a few exceptions; some parts appear six times, some three times and some only once. But it does make sense if you study it carefully in conjunction with the circuit diagram — honest!

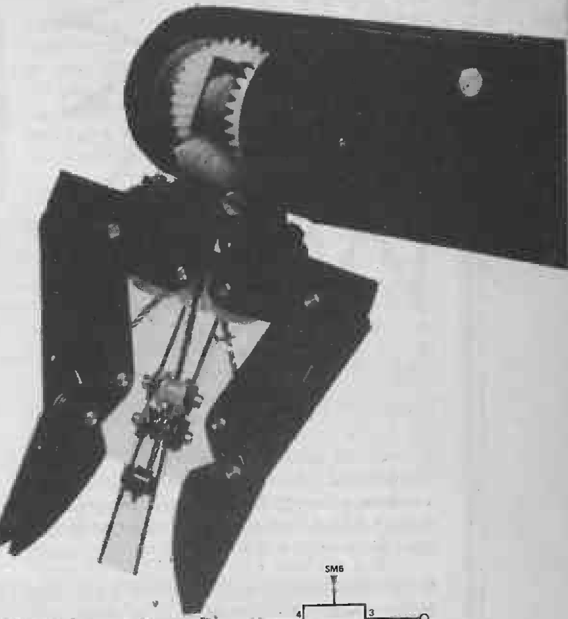
Refer to the component overlays and circuit diagrams provided during construction at each stage. *Do not* simply 'knock the whole thing together' and then start checking! IT WILL FAIL. While the interface and/or control box is not particularly expensive, there is no point in throwing money away by merrily destroying ICs wired in reverse.

The only setting up procedure involves PR1 — this component should be used to adjust the motor speed in manual mode so that the motors do not slip when stepping.

In Use

Normally we can give a pretty good indication to our readers as to which applications a project is best suited to — in this case, however, *you* will have to tell *us!* There will be such a diversity of use that your particular application is likely to be of great interest to other readers.

To this end we will publish — and pay for — applications reports from users of the Armdroid in future issues of ETI. For schools, colleges and so on this obviously represents a chance to recoup some of the cost. Contact the Editor for further details.



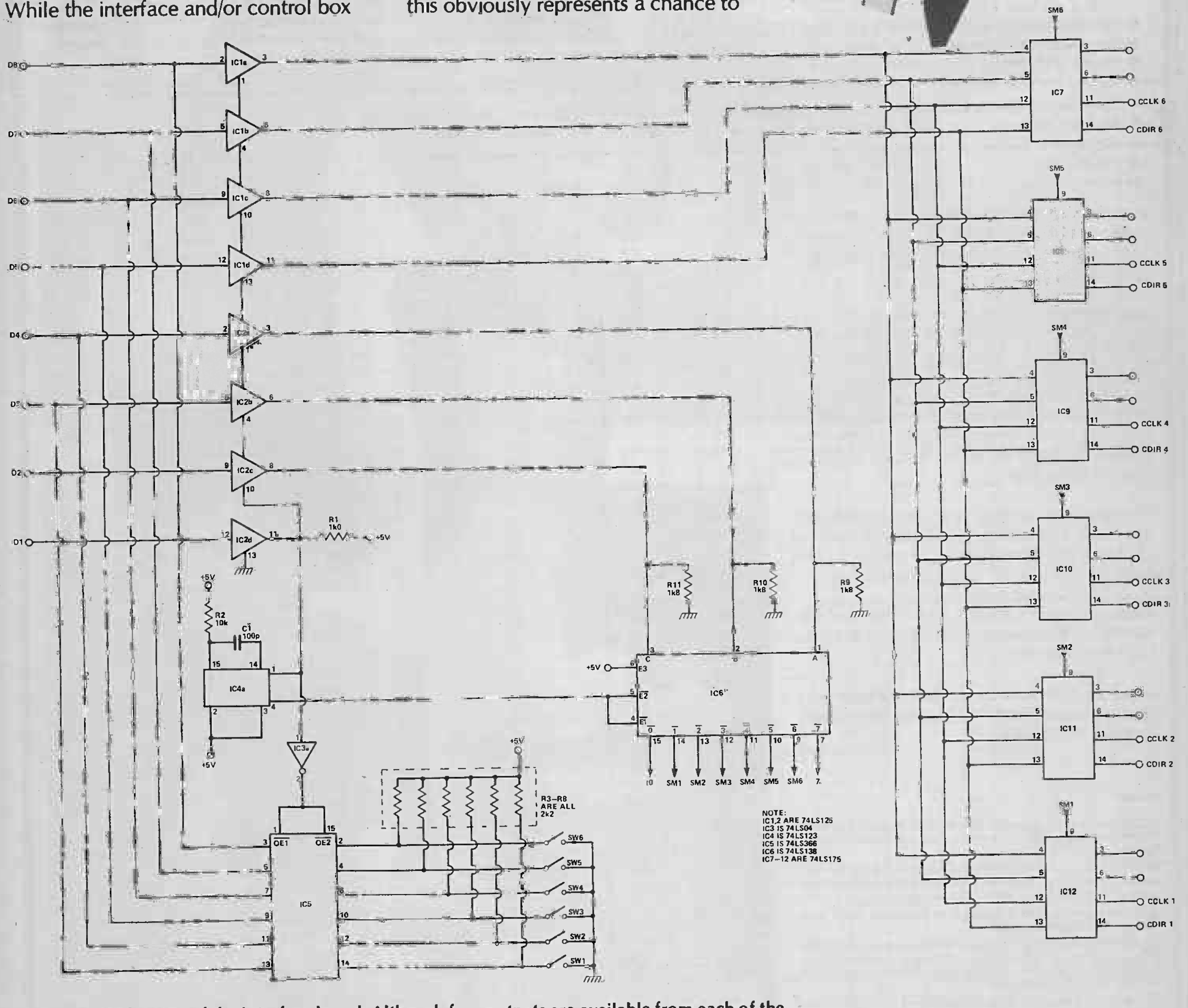


Fig. 4 Circuit diagram of the interface board. Although four outputs are available from each of the six latches, only the two labelled outputs (CCLK and CDIR) are used in this application. This particular section of the design is very versatile; for example, driving triacs from the latch outputs gives a computer-controlled disco lighting console.

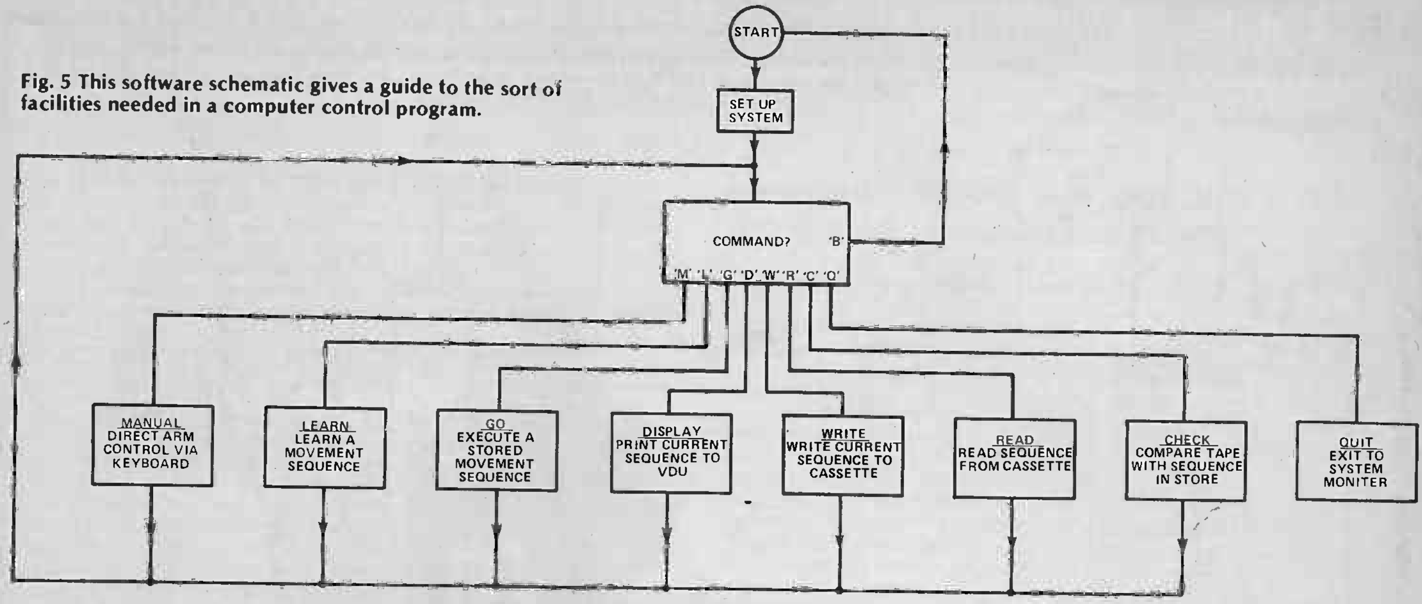
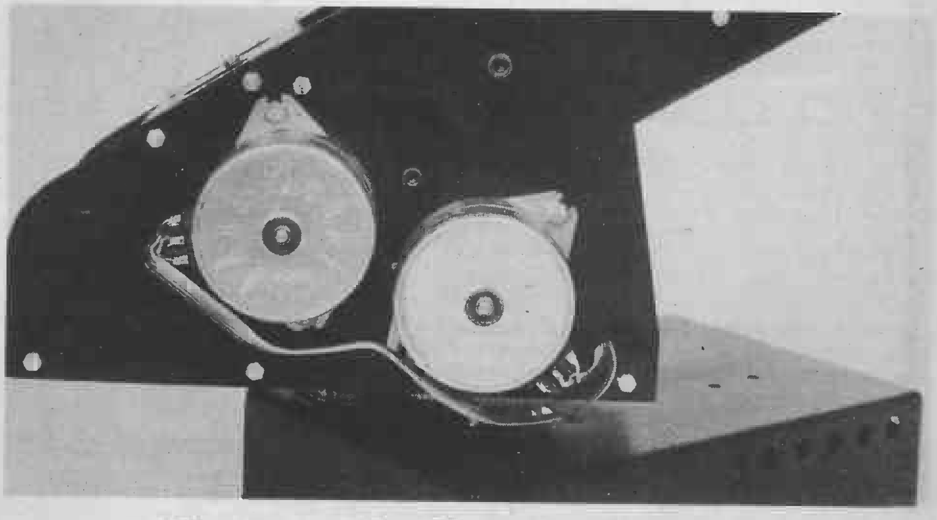


Fig. 5 This software schematic gives a guide to the sort of facilities needed in a computer control program.

CLOCKWISE ROTATION ↑ (read from bottom to top) / COUNTERCLOCKWISE ROTATION ↓ (read from top to bottom)

STEP	Q_A	Q_B	Q_C	Q_D
1	ON	OFF	ON	OFF
2	ON	OFF	OFF	ON
3	OFF	ON	OFF	ON
4	OFF	ON	ON	OFF
1	ON	OFF	ON	OFF

Fig. 6 Coil stepping sequence for the stepper motors used in the Armdroid. Compare this table with the waveforms in Fig. 7 to see how the control signals generate movement.



BUYLINES

Colne Robotics can supply either a complete kit of parts or assembled units for the Armdroid.

Armdroid — Kit (including Manual):	£199
Armdroid — Assembled (including Manual):	£270
Interface/Driver/Power Supply and cassettes of software:	
Kit	£45
Assembled	£55
Manual Control Box:	
Kit	£20
Assembled	£25

All prices are exclusive of VAT (15%) and postage and packing. Add £2.50 p & p for the Armdroid (either kit or assembled), and £1.50 for all other items.

Colne Robotics Co Ltd, 1 Station Road, Twickenham, Middlesed. TW1 4LL. Telephone: 01-892 7044. Telex: 8814066 GCIC.

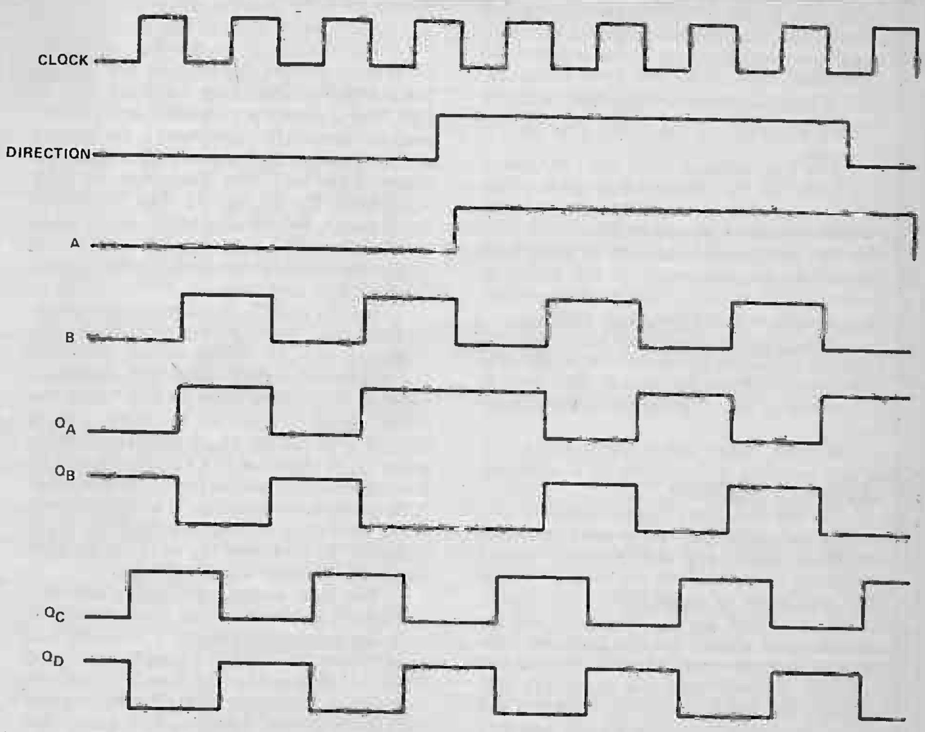


Fig. 7 Waveforms required to step the Armdroid motors correctly. These can be generated using fairly simple circuitry.

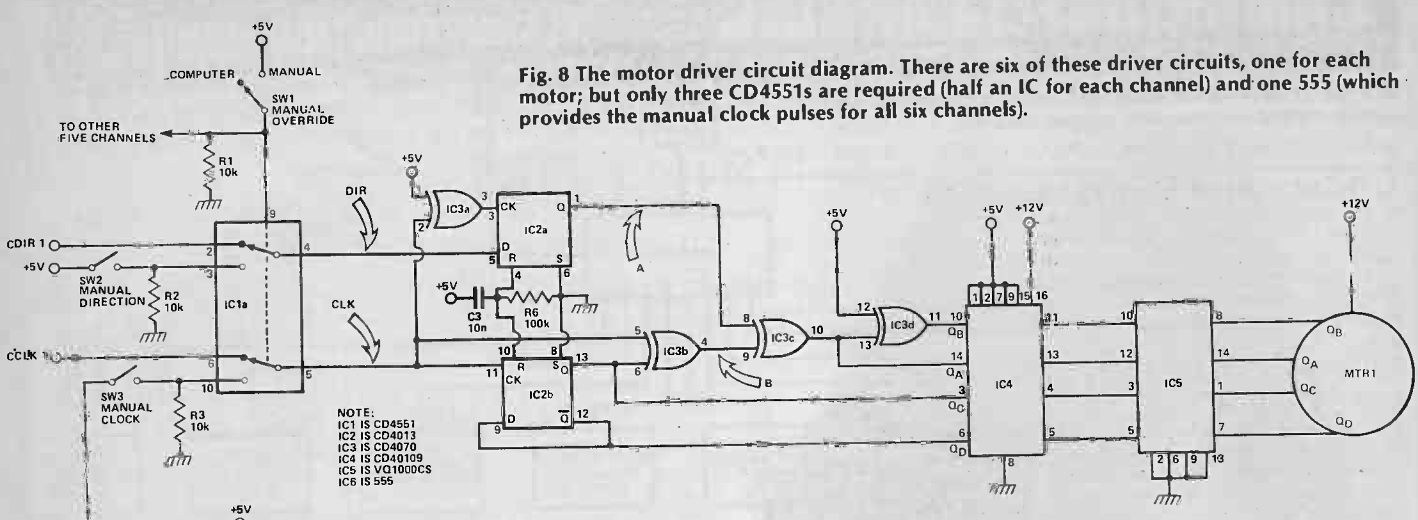


Fig. 8 The motor driver circuit diagram. There are six of these driver circuits, one for each motor; but only three CD4551s are required (half an IC for each channel) and one 555 (which provides the manual clock pulses for all six channels).

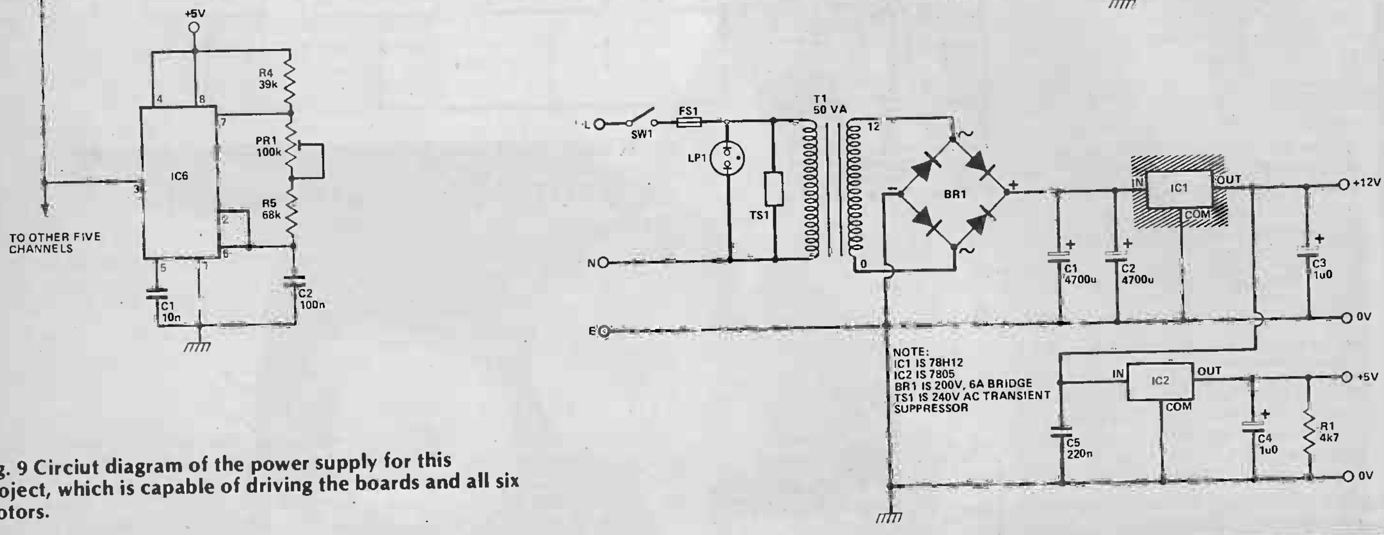


Fig. 9 Circiut diagram of the power supply for this project, which is capable of driving the boards and all six motors.

HOW IT WORKS

THE ARM DRIVERS

The arm motor driver logic has been designed so that it can be driven from a manual control box, or from the output of the computer interface circuitry. If the arm is to be controlled only from the CPU interface, then a large portion of the driver circuitry can be ignored.

The four outputs from the CPU interface logic can be connected to the four inputs of IC4 and the processor must then produce its own drive signals as shown in Fig. 7. This will also enable the motors to be half stepped by the processor. If the above is carried out, then ICs 1, 2 and 3 will be redundant in each motor drive logic section.

The circuitry described has a manual override so that, if for some reason the arm is doing something that you dislike, then it is possible to stop it using the manual controls.

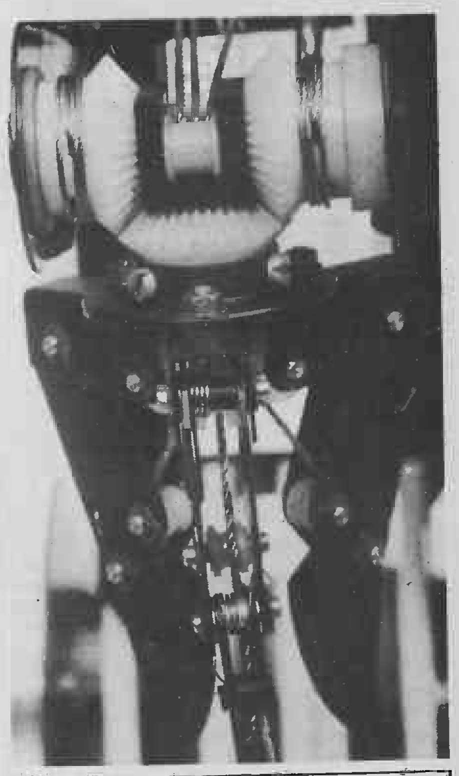
The six motor driver stages need two power supplies to function; 12 V at about 3A5 and 5 V at 150 mA.

At the front end of the circuitry is a CMOS switch (IC1a). This is used to select the clock signal and the direction signal which are to be fed into the system. When the processor is controlling the motor driver, the CDIR and CCLK signals will be selected and placed on the DIR and CLK lines. In manual mode, clock pulses are fed into the system from IC6 (a simple 555 astable) via SW3, and SW2 controls the motor direction. To move a joint one way press SW3; to move it the other way press SW3 and SW2 simultaneously. Pull-down resistors R1,2,3 are needed to prevent the inputs of IC1a floating when the switches are open (CMOS doesn't like this!).

The CLK signal is fed to the clock input of IC2b, a D-type flip-flop, so the data on the D input is latched on the rising edge of CLK. The $\overline{Q}$ output is coupled back to the input so that each latched input is the inverse of the previous one; thus the Q output is a signal with half the frequency of CLK (waveform Q_C in Fig. 7). The waveform Q_D is simply the inverse of Q_C and is taken from the $\overline{Q}$ output of IC2b. A capacitor/resistor network (C3/R6) resets the flip-flops on power-up.

The Q_B and Q_A clock pulses are derived from CLK, the Q output of IC2b and the Q output of IC2a. The Q output of IC2a is the selected direction input DIR, and is latched by the falling edge of CLK, since the clock signal is inverted by IC3a. CLK is XORed with the Q_C clock signal in IC3b so when Q_C is identical to CLK point B will be low, otherwise it will be high. The output of IC3b (waveform B in Fig. 7) is XORed with the Q output of IC2a to produce Q_A. Q_B is obtained by inverting Q_A in IC3d, an XOR gate with its other input tied high.

The four waveforms Q_A-Q_D are then fed into IC4, a level shifter. Here the 5 V inputs are converted into 12 V outputs, and then fed into IC5. This is a high current quad VFET which provides the four high current outputs for the motor coils. The driving current level for the motor coils is about 300 mA at 12 V.



Next month we conclude the Armdroid project with the Parts Lists and component overlays.

THE JOSEPHSON JUNCTION

By 1990, most of the space in your micro may be filled with a helium refrigerator. The important part will occupy a cubic inch or so, but will do the job of one of today's mainframes. Jim McCartney explains.

It isn't easy to see how the present TTL and NMOS logic of the current generation of micros can be pushed much further. The next few years will probably make 16 and 32 bit CPU chips common enough, as well as 64 Kbit memory chips, but there are two barriers to progress. The first is the speed of operation, and the second is the heat dissipation.

On the Z80 chip, for example, the clock pulse rise time is 30 ns, and most other functions, which are more complex, take 100 ns (the propagation time) to change state. The limit of machine performance is therefore about one machine cycle every 250 ns. This allows for rises, falls, and a bit of time between. From this, it follows that the clock frequency is 4 MHz at the maximum.

Frying Chips

Furthermore, the Z80 can use up to a watt of energy. This is a lot of power over the area of the chip itself; about 3-4 W per square centimetre. If we extended the area of the chip, or layered a lot of them on top of each other, this assembly would get very hot. As a useful comparison, the bar of an electric fire radiates about 6 W per square centimetre. The chip is of course kept cool by conduction away through the connectors and the package, otherwise it might tend to glow dull red. Because of this high power dissipation, it is not possible with current electronic technology to make large scale integration more than about an order of magnitude larger than at present.

We can get faster junctions — TTL will give a propagation time of 5 ns at the best for a simple device, but it uses a lot more power; whereas CMOS, which uses less power, can't manage much better than 100 ns for a simple gate. In any case, CMOS power requirements increase according to speed. CPU chips are far from simple, and propagation time is longer the more complex the systems, so NMOS gives a pretty good compromise between overheating and speed. The newer gallium arsenide technology promises that speeds can be increased by a great deal, but power dissipation is still likely to be a problem.

The design of a large CPU chip is not therefore just a matter of putting n times as many components on the chip to produce n times the result. While it would be wrong to suggest that byte size will not increase beyond, say, 64 bits (and there isn't much reason why it should) it would clearly be a difficult job to design and even more difficult to manufacture in a reliable way, and might well require a pretty massive heatsink. In any case, it would be practically impossible to accommodate any useful amount of RAM on the same chip.

Beyond The Limits

The Josephson junction is of interest because it gets round the difficulties of power dissipation and of speed. It isn't really a transistor at all, nor is it an FET. It was discovered by Brian D Josephson at Cambridge in 1962. It operates on millivolts instead of volts and with perhaps one tenth of the usual sort of current, so that, for equivalent circuitry, the power dissipation is about one ten-thousandth of that of present technology. Furthermore it is incredibly fast; propagation times as short as 10 ps (10^{-11} s) have been recorded. It isn't easy to measure times as short as this: it is the time it takes light to travel 3 mm. If 10 ps were scaled to 1 s, 1 s would become over 3000 years. The speed of light itself will then become the limiting feature in LSI design.

The principal disadvantage of the Josephson junction is that it only works at a few degrees above absolute zero; in order to do this is must be immersed in liquid helium. This is because it depends on superconductivity for its properties.

As you probably know, many conductors lose all resistance as absolute zero is approached. Because of various quantum effects, a state is reached in which the normal mechanism of conductivity is changed, and instead of current being carried by single electrons loosely attached to the atoms of the conductor, it is carried by pairs of electrons which are weakly bound only to each other. They drift along with very little relation to the conductor except that they remain in it, and once moving, they will continue to move indefinitely. A current induced in a closed loop will therefore keep on circulating forever, unless it is interrupted. Such interruptions can be caused by:

- Warming the superconductor — a temperature of 7 or 8K is usually enough.
- The presence of a magnetic field. Magnetic fields are absolutely excluded from superconductors, but a moderate field will break in and stop the superconduction.
- An electric field. A potential gradient across a superconductor has a similar effect.

The Tunnel Effect

Another consequence of quantum mechanics is that you cannot say exactly where an electron is or how it is moving. This is the famous Heisenberg Uncertainty principle. The possible position of an electron can be described by its wave function, which extends over an appreciable distance, especially when the electron is not bound to an atom. This means that instead of saying that an electron is at a given point, all you can really say is that the probability of finding the electron at such and such a point is proportional to its wave function, which is centred at a given point.

Now suppose that we have two conductors separated by a very thin layer of insulator. The conductor at the left is negatively charged (it has spare electrons) while the conductor at the right of the insulator is neutral. Consider an electron hard up against the insulation. Its wave function, which is quite independent of any material, extends all round it, and through the insulator. The wave function is therefore present to a small extent to the right of the insulator, and this means, as we have seen, ➡

that there is a distinct possibility of the electron being found on the right of the insulator, without having actually passed through it.

This is a bit like saying that although you have put the car in the garage for the night, and locked it up, there is a possibility that it will be found in the morning on the drive outside, or on the roof, or maybe in the kitchen, without having passed through the doors or walls. Fortunately, wave functions associated with motor vehicles or anything much heavier than elementary particles can be ignored for practical purposes.

Nevertheless, this means that the insulator does in effect pass electrons: although it is not a resistive material because its resistance is not proportional to thickness, but instead increases exponentially. Tunnelling can be distinguished from normal current flow in this way. It is also clear that the layer has got to be very thin; about 10^{-6} cm gives satisfactory results. However, this is very large compared to the size of the electron.

Now the tunnel effect takes place at any or all temperatures at which the materials are stable. What happens if we cool a tunnel junction, as described above, down to superconducting temperatures?

Weak Superconductors

It was this question that Josephson set out to answer. He found that under these conditions, tunnel barriers also became superconducting: the insulator turned into a perfect conductor! This sort of superconductor turned out to be a lot more susceptible to the influence of electrical or magnetic fields than a normal superconductor — it could be 'switched off' a lot more easily. The picture is not, in fact, quite as simple as that; arcane quantum mechanical effects produce peculiar oscillations both in space and in time, and for practical purposes it is helpful to have two or more junctions in parallel. This need not concern us for the moment.

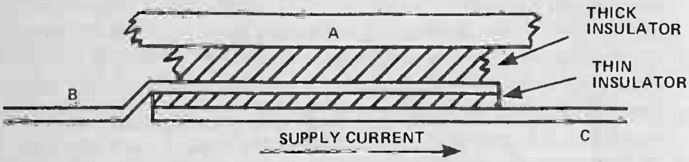


Fig. 1 Construction of the basic Josephson junction.

The Josephson junction switch is made up as shown in Fig. 1. Current flows from superconductor B to superconductor C through the thin insulator, which is a weak superconductor. If we now pass a modest current through superconductor A, it will generate a field which intersects the weak superconductor, and destroys its superconductivity. It then reverts to being an insulator, and although the tunnel effect is still there, the resistance of the junction has jumped from zero to several hundred ohms. A potential difference now exists between B and C, and this gives quite a strong electrical field, which maintains the junction in its high resistance state even after the magnetic field is removed. What we have got is a latching switch. A latching switch appears to be of little use; in a computer built with latching switches everything hangs up after the first machine cycle. Therefore we have to reset all the switches, but this can only be done by returning all the supply voltages to zero. This, you may object, is not only tiresome in practice, but will wipe out all memory as well. Not so; there are convenient techniques for getting round these snags.

The AC Computer

You may have noted that nothing has been said so far about polarity. The main characteristic of conventional semiconductor devices is that they are polar and will not work if the supply voltage is connected the wrong way round; indeed

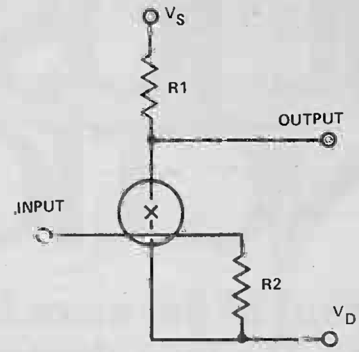


Fig. 2 The Josephson version of a buffer or switch.

they are generally destroyed for good. The Josephson junction, on the other hand, will work equally well with the voltage applied in either direction through the same junction, unlike a bridge rectifier or a triac. So all that is necessary to unlatch the switches is to reverse the current. The weak superconductor resumes its function when the electrical field across it approaches zero, and it starts conducting again. All we need to do is to run the thing on alternating current: this also provides an infallible clock system.

It is no use trying to build a memory out of components which have zero voltage on them at any time in the cycle: we need something quite different. Here we make use of the best-known characteristic of superconductors, that of maintaining the current in a closed loop. In principle this is like the system where a charge is stored in a TTL dynamic memory cell, except that we substitute current for voltage, and in theory we never need a refresh cycle.

Junctions, Fields And Gates

You can see at once that the circuit elements are going to be quite unlike anything we are used to. It is interesting to see how they are made up and utilised.

A single buffer or switch is shown in Fig. 2. The junction is symbolised by the 'X'; in practice, as mentioned above, it will consist of two or more parallel junctions but this does not affect the argument. V_S is the source voltage, which may be either positive or negative, and V_D is the drain voltage, zero. R1 limits the current through the junction (which otherwise provides a short circuit when conducting) and R2 is an input impedance. Now if there is no input current, the junction is conducting and the voltage of the output must be zero. This happens when the input voltage is also zero. Suppose we apply some voltage on the input; the resulting current creates a magnetic field round the junction, and the junction resistance jumps to several hundred ohms. The output voltage will then jump from zero to a value determined by this latter resistance and R1. This gives us a non-inverting buffer: an inverter can be made simply by reversing the gate and the resistor (Fig. 3), and an OR gate by having two inputs (Fig. 4).

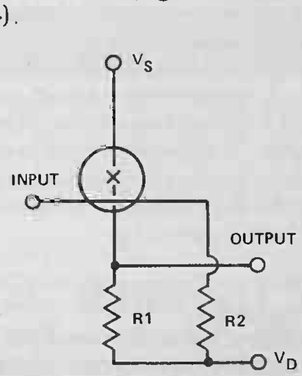


Fig. 3 Implementation of an inverter.

DIGEST

Mike Without Jack

Place: a house somewhere in Britain. Time: late evening. An impoverished amateur punk band is practising in the drummer's living room (or rather his parents'). The lead singer is pogoing around the three-piece suite when he trips over his microphone cable, knocks the coffee table flying and sends himself and the prize aspidistra right through the bass drum. Silence falls and the neighbours mutter a short prayer of thanks. . .

This sort of mishap need never trouble you again now that the TVC Wander-Mike cordless microphone has been launched in Britain. Available from Watford Electronics at an introductory price of £39.50 plus VAT, the Wander-Mike replaces the lead and jack-plug of a conventional mike with a short antenna — sounds are transmitted by the mike on a frequency of about 90 MHz and can be picked up on any FM (VHF) radio. Similar systems are already used extensively in TV studios and on the West End stage; applications suggested for the Wander-Mike include snooker exhibitions, darts matches, bingo and so on in pubs and clubs (alcohol plus cables equals accidents!), garden fetes, sports days and, of course, amateur musicians practising at home. You could even make demo tapes by plugging your radio into a tape recorder.

The Wander-Mike measures 8" x ¾" and is finished in polished stainless steel. It comes complete with stand attachment, batteries, instruction leaflet and 5 m of cable terminated in a jack plug for use with conventional sound equipment; the aerial section is removed using the screwdriver provided and replaced by the cable connector, a 60 second conversion. The unit runs on two HP7 batteries.

This equipment is not Type Approved by the Home Office when used in cordless mode in the UK.

Multiple

Thurlby's model 1503 multimeter also incorporates a built-in frequency meter. Frequencies up to 3999.9 kHz can be measured directly with a resolution of 100 Hz. Accuracy is ±1 digit over a 10°C-30°C temperature range and is defined by a 6 MHz crystal timebase. A movable decimal point allows for external pre-scaling if you wish to extend the measurement range to 40 MHz or 400 MHz. As a normal multimeter, it has a high resolution 4¾ digit scale length and sensitivity figures of 10 uV, 10 mR and 1 nA. 32 ranges are provided. The display is liquid crystal and the unit is powered from internal batteries or from an AC power line. The price for the unit is £139 plus VAT. Further information from Thurlby Electronics Ltd, Office Suite 1, Coach Mews, The Broadway, St. Ives, Huntingdon, Cambs, PE17 4BN.

Sockets!

Lab-Aid Ltd have announced their range of slim-line 13 A multi-sockets, complying with BS 1363. Every component is earth bonded for safety through two independent paths and there is a red 'mains on' warning lamp. Models available have a choice of four or six sockets and can have flexible cable and plug fitted for portable use or without cable for permanent fixing to walls or benches. Prices start at £19.00 (excluding VAT) and the range is available from Lab Aids Ltd, New Lodge, Ashorne, Warwick CV33 9QN.

Here Comes The Sun

Kappa Instruments Ltd of Studio 11a, Cochrane Mews, London NW8 6NY are offering the Ferranti MST 300 totally encapsulated silicon solar array for a mere £195 plus VAT. It is ideally suited for use in boats and at home for powering radio and hi-fi equipment. It is simply attached using four screws and weighs only 4.1 kilos. Dimensions are 562 mm x 476.25 mm x 9.53 mm and has an output of 15 V, 15.75 W and 1.05 A.

Fighting The Big 'C'

London's Royal Marsden Hospital has had a new Microcomputer-based ultrasound scanning system installed, which, it is hoped, will speed up detection of cancer while it is still in its 'embryo' stages. For the past seven years clinicians have been attempting to detect similarities in scans of malignant tissue using computer analysis. They hope that eventually some form of computer diagnosis will be possible. The system they have just installed was developed by the General Electric Company of New York Ltd and has its own built-in microprocessors based on the latest technology, so that the system can be continuously upgraded to meet the future diagnostic demands of the hospital. The use of ultrasound scanning is used in conjunction with routine X-ray and isotope scanning, but it has the advantage of not presenting a radiation hazard which means that more frequent screenings can be carried out. Ultrasound is also extremely useful for diagnosing cancer in the 'soft tissue' areas of the body such as the liver, abdomen and ovaries.

Electronics At School

BBC School Radio will be launching a new project in the autumn term this year which aims to help teach microelectronics in secondary schools. Entitled 'Electronics and Microelectronics', it starts on Tuesday September 22nd at 2.20 pm on Radio 4 VHF and is a sound-plus-vision package for 14-16 year olds. The 10 programmes are accompanied by five Radiovision filmstrips and a complete package of materials and components is provided for practical work in the classroom. The circuit boards and ICs require no soldering. The aim of the programme is to introduce some of the developments in electronics in the last 10 years. Full details of how to obtain the pupils' kit are included in the 24-page set of Teachers' Notes, available free of charge from 'Electronics and Microelectronics', BBC School Radio, 1 Portland Place, London W1A 1AA. (Please enclose an A4 sized SAE stamped at 20p.)

Live Radio

On Sunday 17th May, listeners to BBC Radio 3 heard the first ever live digital stereo concert from China. The digital encoding equipment was used for the BBC Symphony Orchestra's concert from the City Hall in Shanghai and it was relayed via the Intelsat satellite to Broadcasting House in London. This new equipment is called 'Nicam 3' (Near Instantaneously Companded Audio Multiplex). It has been developed by the BBC's Engineering Research and Design departments. The equipment is designed to convert stereo signals from analogue to digital form and then compress the signal so that up to three stereo pairs can pass over conventional 2048 digital telephone systems. For this particular broadcast only one stereo channel was used, and because there were no suitable digital circuits available, wideband TV circuits were used. Listeners described the technical quality as excellent. The Shanghai concert was the only one to be broadcast live, although others were recorded for later broadcast.

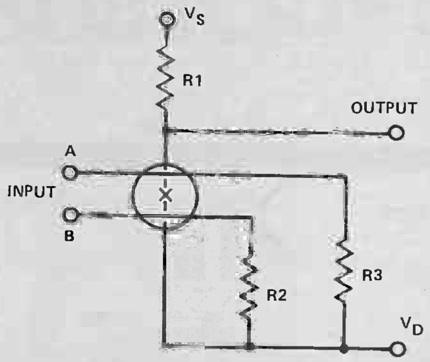


Fig. 4 With two inputs the junction becomes an OR gate.

The AND gate uses a rather different and more complex system: this depends on the fact that too large a current flowing through a superconductor will itself switch the superconductor off. Two input currents are arranged to pass through a pair of junctions: if these add to give a sufficient current, the junctions are triggered to the off state.

In practice, each logic device will be followed by a non-inverting buffer. One circuit element can in theory trigger an infinite number of others: all that is necessary is to pass the output current through the necessary inputs in series (Fig. 5). In practice there is a sufficiently high fan-out for any conceivable purpose.

Memory cells bear more resemblance to the old-fashioned core store than to any semiconductor device. Their operation is shown in Fig. 6. This system is very fast and non-volatile; it would probably be used for immediate access memory. A slower system which is erased by reading can be used for back-up.

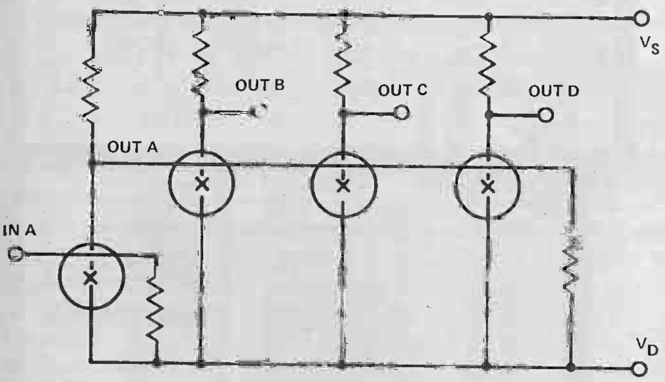


Fig. 5 One buffer driving three others.

High Velocity, Low Volume

Light travels about a foot in 1 ns; electric current in a conductor is propagated at perhaps a third of this speed, depending on capacitance and inductance. It is estimated that a Josephson junction computer might have a machine cycle time of 3 ns at the best: this corresponds to an AC cycle of 6 ns or a frequency of 167 MHz. To keep all components in good synchronisation the maximum size of a computer should be an order of magnitude less than the distance which light can travel in 3 ns, since all routes are not direct in the circuit and some will be more affected by capacitance and inductance problems than others. This give a requirement for a computer and memory a few centimetres along each side.

This can be constructed by using a micro-motherboard system, in which several chips are made on a microcard, which is slotted into the motherboard. The cards and motherboard are made by the same techniques as the chip itself, using a silicon base. The whole assembly is then put together using tiny droplets of mercury as a solder — mercury is of course solid at the working temperature.

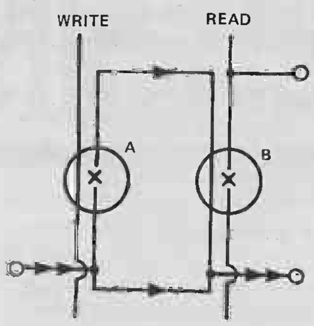


Fig. 6a A superconducting memory element. A current is passed through the memory loop and divides between the two branches.

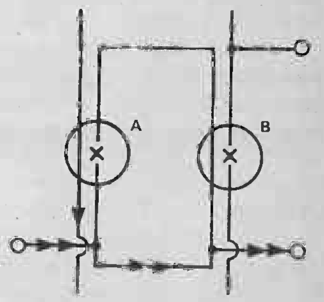


Fig. 6b A 'Write' current is passed, opening junction A. The loop current passes through the other arm.

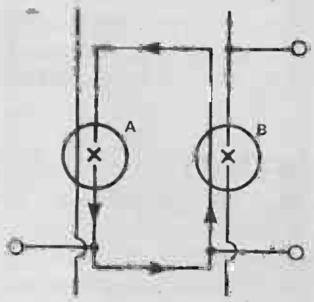


Fig. 6c Both supply currents are turned off. Junction A becomes superconductive again and the current which flowed in the lower arm now continues around the upper arm.

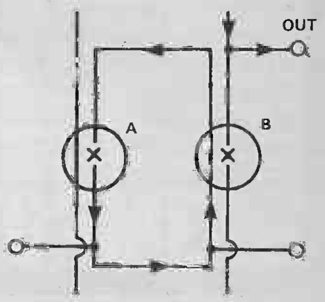


Fig. 6d This disables junction B so that any subsequent 'read' current is diverted to the output.

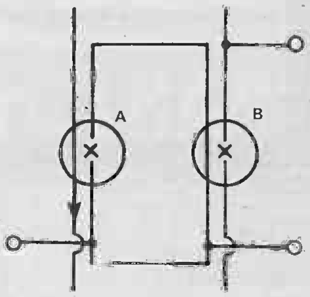


Fig. 6e A 'write' current without an applied loop current will open junction A again and stop the circulating current. This enables B again.

The high density of packing is possible because of the very low power consumption and the excellent cooling system: the assembly is actually immersed in liquid helium. This liquid also has the property of being superfluid because of quantum effects: it has zero viscosity and flow is restrained only by inertia. Circulation of the cooling fluid is therefore even better than for a normal liquid cooling system.

If I Could Talk To The Micros . . .

What can we do with a microcomputer running 50 to 100 times faster than present systems, and with at least 10 times the computing capacity? Certainly most of today's mainframes could be replaced by much more compact assemblies of such micros, but space is not usually at such a premium nowadays. On the other hand today's desk-top computer can be replaced by something perhaps a thousand times as powerful and (we hope) at not too much greater expense. We could expect to have practical verbal and video recognition systems from such systems, and super-high level interactive languages.

This new technology is still in its infancy, but if you cast your mind back to the state of the art in 1971, it is reasonable to expect that I might be able to dictate an article of this sort to a voice-controlled word processor by 1991, no larger and no more expensive than today's micros.

ETI

SYSTEM A AUDIO AMPLIFIER

Stan Curtis concludes the System A with the testing and setting-up procedures.

This amplifier is straightforward to test providing a logical sequence is followed. The first test is without the main PCB fitted and without the power-transistors connected to the power supply. Check that there is no leakage between the collector of any power transistor and heatsink using a high-resistance range of your meter. Next check the output transistor junctions (base-collector, base-emitter, collector-emitter and so on) at the PCB end of the wiring loom. If all is well the power transistors can be forgotten for the moment.

Next, the power supply. Fit a mains fuse; switch on and check that the voltage across the reservoir capacitors is ±40 V (within 2 V). Allow these capacitors to discharge and then fit the PCB assembly, connecting all the wires except those to the power transistors. Both the presets should be set to mid-travel and the power again switched on. The secondary supply rails can now be measured and should be about ±50 V. The output DC offset voltage (junction of R28, R29) should be measured and should be adjustable to zero by turning PR1. If the offset voltage cannot be adjusted you have a fault on the board.

If all is well, disconnect the supply and again wait for the power supply to discharge. Now connect up the power transistors to the PCB but with a current meter (able to measure greater than 3 A DC current) in series with the positive supply to the three collectors (Q22, Q26 and Q30). Ideally a voltmeter should be connected between the output rail and ground. Say a short prayer and switch on. You should find that PR2 (turned clockwise) will increase the current and PR1 should still adjust the DC offset voltage. Adjust the current to about 1 A and, using a loudspeaker and convenient signal source, quickly check that the amplifier works. If it does, the amplifier can be set up properly; but be warned that this takes several hours. Set the current to 3 A and allow the amplifier to heat up. The current will vary so adjust it *gradually* every 10 minutes or so until it is stable. The DC offset can now be nulled to zero but as this can interact with the current some alternate adjustments will be needed. After a couple of hours the amplifier should be stable and ready for use.

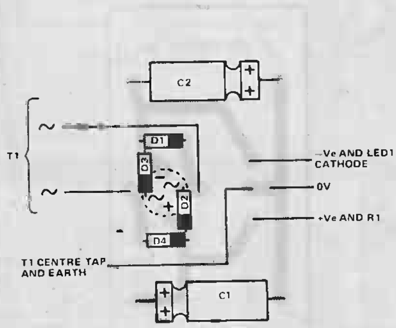


Fig.1 The long-awaited preamp power supply overlay (and Parts List at top right). Provision has been made on the board for either four diodes or a small bridge rectifier, as shown.

The foil pattern published in the July ETI for the preamplifier main board (A-PR) was incorrect, and we apologize to readers who have experienced difficulties. To correct the fault, break the track joining Q12 base to Q8 collector, and solder an insulated link between Q12 base and Q9 collector. Do this for both channels. The PCBs being sold by Jelgate and our PCB service are correct.

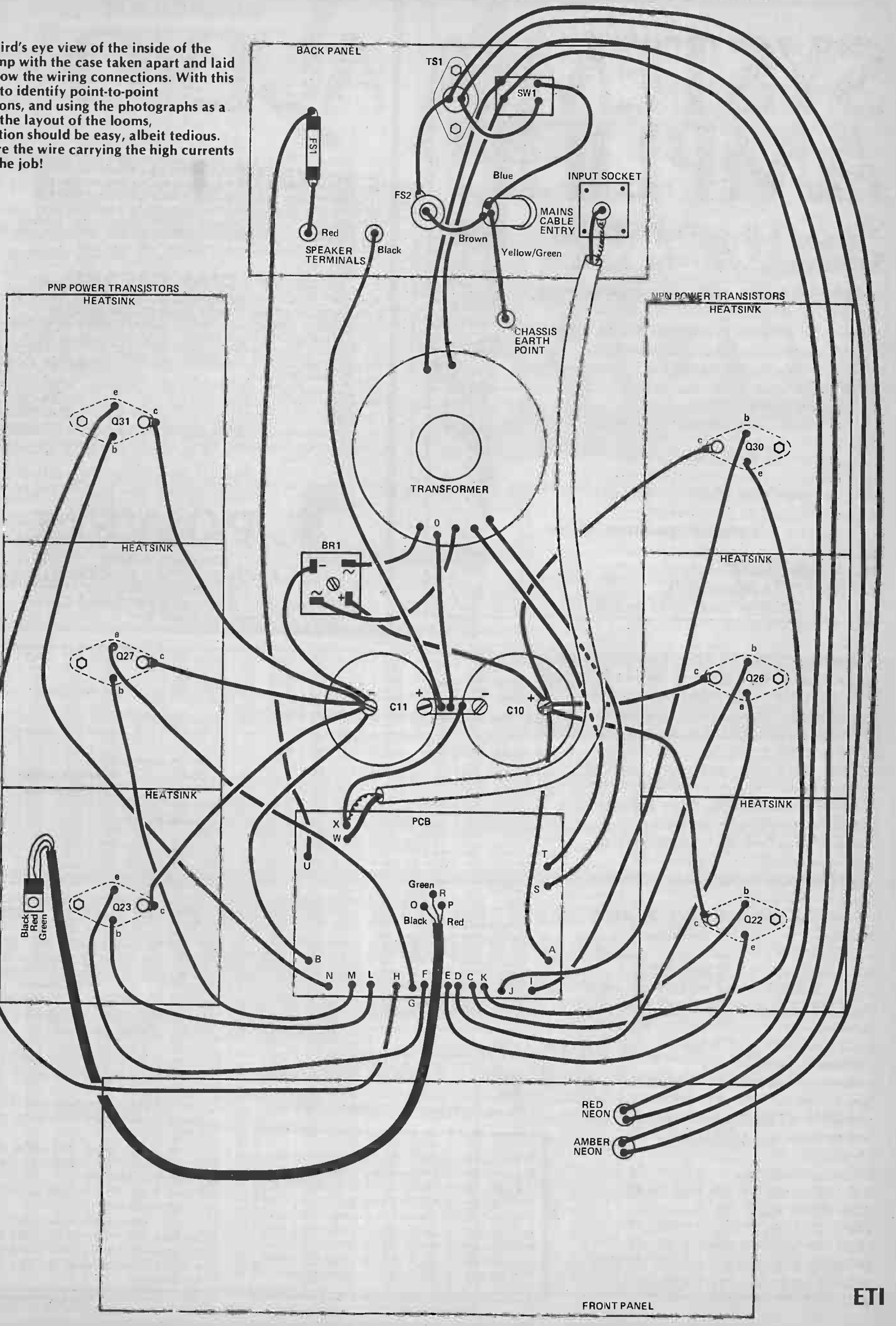
PARTS LIST

Resistor	
R1	2k7 ¼W 5%
Capacitors	
C1,2	1000u 25 V axial electrolytic
Semiconductors	
D1-4	1N4002 or similar
LED1	TIL209 or similar
Miscellaneous	
SW1	DPDT mains switch

Transformer (15-0-15, 20 VA), 1 A quick-blow fuse and fuseholder, case.

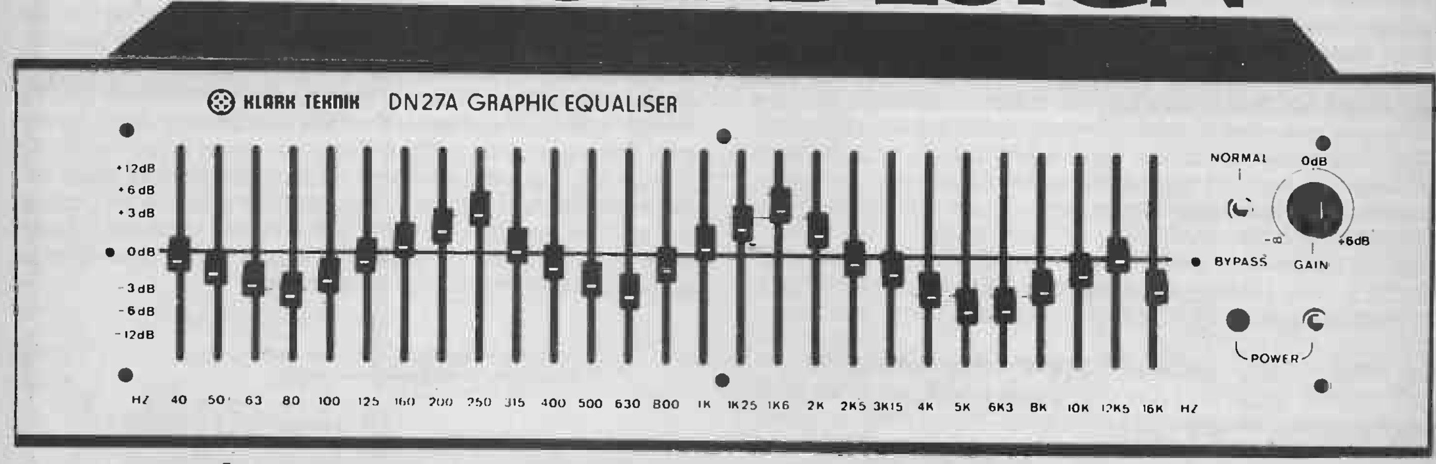
BUYLINES

Fig.2 A bird's eye view of the inside of the power amp with the case taken apart and laid flat to show the wiring connections. With this diagram to identify point-to-point connections, and using the photographs as a guide to the layout of the looms, construction should be easy, albeit tedious. Make sure the wire carrying the high currents is up to the job!



ETI

EQUALISER CIRCUIT DESIGN



Everything in life has its little ups and downs, and the frequency spectrum of an audio signal is no exception. Tim Orr gives you a whole bunch of circuits for ironing out the bumps.

An equaliser is a signal process device used to modify the frequency spectrum of an audio signal. A graphic equaliser is an equaliser that graphically displays the frequency response curve being imposed upon the audio signal, as shown in Fig. 1 and the photograph. The frequency spectrum is split up into bands, the gain of each band being controlled by a slider pot. The normal control range is about ± 14 dB. Each band or channel is, in fact, a filter which can be controlled so as to give a continuously variable response from a peaky bandpass to a notch (Fig. 2). Note that the Q factor of the filter reaches maximum at maximum lift and cut, the response being flat in the central position. If a bank of these filter networks is employed to process an audio signal, then their individual responses may be concatenated to define an overall frequency response. The control sliders will graphically dictate the signal gain at their respective frequencies.

There are of course problems involved in using such a method. The precision with which the sliders can define the frequency response will depend upon number of sliders used; more sliders will give a better resolution and vice versa. Also, the band-pass response of the individual channel is not ideal. Perhaps a rectangular response would be best, but this would be impossible to construct and would suffer time domain ringing effects.

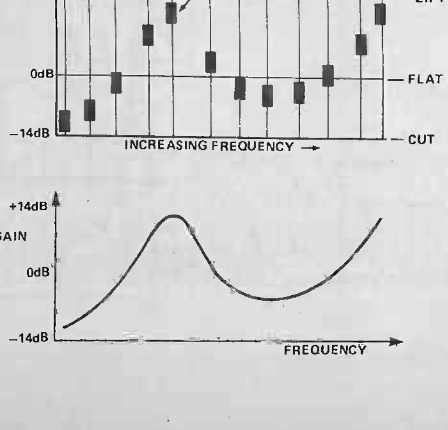


Fig. 1 Operation of a graphic equaliser. The slider positions correspond to the overall frequency response.

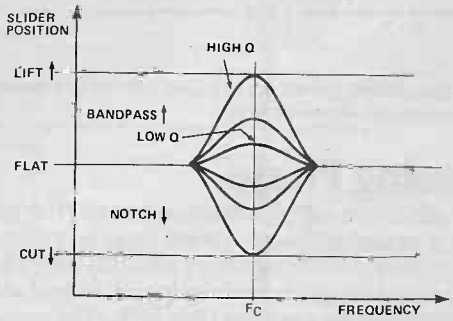
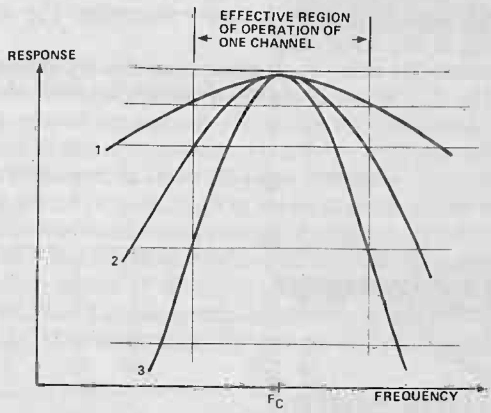


Fig. 2 The frequency response of a single channel. Note that the Q factor increases as the amount of cut or lift increases.



SPACING IN OCTAVES	2	1	1/2	1/3
TYPICAL Q	1 TO 1.1	2.7 TO 4	5	7 TO 8

Fig. 3 Choosing Q factors. Curve 2 shows how optimum Q results in the best compromise between channel interaction and inter-channel ripple. The chart gives typical Q factors that are used in graphic equaliser design.

➡

Q Dips

There are two interlinked problems associated with using the band-pass response. To reduce interaction between adjacent channels the filter response must be relatively sharp (high Q), but a high Q response will cause large dips (ripple) to occur between the filter peaks when all the sliders are set to maximum or minimum positions (Fig. 3). The chart in Fig. 3 shows the best compromise for Q factor versus the frequency spacing of the filter channels. This assumes a control range of ± 14 dB. It is relatively easy to change the design so that the control range is ± 40 dB for individual channels taken in isolation, but the whole system would have severe interaction between channels, thus destroying the 'graphic' feature, and would also suffer from a large amount of ripple. Figure 4 shows the frequency responses for several Q factors.

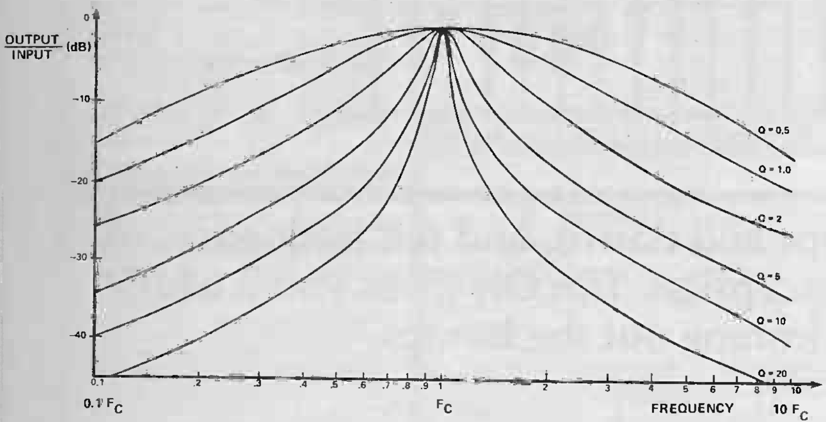


Fig. 4 Transfer characteristics for a band-pass filter. The responses for various Q factors have been normalised.

A Passing Phase

Figure 5 shows the classic equaliser circuit. The band-pass resonator is a series resonant circuit having minimum impedance at the resonant frequency F_c and also zero phase shift (Fig. 6). The amount of cut and lift can be calculated as follows. Let the resonant impedance of the filter be R_F. The phase shift at resonance is zero and so this impedance may be treated as a resistance. With the slider in the cut position, the input signal is attenuated (shunted to ground) by the resonator. The attenuation is $20.\log(R_F/(R_F + R_A))$ dB.

At frequencies other than resonance the attenuation will be defined by R_A and the complex impedance of the resonator; the attenuation will thus follow the frequency response, eventually ending up at zero. In the cut mode the circuit behaves as a voltage follower; whatever signal is seen at the non-inverting terminal of the op-amp appears at its output. With the slider in the lift position the feedback signal is attenuated, with the result that the output signal must be proportionally larger. The gain at resonance is also $20.\log(R_F/(R_F + R_A))$ dB. With the slider in the central position there is an equal attenuation of both input and feedback signals and so the overall response is flat (Fig. 2).

Shifting Shifts

Graphic equaliser designs suffer from all the usual circuit design problems plus a few that are unique to themselves. Stability is a problem. If several high Q resonators are introduced into the feedback loop of an op-amp then their accumulated phase shift may push the network into instability. This is usually overcome by splitting up odd and even resonators into two separate networks so that the phase shifts of adjacent channels do not add up in the feedback loop of one op-amp. Noise is also a problem. The more treatments that operate upon a signal, the worse the signal-to-noise ratio becomes. A graphic equaliser with lots of channels introduces more noise than one with fewer. Noise problems may be minimised by using low noise op-amps and by operating at as high a signal level as possible.

Once a design has been selected for Q factor, frequency spacing and absolute centre frequencies, the component values for the resonators are calculated, and guess what; not a single one of them is a preferred value! It is usual to find that the capacitors are constructed from two components in parallel, and the resistors are E24 types. The component accuracy is dependent upon the channel spacing. For a one-octave spacing design, a tolerance of better than 5% is recommended. Component tolerance errors will manifest themselves in two ways; as a spread in Q factors and centre frequencies. Both of these will cause the overall frequency response to be arbitrary and lumpy. Yet another problem that affects the overall response is bandwidth limiting in the op-amps. This causes active resonators to go flat in frequency at high frequencies.

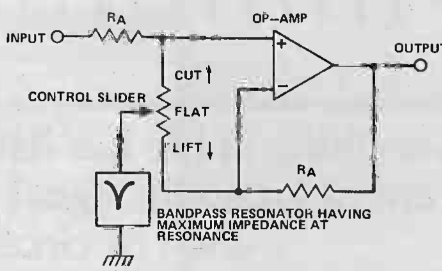


Fig. 5 A typical graphic equaliser section.

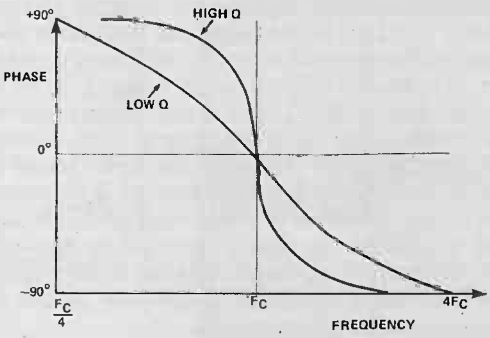


Fig. 6 The phase response of a simple band-pass resonator.

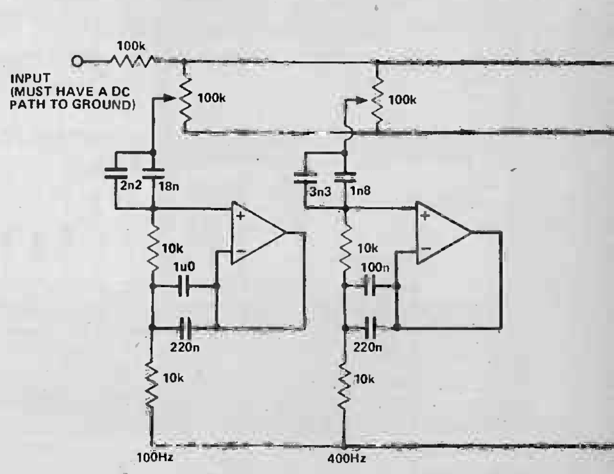
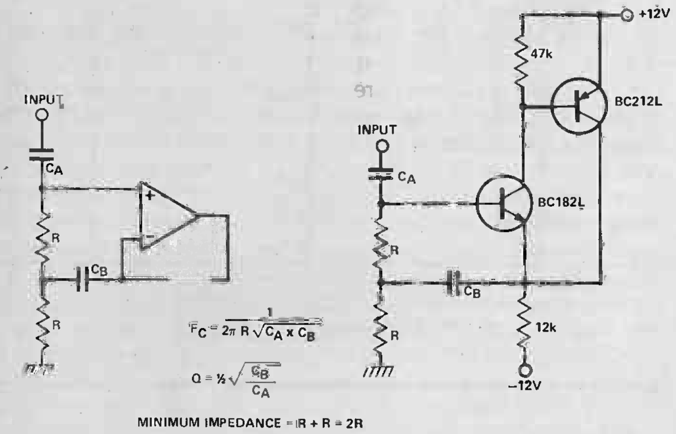


Fig. 7 A multiple feedback band-pass resonator using an op-amp (left) and discrete components (right). As a rule of thumb the op-amp should have a gain bandwidth product in excess of 20 × Q^2 × F_C.



Active Designing

A simple multiple feedback filter can be made to simulate a series resonant LCR network (Fig. 7). This is known as a gyrator, an active simulation of an inductance. Note that the two capacitors define both the Q factor and the centre frequency.

This circuit makes very heavy demands upon the bandwidth of the op-amp. A resonator with a Q of 4, operating at 12.8 kHz, needs a bandwith in excess of 20 x 4 x 4 x 12.8 x 1000 = 4.096 MHz. Even with this bandwidth its performance would not be perfect. Figure 8 shows the complete circuit for a five-section, two-octave equaliser. The design procedure is as follows. The centre frequencies and spacing are arbitrarily selected. For two-octave spacing the Q is 1.1 (Fig. 3). Therefore the component values may be determined from the equations in Fig. 7. For low noise and wide bandwidth operation, RC4558 op-amps were used.

Another equaliser is shown in Fig. 9. This is the same circuit as before, although the channel spacing is now one octave and so the Q factor is higher, having a value of 4. Note that the odd and even channels have been split up into two sections so that filter interaction may be minimised and stability maintained. The actual centre frequencies were measured and compared against the calculated ones (Fig. 10). The graph shows a random distribution caused by component tolerances plus a strong underlying trend caused by the bandwidth limitation effect of the op-amps.

Yet another active resonator is shown in Fig. 11. Again this network looks like a series resonant LCR filter, and is often found in active graphic equalisers. It has the same problems and advantages as the previous design. Active resonators possess several advantages. They are cheap, small, non-mechanical, they work well at low frequencies, and can be implemented using small capacitor values. However, they don't work well at high frequencies.

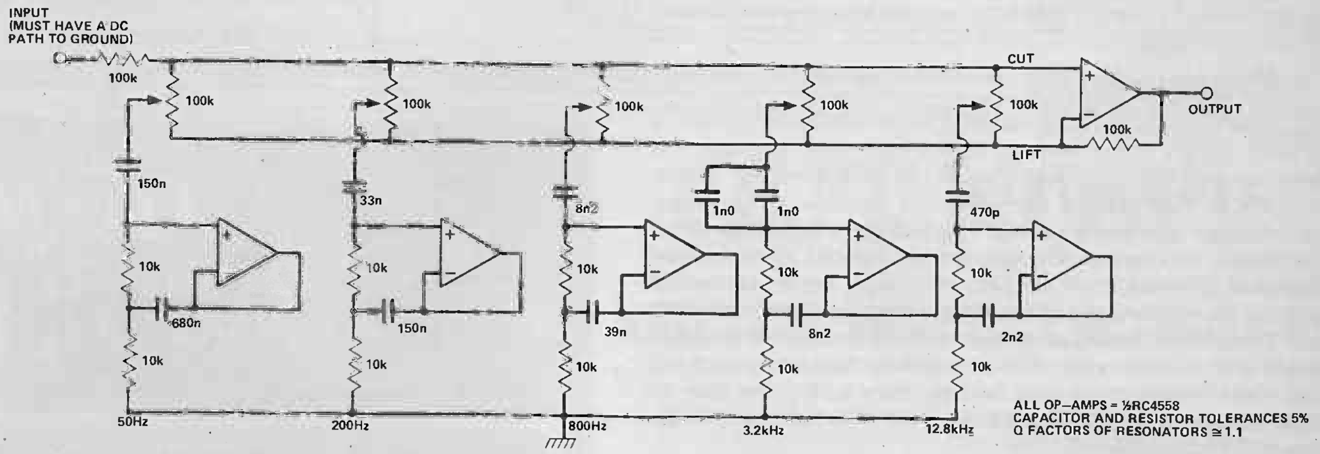


Fig. 8 Circuit diagram of a five-section, two-octave graphic equaliser (Courtesy of Powertran Electronics).

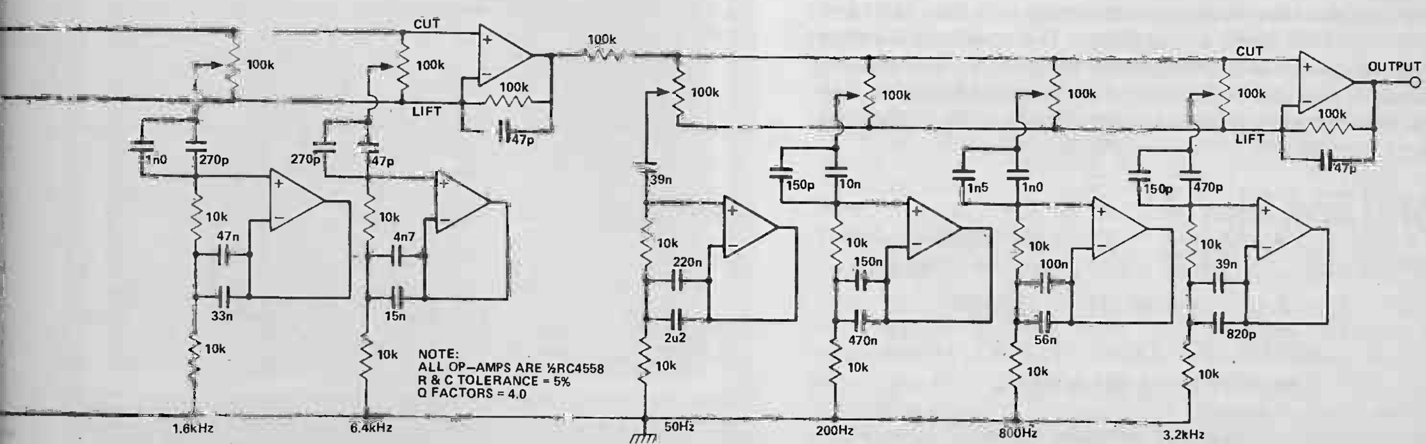


Fig. 9 Circuit diagram of an eight-channel, one-octave spacing graphic equaliser.

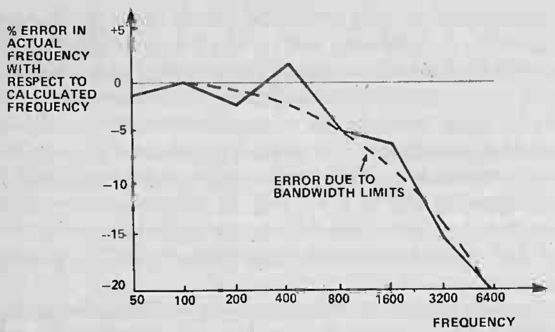
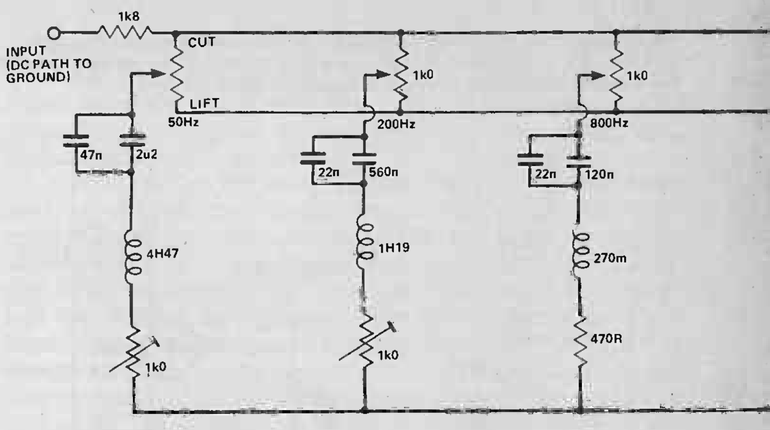
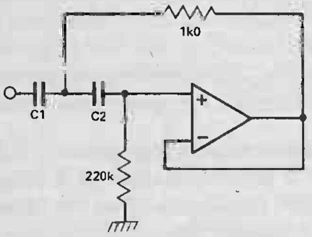


Fig. 10 The frequency error performance of the eight-channel equaliser shown in Fig. 9.





$$C1 = \frac{1}{2\pi \times F \times 3 \times 0.001}\ \text{uF}$$

$$C2 = \frac{3}{2\pi \times F \times 0.22}\ \text{uF}$$

Fig. 11 Another active resonator designed for one-octave spacing and a Q of 3; equations are given for the required capacitor values. If C1 = 390nF and C2 = 18nF, the resonant frequency is 125 Hz. Doubling the values of C1 and C2 halves the resonant frequency and vice versa.

Passive Parts

Figure 12 shows a passive design for an equaliser channel. A passive design works well at high frequencies because the resonators do not suffer from bandwidth problems, but at low frequencies the sizes of the inductors become rather large, several Henries in some cases. The inductors will have to be specifically wound; no-one supplies a range of E24 high value inductors. The inductors are also very large, heavy, expensive and sensitive to mains hum pick-up. However, they work very well at high frequencies, they are relatively insensitive to signal levels and are low noise. Also, if the inductance has a tuning slug, then the resonator may be frequency tuned. Because of these advantages, passive resonators are often used in professional studio equalisers.

Figure 13 shows a design for a nine-channel equaliser using passive components. Note that the capacitors are made by paralleling up standard values, but the inductors are wound to the exact value. Also note that the series resistor is a preset on the four largest inductors (due to the significant resistance of the windings) and that the resistance values are very low, 1k8 compared with the 100k of the active design. The component values are designed as follows. The channel frequencies and spacing are arbitrarily selected. A Q factor of 3 is selected from the chart in Fig. 3. Therefore using the equations shown in Fig. 12 we have

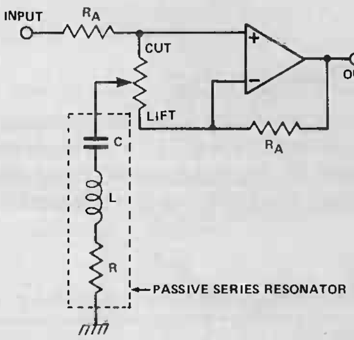
$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

which is held constant for each resonator at a value of 3. Select a reasonable value for R, 470R in this case. Rearranging,

$$\frac{L}{C} = (QR)^2 = (3 \times 470)^2 = 1{,}988{,}100$$

$$\text{Therefore } L = 1.988 \times 10^6 \times C$$

$$\text{But } F = \frac{1}{2\pi\sqrt{LC}}$$



$$F_C = \frac{1}{2\pi\sqrt{LC}}$$

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

$$\text{CUT/LIFT} = 20 \log\left(\frac{R}{R_A + R}\right) \text{dB}$$

WHERE F_C = RESONANT FREQUENCY IN HERTZ
C = SERIES CAPACITOR IN FARADS
L = SERIES INDUCTANCE IN HENRYS
R = TOTAL SERIES RESISTANCE INCLUDING THE RESISTANCE OF THE INDUCTANCE IN OHMS

Fig. 12 Circuit diagram and design equations for one stage of a passive equaliser.

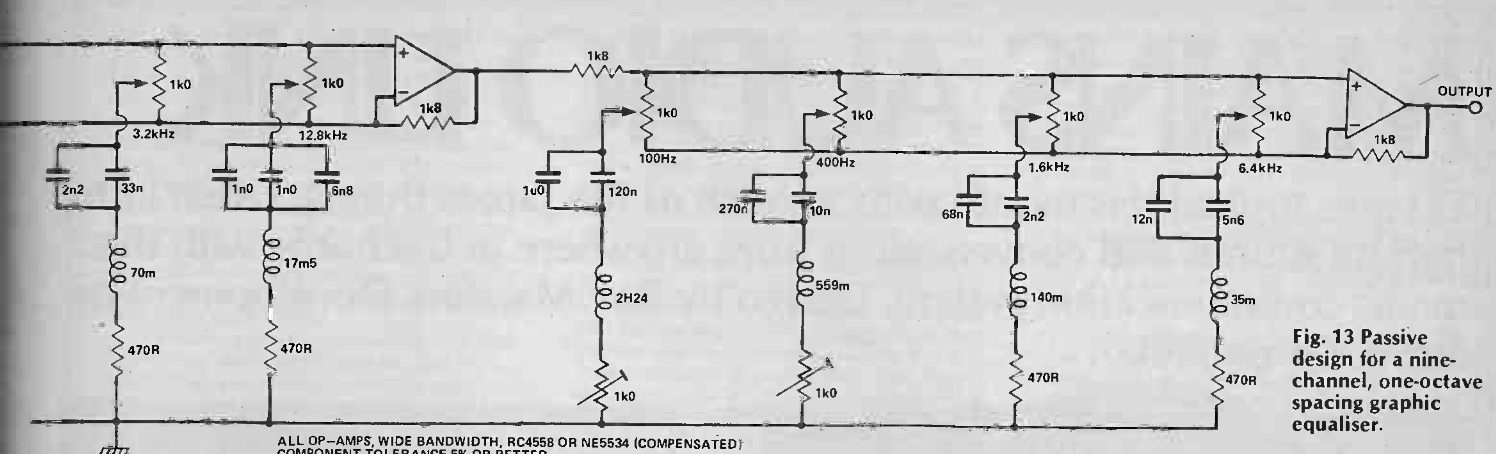
Substituting for L and rearranging,

$$C = \frac{1}{2\pi \times 10^3 \times F \times \sqrt{1.988}}$$

Calculate the values of C for all frequency values. Then calculate the values of L from the equation

$$L = 1.988 \times 10^6 \times C$$

Now that all the component values have been calculated, all we need is a source for the inductors. The ferrite cores and self



ALL OP–AMPS, WIDE BANDWIDTH, RC4558 OR NE5534 (COMPENSATED)
COMPONENT TOLERANCE 5% OR BETTER
Q FACTOR OF ALL RESONATORS = 3
USE THE FOUR PRESETS TO ADJUST THE CUT AND LIFT OF THE BOTTOM FOUR FREQUENCIES

Fig. 13 Passive design for a nine-channel, one-octave spacing graphic equaliser.

tinning enamelled copper wire can be obtained from Electrovalue and RS Components, to name but two distributors. The 'Winding Inductors' box gives details for calculating the number of turns necessary to produce a particular inductance. It is important that the ferrite you use is suitable for the selected operating frequency; the manufacturer's data will tell you this. Select a ferrite core and calculate the required number of turns for its particular A_L value. Next, decide which wire gauge will fit the core size; again manufacturer's data. Wind the inductor, and measure its inductance and DC series resistance. Subtract this resistance from the calculated external series resistor, to give you the value of the external component.

WINDING INDUCTORS

$$L = N^2 \times A_L$$

where

L = inductance in nanohenries (ie 10^{-9}H).

A_L = inductance factor. This is usually printed on the side of the ferrite core, and is a constant.

N = the number of turns of wire on the inductor.

Rearranging the equation,

$$N = \sqrt{\frac{L}{A_L}}$$

Example: construct a 5mH inductance to work at 8 kHz. Pick a suitable ferrite core, let's try one with $A_L = 250$. Therefore

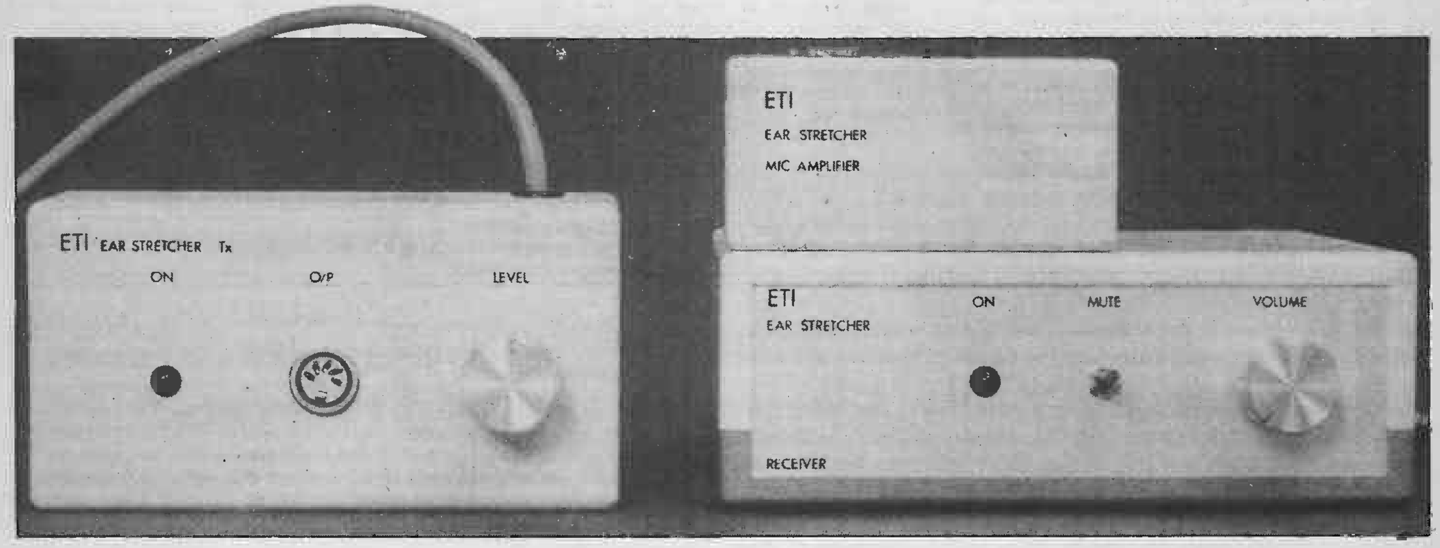
$$N = \sqrt{\frac{5 \times 10^6}{250}} = \sqrt{2 \times 10^4} = 141.4 \text{ turns}$$

Pick a suitable wire gauge that will fit the core size. An RM6 ferrite core, for example, can take 160 turns of 34 swg wire and has a recommended operating frequency range of 5.5 kHz to 800 kHz.

ETI

MAINS AUDIO LINK

ETI gets topical this month with a touch of the James Bonds. Listen in to remote sounds and conversations from anywhere in the home with this mains communication system. Design by Ray Marston. Development by Steve Ramsahadeo.



The ETI Ear-stretcher is designed to enable the user to listen in to remote sounds or conversations (the sounds of a crying baby, the ringing of a doorbell or telephone, and so on) from any domestic location (the lounge, garage or garden shed, for example), without the hassle of having to lay down yards of communication wiring. Instead, our system uses the existing domestic mains wiring as the communication link between a special sound-modulated transmitter unit and a matching receiver/decoder unit.

The system consists of three individual units: a microphone unit, a 200 kHz FM mains-line transmitter, and a mains-line 200 kHz FM receiver/decoder/amplifier unit. In use, the microphone unit is connected to the transmitter input after first being placed near to the sound source of interest, and the transmitter is plugged into the nearest mains socket. At the desired listening location, the receiver unit is then simply plugged into a convenient mains socket where it picks up and demodulates the transmitted FM signal, so that the transmitted sounds come through loud and clear in an external speaker.

Our Ear-stretcher can be used to communicate sounds between any two points (in a normal domestic environment) interconnected by the mains wiring, and the system can be expected to have a maximum range of up to a few hundred yards. In the interest of safety, the system uses the neutral mains line as the data link. The audio bandwidth of the system has been deliberately limited to the speech band and filters have been incorporated to give excellent rejection of 50 Hz and 100 Hz mains-related signals.

The receiver unit incorporates a mute facility which automatically kills the audio output if the FM transmitter is switched off. Finally, the microphone unit uses a pair of cheap acoustic pick-ups, connected in anti-phase to give excellent rejection of unwanted 50 Hz hum signals and unpleasant room reverberations.

Construction

All three units must be built before the system can be properly tested. Construction of the individual units should present few problems, provided that the usual care is taken in observing component polarities and only the specified components are used in the project. Proceed with the construction of the three units as follows.

The Microphone Unit Start the construction by drilling sets of air vents in the ends of the specified Verobox to give acoustic access to the crystal inserts, and cut a hole in the side of the top half of the case to accept SK1 (a five-pin DIN socket). Fit the socket and the two crystal inserts into place; the latter fit snugly between the case end pillars.

Next, assemble the components on the small PCB (see overlay and photos) and complete the interwiring to SK1 and the two crystal inserts, taking particular care to note that the 'negative' pins of the insets (which are internally tied to the insert cases) are both taken to the 0 V terminal of the circuit. When construction is complete, fix the PCB into the lower half of the case with a couple of sticky pads.

The Transmitter Unit Start the construction by drilling the top half of the specified Verocase to accept LED1, SK2, RV1 and a length of mains lead, then fit these components into place. Next, proceed with the assembly of the components on the larger PCB, noting the use of Veropins to facilitate the interwiring, then bolt the completed PCB and mains transformer T1 into place in the lower half of the case and set PR1 and the core of T2 to mid position. Finally, complete the interwiring to T1, LED1, SK2 and so on.

The Receiver Unit Start the construction by drilling the case front panel to accept LED1, SW1 and RV1, and the rear panel to accept the speaker socket and a mains lead, then

HOW IT WORKS

The Ear-stretcher system is designed to transmit sound signals from one room to any other room by using the neutral line of the mains wiring as the communication link. The original sounds are picked up by a microphone unit and used to frequency-modulate the carrier of the 200 kHz transmitter, which superimposes the resulting FM signal on the mains neutral line. At the remotely located receiver, the FM signal is picked up from the neutral line and then demodulated, and the resulting audio signal is passed on to an external speaker via a built-in 2 W audio amplifier IC.

System operation relies on the fact that the mains wiring is highly inductive and acts as a fairly high impedance to a 200 kHz signal. At this frequency the wiring can be regarded as an inductive potential divider, with the power sub-station at its 'low' end. This divider normally produces relatively little signal attenuation between power points that are separated by hundreds of yards of wiring and can be used as an excellent built-in data link in any home.

THE MICROPHONE UNIT

The microphone unit is unusual in that it uses a pair of cheap crystal inserts to pick up the acoustic signals; these inserts are faced in opposite directions and their signals are fed to the inputs of differential amplifier IC1, which gives a voltage gain of x 10 to each input. The major advantages of this configuration are that it causes electrically-induced 50 Hz mains signals to self-cancel, gives high overall acoustic sensitivity, and gives self-cancelling of unpleasant reverberation effects.

The output of IC1 is passed through 50 Hz twin-T notch filter R5-R6-R7-C1-C2-C3, which eliminates any residual 50 Hz signals, and the resulting 'clean' audio signals are then further amplified a hundred fold by IC2 and made available at socket SK1, from which they are used to frequency-modulate the transmitter unit. The 12 V positive and negative supplies of the microphone unit are derived from the built-in power supplies of the transmitter.

THE TRANSMITTER UNIT

The heart of the transmitter is IC5, a voltage-controlled oscillator or VCO: its operating frequency is determined by the values of PR1-R16-C13 and by the voltage on pin 5. With the component values shown, the VCO operates at a centre frequency of about 200 kHz, but can be frequency-modulated (via RV1) by audio signals from the microphone unit, and produces a square wave output at pin 3. This output is used to drive common emitter amplifier Q1, which uses a standard IF transformer (T2) as its collector load; the centre frequency of T2 is shifted to 200 kHz by C11 and its Q is reduced to a fairly low value (to give a broad-band response) by R14.

The frequency-modulated output of T2 has a peak-to-peak amplitude of about 3 V and is taken from between pins 5 (earth) and 4 and is applied to the mains neutral line via C5 and R11, which protect the unit against damage if the output signal is accidentally fed to the live (rather than neutral) side of the mains.

The transmitter unit is powered from the mains via T1-BR1-IC4 and associated components. IC4 is also used to provide the +12 V supply to the microphone circuit, and IC3 provides the −12 V supply.

BUYLINES

The only components in this project that might cause any problems are the LM565, the C2 crystal inserts and the IF transformers (T2). All of these are available from Watford Electronics. The PCBs can be obtained from our new PCB service — see page 45 for details.

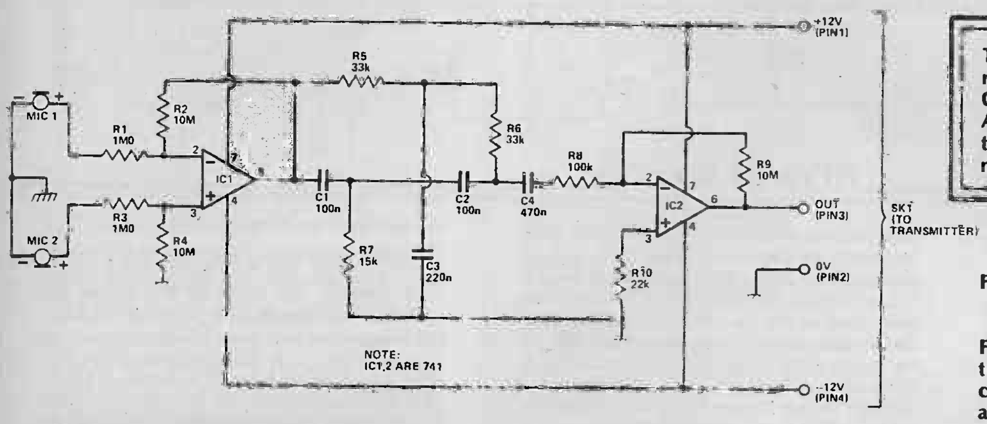
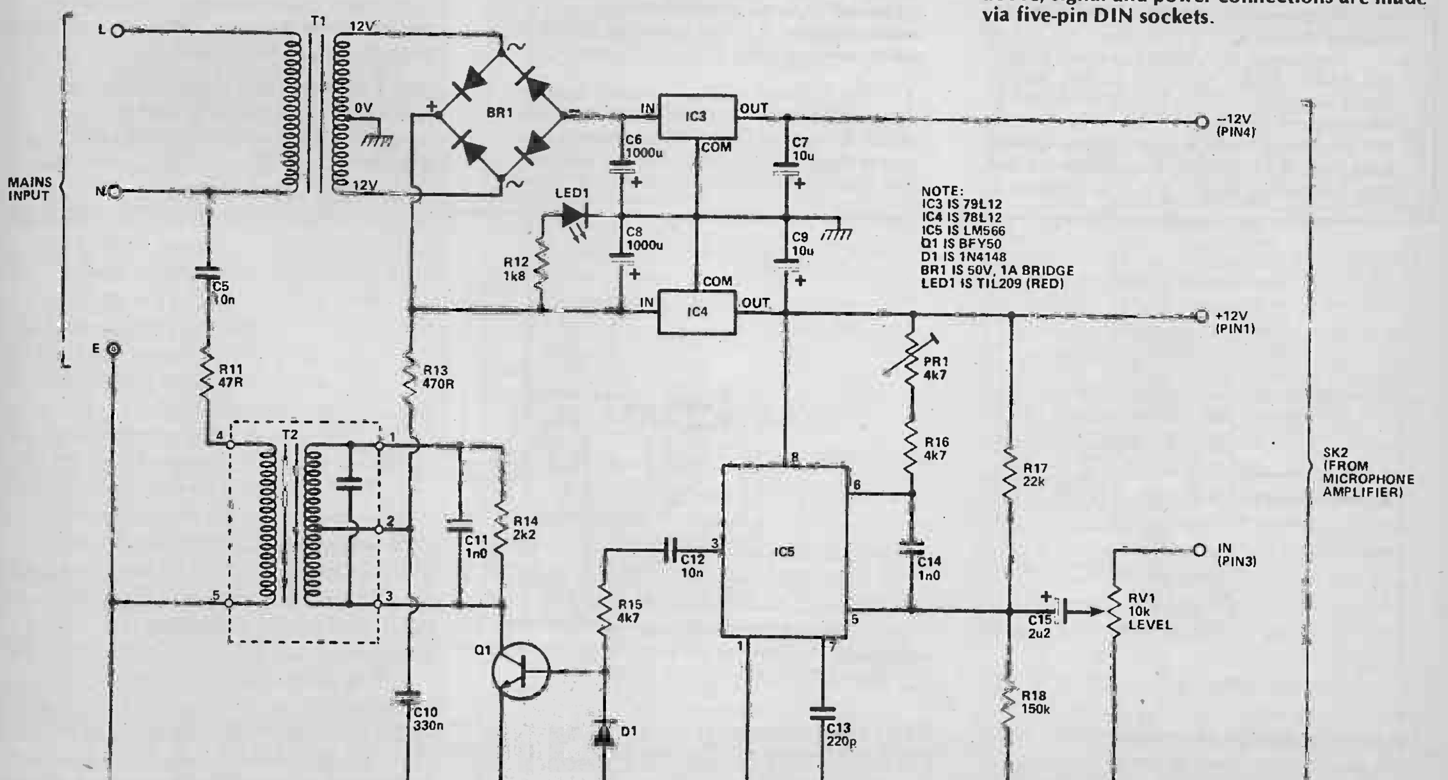
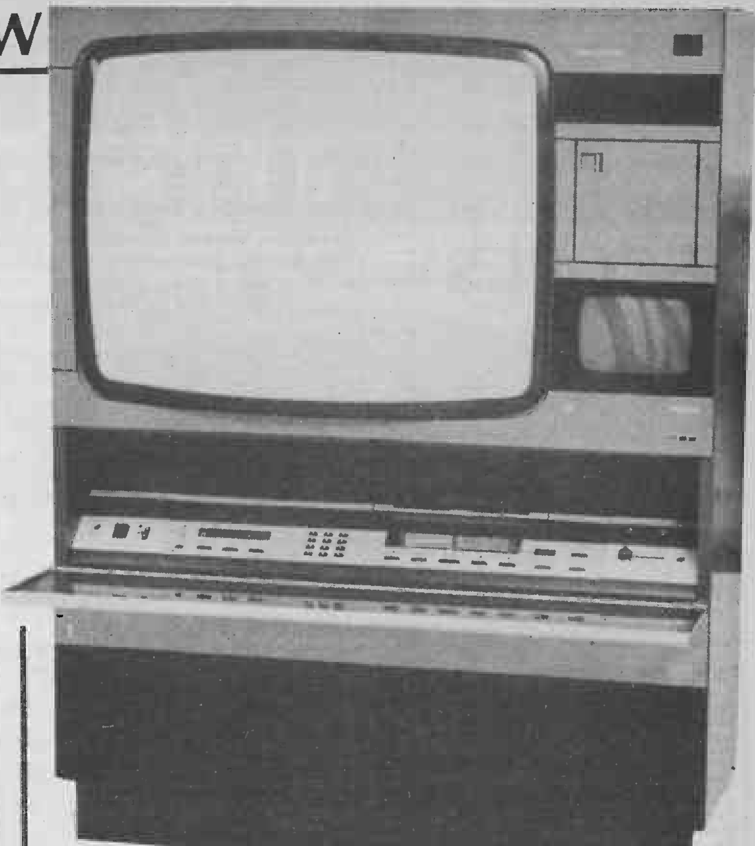


Fig.1 Circuit diagram of the microphone unit.

Fig.2 (below) The circuit diagram of the transmitter unit. This unit also supplies the correct voltage rails for the microphone unit above; signal and power connections are made via five-pin DIN sockets.





All In One

For those of you who are into luxury and laziness, Philips have come up with the ultimate in home television entertainment — the Video Centre. The Centre combines a top quality 26" colour set, a 6" black and white monitor and a VR2020 video cassette recorder in a 3'6" tall silver-grey cabinet. The two-speaker audio system gives out 10 W of sound and all the Video Centre's functions can be operated from one infra-red remote control handset. So, sitting comfortably in your favourite armchair you can watch one channel on the colour screen, record a programme on another channel, see what you've taped on the 6" screen, or check if you're missing something on the other channel. And, if that isn't enough for you, the colour receiver automatically adjusts the brightness to compensate for the room's light level. Two headphone sockets are also provided — one for the main screen and one for the monitor, so two people can watch and hear separate programmes. The VR2020 video recorder is housed behind a hinged smoked perspex cover and uses the Philips V2000 'flippable' cassette with up to eight hours' playing time on one tape. There is also capacity for shooting your own material or setting up a video camera to relay pictures to the 6" screen — great for keeping your eye on the baby or checking for unwanted visitors at the front door. You can enjoy all this for around £1,600 and the centre is available from selected stockists like Harrods, John Lewis and Selfridges.

Under New Management

Drinking is a subject very close to the hearts of the editorial staff of ETI. So we were very interested to hear of a new bar management system launched by MKR. The Microptic System is designed to control losses and provide detailed information from an analysis of accurately recorded sales transaction data. The system is capable of electronically monitoring all drink transactions during every hour of bar operation. The nerve centre of the system is a microprocessor, complete with keyboard, monitor, printer and real-time clock. It uses floppy discs and inputs are MKR patented sensing devices attached to spirit, beer and wine dispensing equipment, including cold shelf and post-mix dispensers. Further information on the system can be obtained from MKR Holdings Ltd, 6 Park Terrace, Worcester Park, Surrey KT4 7JZ.

Doin' It With Lasers

British Telecom will soon begin trials of rooftop lasers for business customers, which could be on offer in London by September. They will be testing two systems, one British, one American, for carrying data from one building to another. The British system is called Interlaser, designed by Modular Technology in the UK. These trials, including some with microwaves, are part of preparations for British Telecom's new City secondary network. The services will include rooftop lasers and microwave radio links with the two laser systems carrying characters of information as pulses in the infra-red part of the light spectrum. The system will be funded by special premiums paid by the users of the facilities. Although the systems vary in design and performance, approximately 30 channels of speech can be accommodated. This British Telecom initiative has come about so that they will be able to compete with the private networks which may well appear once the Telecommunications Bill has been given Royal Assent. In competition with them will be a consortium of Cable & Wireless, the state owned telecommunications company, Barclays Merchant Bank and British Petroleum (BP) who intend setting up a private network using microwave, lasers and cable.

Mini Discs

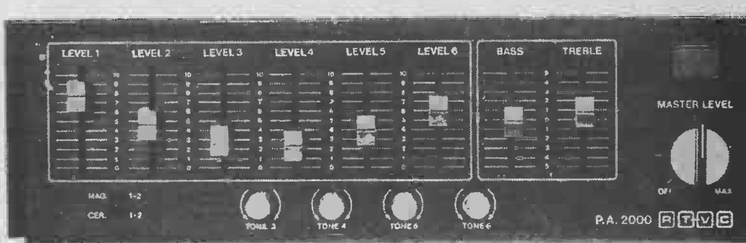
Philips, Sony and PolyGram have declared the Compact Disc Digital Audio System ripe for production. These companies are unanimous in the belief that this new system will eventually replace the LP as we know it. PolyGram Records Operations and CBS/Sony have now put their productions on Compact Disc. It is not expected that the CD will be on the market before the autumn of next year.

Mixing It

Any pop groups out there that are looking for a cheap mixer/amplifier will be interested in the latest offering from RTVC. The PA 2000 is a 50 W RMS (continuous) mono mixer amplifier with six inputs; two for pickups (switch-selectable magnetic or ceramic), two for moving coil microphones and two auxiliary inputs for tape, tuner, electronic organs and other musical instruments. You could also plug a microphone mixer amp into one of the aux sockets if you need to use extra mikes. Six slider controls set the level of each input, and a further two control the overall bass and treble response — additional tone control on inputs 3,4,5 and 6 can be made using the four rotary controls. The remaining rotary pot is the master level control.

For maximum power output a speaker impedance of 4R is needed, and RTVC recommend a power rating of 75 W RMS to provide a safety margin. If necessary the required power and impedance can be obtained by wiring several speakers in series/parallel — instructions are given on how to do this.

The PA 2000 is supplied ready-built in a black vinyl case with matching fascia and knobs (size is approximately 13¼" x 6½" x 3¾") and will cost you £39.95 plus £3.70 postage and packing from RTVC, 323 Edgware Road, London W2.



Connectors

The latest range of PCB connectors and sockets from OK Machine & Tool (UK) Ltd, includes units conforming to DIN 41612, VG95324 and MIL C 24 308 standards. Further information from them at Dutton Lane, Eastleigh, Hants S05 4AA.

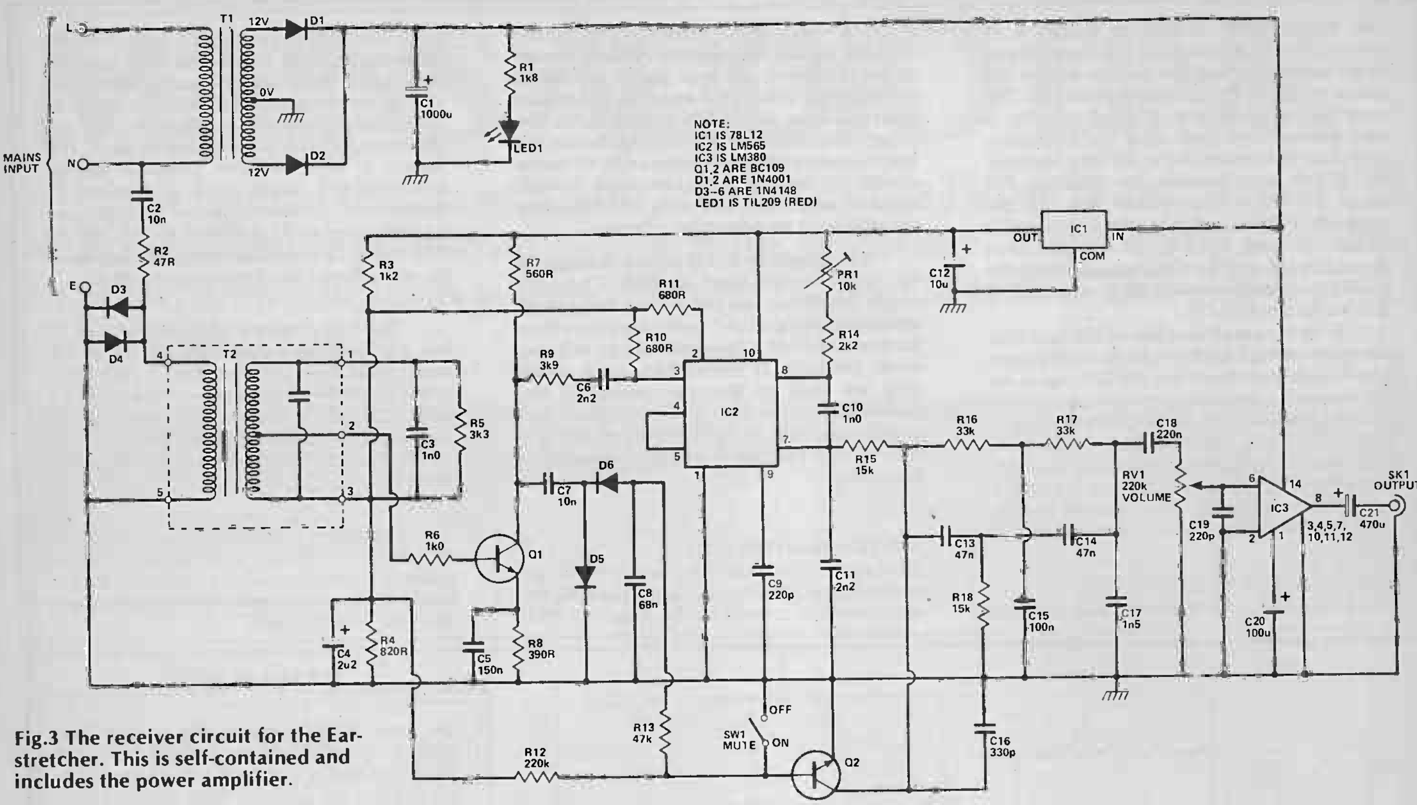


Fig.3 The receiver circuit for the Ear-stretcher. This is self-contained and includes the power amplifier.

HOW IT WORKS

THE RECEIVER UNIT

The 200 kHz FM signal is picked up from the mains neutral line and applied to the input of IF transformer T2 via C2 and R2; D3 and D4 limit the signal amplitudes to a few hundred millivolts. Transformer T2 is tuned to 200 kHz by C3 and has its Q reduced by R5. The isolated output signal of T2 is fed to the base of common-emitter amplifier Q1 via current-limiting resistor R6.

The base of Q1 is biased to about 4V5 by the R3-R4 divider network, so the output signal amplitude of Q1 is limited to about 6 V peak-to-peak: this output is fed to the input of IC2 (pin 3) via R9 and C6. This is a phase-locked loop (PLL) and is used to demodulate the 200 kHz FM carrier signal. The chip contains a reference oscillator which is set to the same frequency as the carrier using PR1, and the demodulated audio signal appears at pin 7 of IC2, where it is filtered by C11-R15-C16 to suppress most of the carrier. The resulting 'semi-clean' audio signal is then passed through 100 Hz twin-T filter R16-R17-R18-C13-C14-C15 to eliminate any signs of power-supply hum, and is finally further cleaned up by C17 before being passed on to the external speaker via 2 W audio amplifier IC3. The complete circuit is mains powered using T1-D1-D2-C1 and IC1.

The receiver unit is provided with an automatic mute facility, which kills the audio output by turning Q2 on in the absence of a carrier signal. Q2 is biased from two independent sources; it is positively biased via R12 and the 4V5 from the R3-R4 potential divider, and can also be negatively biased from the output of Q1 via the C7-D5-D6-C8-R13 'signal detection' network. The R12 and R13 values are such that the negative bias predominates and Q2 is turned off (mute is off) in the presence of a carrier signal with sufficient strength to produce a peak-to-peak signal in excess of about 1V5 at Q1 collector. In the absence of a suitable carrier signal the negative bias falls to a negligible value and Q2 is turned on via R12, muting the audio output signals.

The automatic mute circuit can be disabled by closing SW1, in which case the PLL tries to lock on to noise signals in the absence of a carrier and consequently produces very high noise levels at the output of IC3.

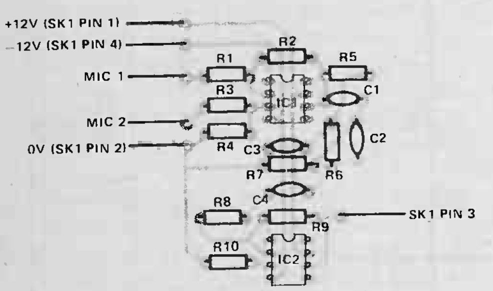


Fig.4 Overlay for the microphone unit.

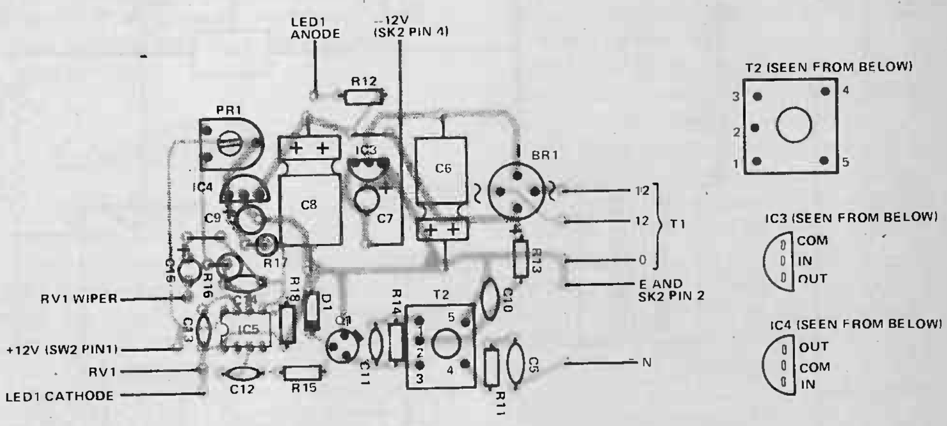


Fig.5 Component overlay of the transmitter unit, the pinouts for the voltage regulators and the IF transformer T2. The case pin of T2 (not shown) will have to be cut off to fit the PCB.

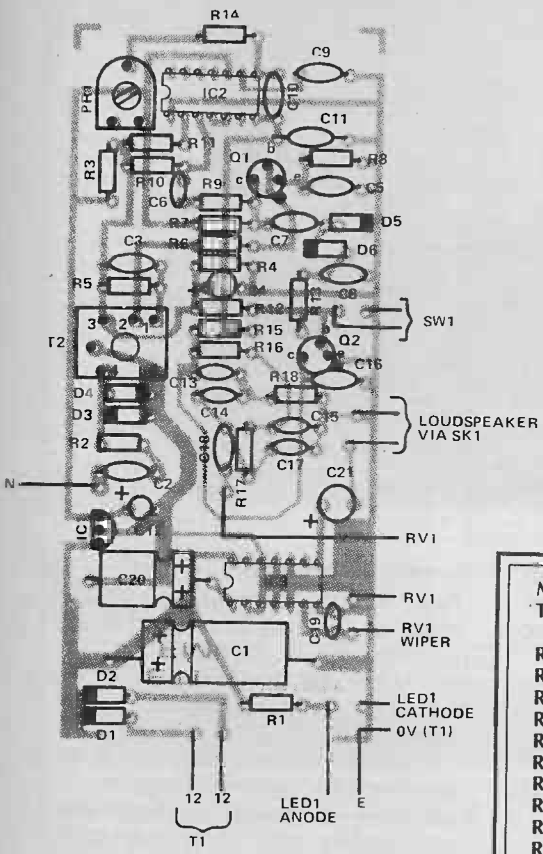
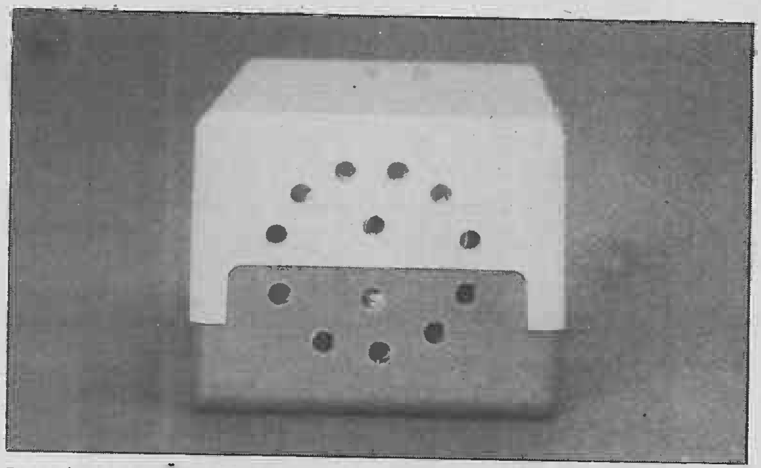
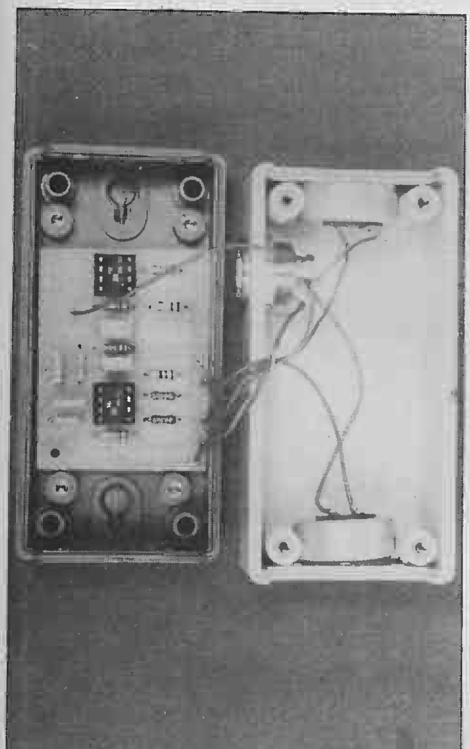


Fig.6 The component overlay for the transmitter unit. A pad has been provided for the case pin of T2 — no surgery needed here!



Don't forget to drill a few holes in the ends of the microphone unit or you won't be able to hear very well!



Internal photograph of the microphone amplifier showing how the crystal inserts fit between the case pillars.

PARTS LIST

MICROPHONE AMPLIFIER AND TRANSMITTER

Resistors (all ¼ W, 5%)

R1,3	1M0
R2,4,9	10M
R5,6	33k
R7	15k
R8	100k
R10,17	22k
R11	47R
R12	1k8
R13	470R
R14	2k2
R15,16	4k7
R18	150k

Potentiometers

RV1	10k logarithmic
PR1	4k7 miniature horizontal preset

Capacitors

C1,2	100n polycarbonate
C3	220n polycarbonate
C4	470n polycarbonate
C5	10n 750 V disc ceramic
C6,8	1000u 25 V axial electrolytic
C7,9	10u 16 V tantalum
C10	330n polycarbonate
C11,14	1n0 polycarbonate
C12	10n polycarbonate
C13	220p ceramic
C15	2u2 35 V tantalum

Semiconductors

IC1,2	741
IC3	79L12
IC4	78L12
IC5	LM566
Q1	BFY50
D1	1N4148
BR1	50 V, 1 A bridge rectifier
LED1	TIL209 (red)

Miscellaneous

T1	12-0-12, 6 VA
T2	IFT14
SK1,2	five-pin DIN socket (and plugs)
MIC1,2	crystal insert type C2

Verocase order no. 202-21030K (transmitter), Verocase order no. 202-21028B (microphone amplifier), knob to suit.

RECEIVER

Resistors (all ¼ W, 5%)

R1	1k8
R2	47R
R3	1k2
R4	820R
R5	3k3
R6	1k0
R7	560R
R8	390R
R9	3k9
R10,11	680R
R12	220k
R13	47k
R14	2k2
R15,18	15k
R16,17	33k

Potentiometers

RV1	220k logarithmic
PR1	10k miniature horizontal preset

Capacitors

C1	1000u 25 V axial electrolytic
C2	10n 750 V disc ceramic
C3,10	1n0 polycarbonate
C4	2u2 35 V tantalum
C5	150n polycarbonate
C6	2n2 ceramic
C7	10n polyester (C280)
C8	68n polycarbonate
C9	220p polystyrene
C11	2n2 polystyrene
C12	10u 35 V tantalum
C13,14	47n polycarbonate
C15	100n polycarbonate
C16	330p polystyrene
C17	1n5 polycarbonate
C18	220n polycarbonate
C19	220p ceramic
C20	100u 25 V axial electrolytic
C21	470u 25 V electrolytic (PCB type)

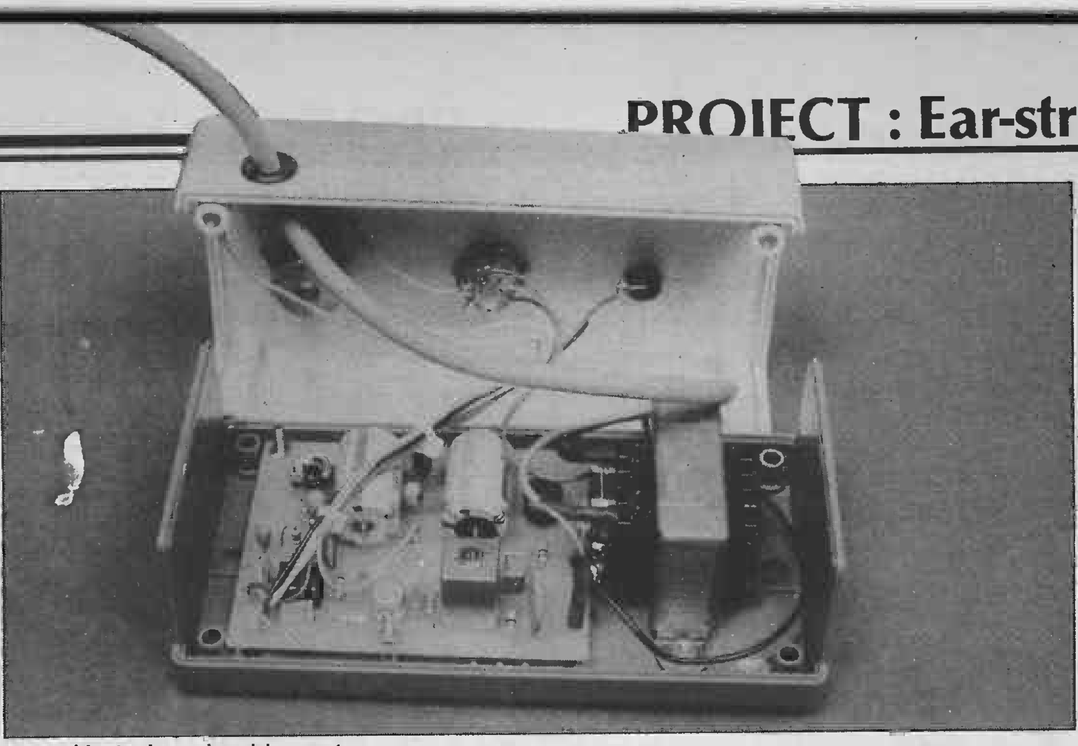
Semiconductors

IC1	78L12
IC2	LM565
IC3	LM380
Q1,2	BC109
D1,2	1N4001
D3-6	1N4148
LED1	TIL209 (red)

Miscellaneous

T1	12-0-12, 6 VA
T2	IFT14
SW1	SPST miniature toggle
SK1	phono socket

Verocase order no. 202-21038H, knob to suit.



Inside the transmitter. Cable ties keep the wiring neat.

fit these components into place. Next, assemble all the specified components on the large PCB, then bolt mains transformer T1 and the PCB into place in the lower half of the case and complete the interwiring. The complete system is then ready for initial setting up and use.

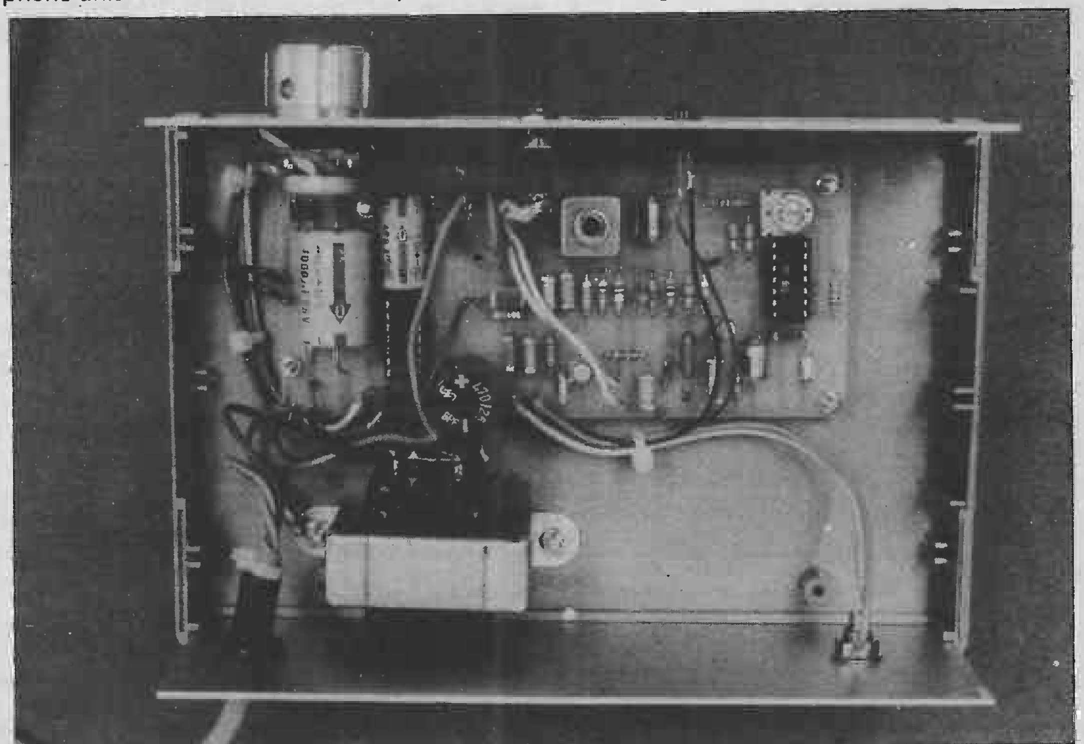
Setting Up

Before attempting to use the system, first check (with a voltmeter) that the neutral line of your house wiring is correctly polarised, with only a few volts appearing between neutral and ground.

To initially test and set up your Ear-stretcher system, first plug the microphone unit into the transmitter, locate the microphone unit near some kind of sound source, turn RV1 to mid position and then plug the transmitter unit into the mains: check that the two 12 V DC supplies are reaching the microphone unit. If you have access to a scope, check that a 200 kHz (nominal) signal of about 3 V peak-to-peak appears between pins 5 and 4 (earth and effective neutral) of T2, and that this signal can be frequency-modulated by microphone sounds. The centre frequency can, if desired, be set to precisely 200 kHz using PR1.

Now connect a speaker (8R0) to the output of the receiver unit, set volume control pot RV1 to mid position and mute switch SW1 to the off position, and then plug the unit into the mains. Now trim preset PR1 (in the receiver) until the transmitted signal is heard to come in with minimal distortion; if distortion is excessive, try reducing the modulation level at the transmitter. Turn the mute switch on and check that the volume falls to near zero when the transmitter unit is switched off.

If desired, the system can be set to give maximum possible range by progressively moving the transmitter and receiver units further apart and trimming the cores of T2 (in the transmitter and the receiver) to give the best possible sensitivity. A maximum range of a few hundred yards is possible in most domestic environments. When these adjustments are complete, the system is ready for use and should require no subsequent adjustment.



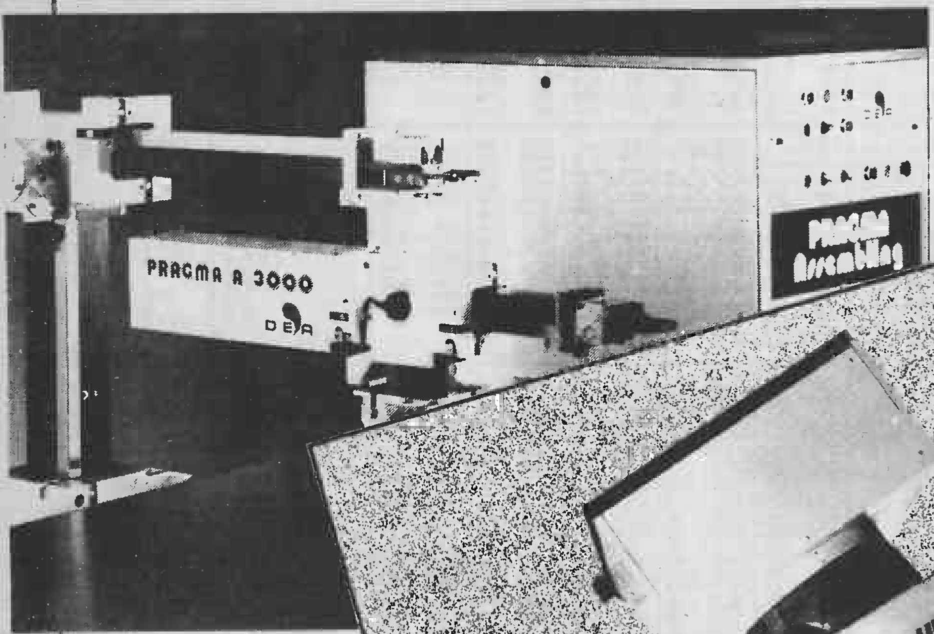
How we built the receiver; remember to take care with the mains wiring. A phono socket is provided on the back panel for connection to an external speaker.

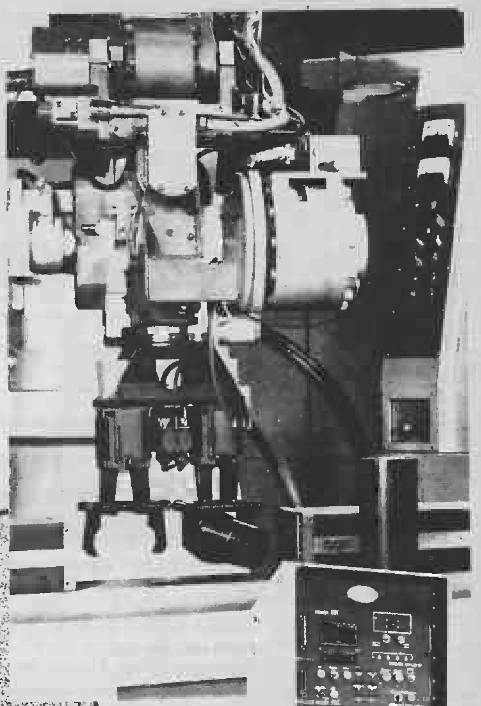
ETI

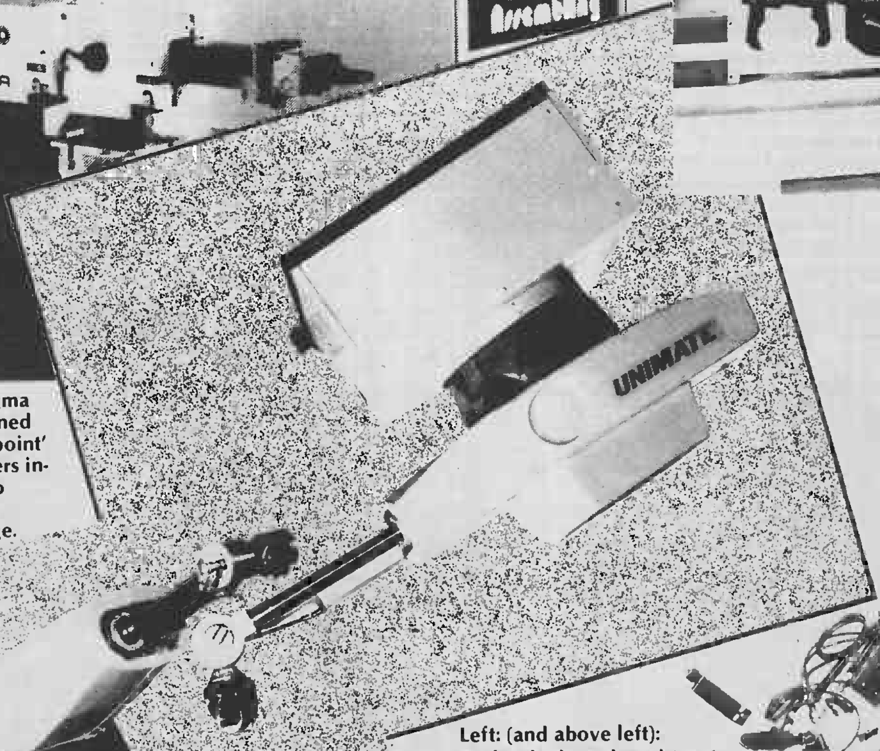
AUTOMAN '81

A photo-report from this year's robotics show in Brighton.

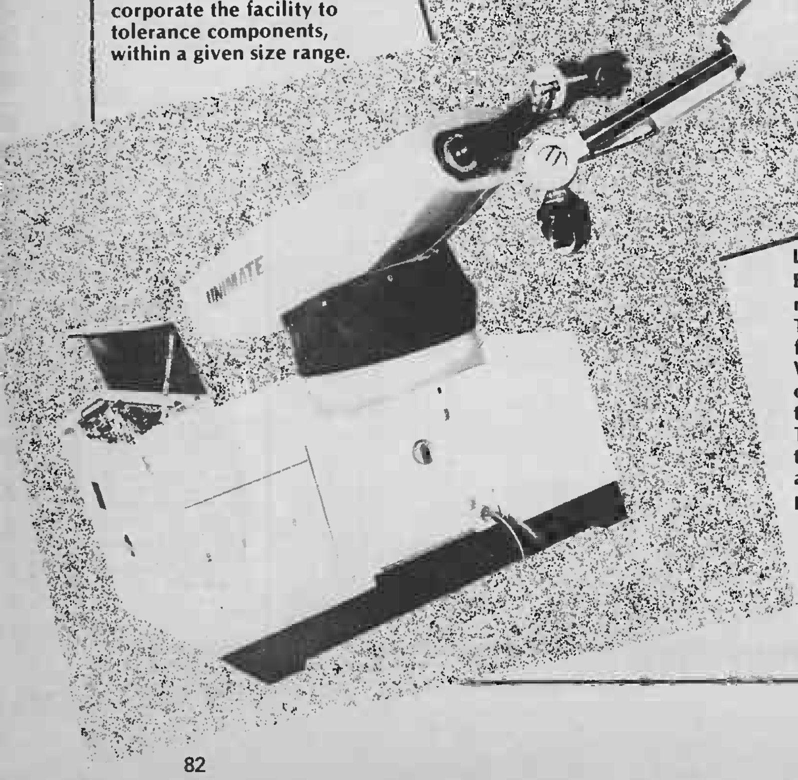
The well-attended Automan '81, held at the Metropole in Brighton recently,was something of a disappointment in technological terms. It was encouraging to note the high level of interest in being shown in automation at a British exhibition, but surprising at how little 'front-line' technology was on show. For example, the show was dominated by arms of one sort or another. All these were 'fixed station' machines, unable to operate in a mobile manner. There was one, and only one, company showing image recognition techniques and overall little that could not have been there equally well last year.





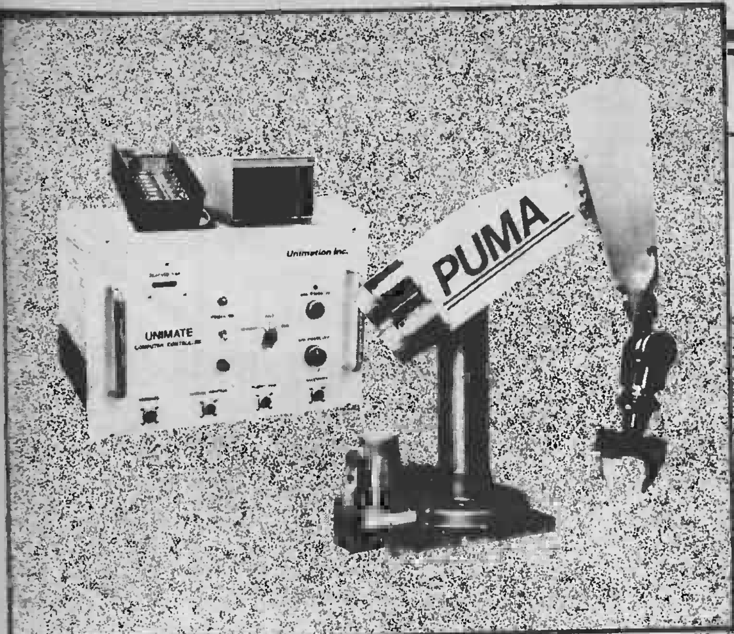


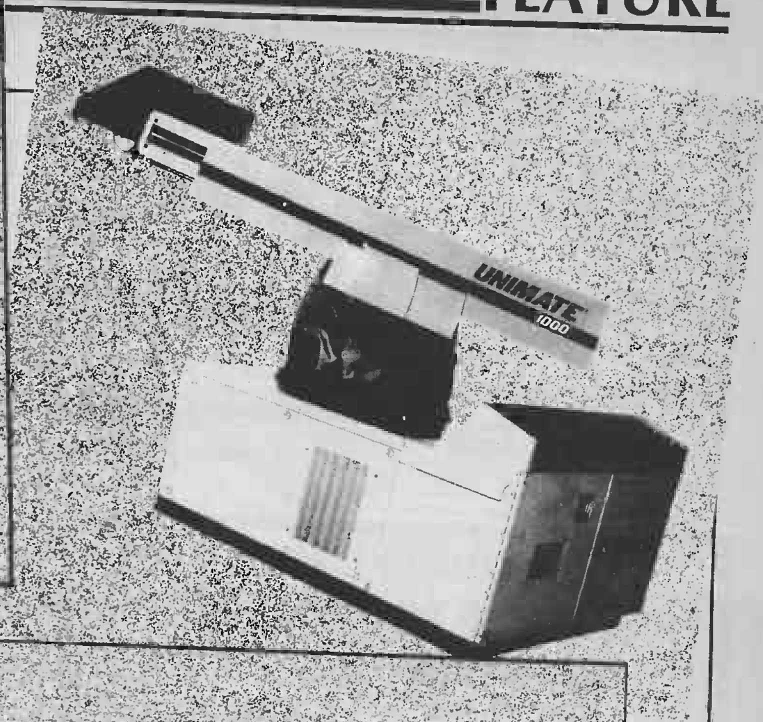
Above: The Italian Pragma twin-arm sytsem. Designed as a versatile 'point-to-point' manipulator, the grippers incorporate the facility to tolerance components, within a given size range.

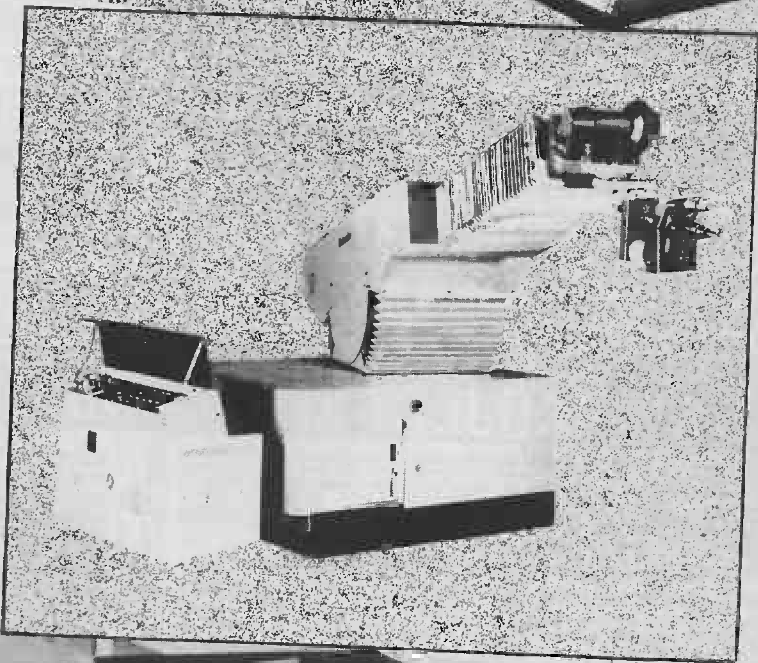


Left: (and above left):
By far the best thought out range of machines was from Unimate. Their 2100 models are available in either a floor mounting or overhead configuration. Weight limit on the arms is around 70 kg. The overhead arm allows the controls and drivers to be mounted remotely.
These are 'heavyweight' designs and would be typically employed in die casting, car assembly, welding etc where power is an important part of the requirement specification.

Right: The cleverer of the arms is taught its job by being led through the sequence by a skilled operator, ie paint sprayer. After this the robot repeats the operation faultlessly ad infinitum. This Norsden System is sold complete with 'teaching arm' and control console. →

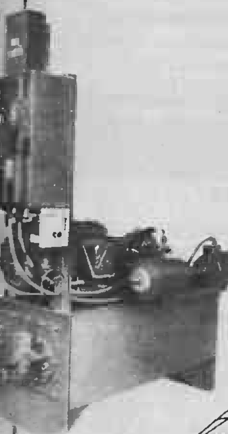






Above (left): Cincinnati Milacron Ltd produce a complete automated manufacturing centre. This comprises a manipulator arm assembly and one or two 'turning centres' ie automatic lathes. The arm will feed the machines new work material and remove completed items as and when required to do so by the control program.

Above: Some robotics arms are designed to mimic the action of the human version, so that they may take over tasks directly from a human agent. This Puma is claimed to have a repeat accuracy of ± 0.05 mm. (How many humans can claim that?)
Above: (right) in areas where limited movement is required, with a fair degree of strength, no attempt need be made to model the present operator. Both these examples are designed to minimise workspace, rather than adapt to present conditions. The lower device can lift 205 kg!



LABORATORY PSU

This unique design can be used as a 0-30 V, 1A2 precision PSU project or as a 20 mA-1A2 constant-current generator. The design features electronic short-circuit protection, high transient current-drive capability, and a built-in audio-visual over-current alarm. Design by Ray Marston. Development by Steve Ramsahadeo.

A variable power supply unit (PSU) is one of the most basic and essential pieces of test gear in any amateur or professional laboratory or workshop. Trouble is, most cheap PSUs of the amateur type tend to suffer from quite severe performance restrictions, while professional PSUs tend to be very expensive and to suffer from various usage restrictions. Cheap PSUs, for example, often span the simple voltage range 1.2-25 V and have fixed 1 A current limiting, while professional units usually span the full 0-30 V range and have variable current limiting, but have no transient over-current driving capability.

A New PSU

We at ETI have recently taken a careful look at some of the basic concepts of conventional PSU design and, as a result, have come up with this brand new and ultra-practical PSU project. To arrive at our final design, we started off with the following basic precepts.

- Most of the cost of a PSU is attributable to the cost of the mechanical and electrical hardware (the case, transformer, moving-coil meter and so on), rather than to the electronics. Thus, PSU performance sophistication can be greatly increased, with little growth in total costs, by sensibly increasing the amount of electronics in the project.
- Our ideal PSU should fully span the 0-30 V range and be provided with fully-variable semi-precision 20 mA-1A2 current limiting. This variable current-limiting facility will also enable the PSU to serve the dual function of a variable constant-current generator or Ni-Cd charger.
- The ideal PSU should have two independent types of current-limiting facility. In our system, the variable (20 mA-1A2) limiter responds to *mean* currents and has a time constant of a few milliseconds; the second limiter is a fixed 1A8 instantaneously-acting type. The provision of the two types of limiter gives the completed PSU excellent mean-current-limiting characteristics combined with a high transient current-drive capability.
- The PSU should provide an audio-visual alarm indication of the variable over-current state, so that the user is given an instant warning of circuit defects when using the PSU to develop experimental circuits. The audible part of the alarm should be manually switchable, so that the alarm can be disabled when the PSU is used as a constant-current generator or Ni-Cd charger.

The results of our design efforts are shown in this article. You'll note from the circuit diagram that, although the design is moderately complex and unconventional, the design makes wide use of inexpensive ICs and transistors. As a result, you'll find that our PSU unit costs little more than the cheapest of PSUs to build, but gives a performance that is better than the best of professional units. Well, of course, you'd expect that from an ETI project, wouldn't you?

Construction

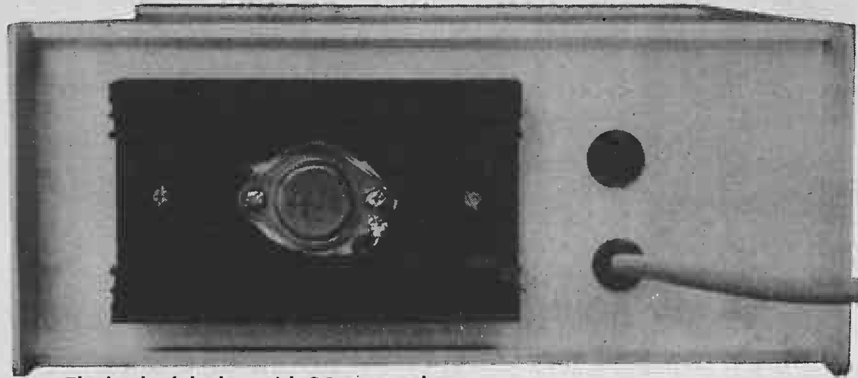
Using our PCB greatly simplifies construction and reduces the possibility of any errors. As usual, check the orientation of all semiconductors and capacitors against the overlay.

As you can see from the photographs, Q4 and Q8 are fitted with T05 style heatsinks; Q9 will dissipate approximately 45 W at the maximum setting and has to be mounted on a 100 mm x 60 mm finned heatsink. This heatsink must be insulated from the rear panel by plastic bushes. We also recommend the use of heatsink compound, to be applied on both mating surfaces. Heavy gauge wire (13/0.2 mm) should be used to connect Q9 and the output sockets to the PCB. As an added safety precaution all mains wiring, including the transformer terminals, should be insulated with rubber or PVC sleeving.

You may have difficulty obtaining a meter whose scale is printed with the required scale of 0-1.5 and 0-30. We overcame this problem by using a common-or-garden 100 uA meter and recalibrating the scale with dry transfer lettering (eg Letraset).

To set the FSD of the meter, connect a voltmeter across the output terminals and turn RV2 up to maximum. Now alter PR1 until the reading on M1 agrees with that of the voltmeter.

→



The back of the box with Q9 mounted on a substantial heatsink.

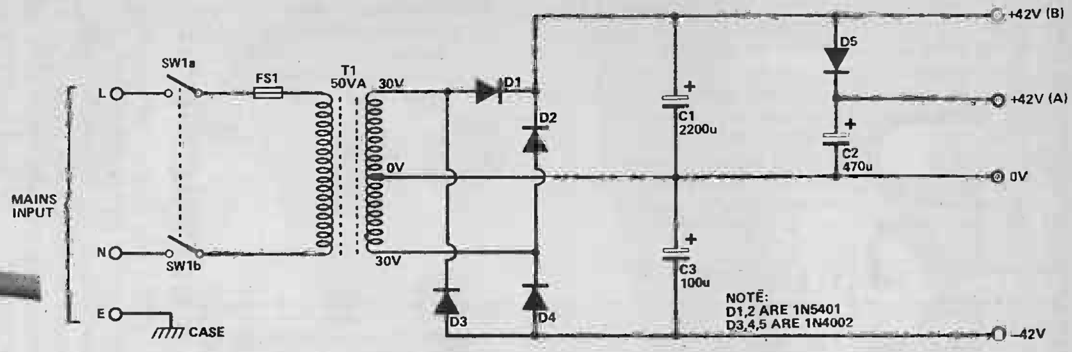


Fig.1 The basic power supply circuit.

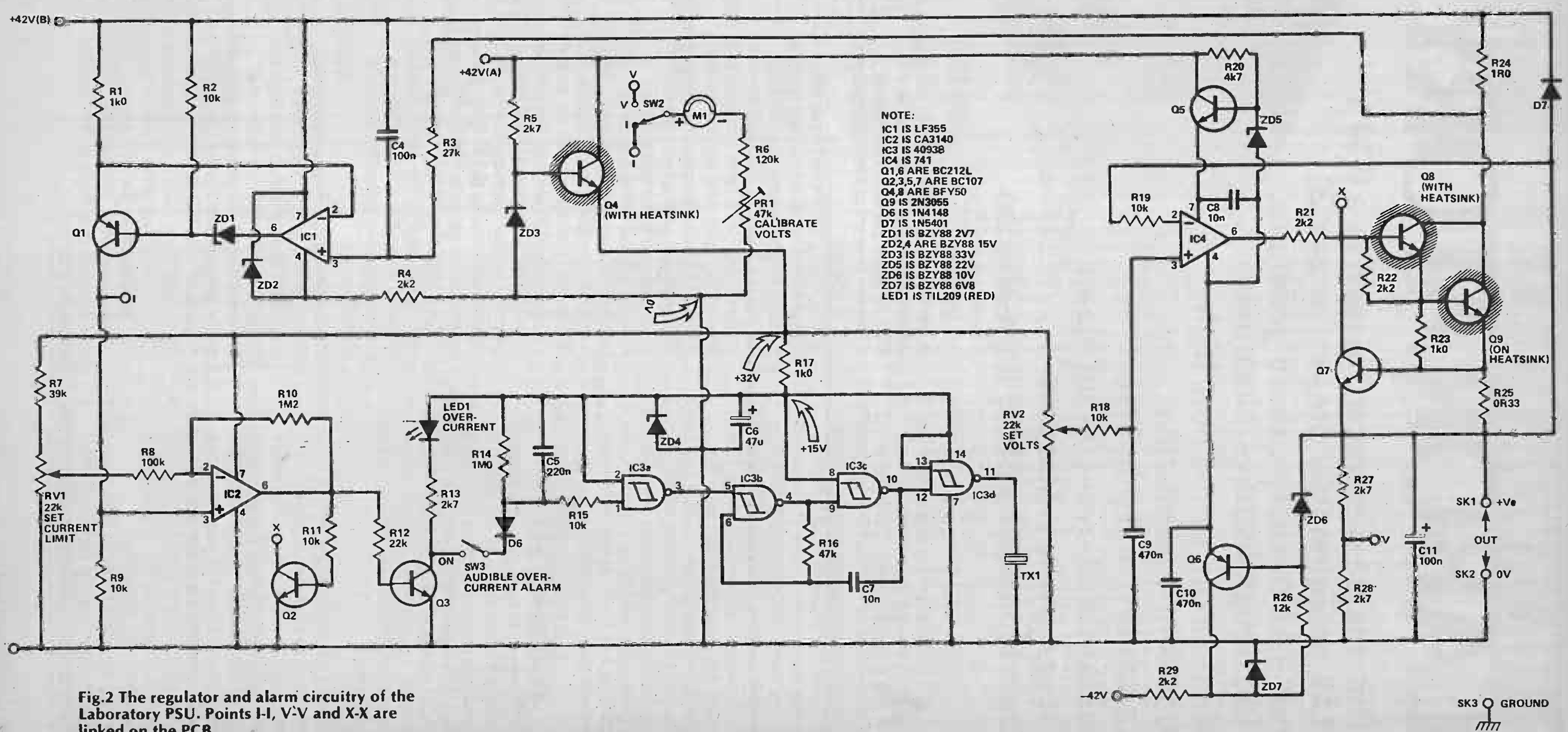


Fig.2 The regulator and alarm circuitry of the Laboratory PSU. Points I-I, V-V and X-X are linked on the PCB.

PARTS LIST

Resistors (all ¼ W, 5% except where stated)	
R1,17,23	1k0
R2,9,11,15, 18,19	10k
R3	27k
R4,21,22,29	2k2
R5,13,27,28	2k7
R6	120k
R7	39k
R8	100k
R10	1M2
R12	22k
R14	1M0
R16	47k
R20	4k7
R24	1R0 2W5
R25	0R33 ½ W
R26	12k

Potentiometers	
RV1,2	22k linear
PR1	47k miniature horizontal preset

Capacitors	
C1	2200u 63 V axial electrolytic
C2	470u 63 V electrolytic (PCB type)
C3	100u 63 V axial electrolytic
C4	100n ceramic
C5	220n polycarbonate
C6	47u 25 V axial electrolytic
C7	10n polycarbonate
C8	10n ceramic
C9,10	470n polycarbonate
C11	100u 63 V electrolytic (PCB type)

Semiconductors	
IC1	LF355
IC2	CA3140
IC3	4093B
IC4	741
Q1,6	BC212L
Q2,3,5,7	BC107
Q4,8	BFY50
Q9	2N3055
D1,2,7	1N5401
D3,4,5	1N4002
D6	1N4148
ZD1	BZY88 2V7
ZD2,4	BZY88 15 V
ZD3	BZY88 33 V
ZD5	BZY88 22 V
ZD6	BZY88 10 V
ZD7	BZY88 6V8
LED1	TIL209 (red)

Miscellaneous	
T1	30-0-30, 50 VA
SW1	DPDT miniature toggle
SW2,3	SPDT miniature toggle
M1	moving-coil meter, 100 uA FSD
SK1,2,3	4 mm terminal post
FS1	500 mA fuse and holder
TX1	PB-2720

Heatsinks (two off T05 and one off 60 x 100 mm finned), mounting kit for T03 transistor, case ref SWF 222X (see Buylines).

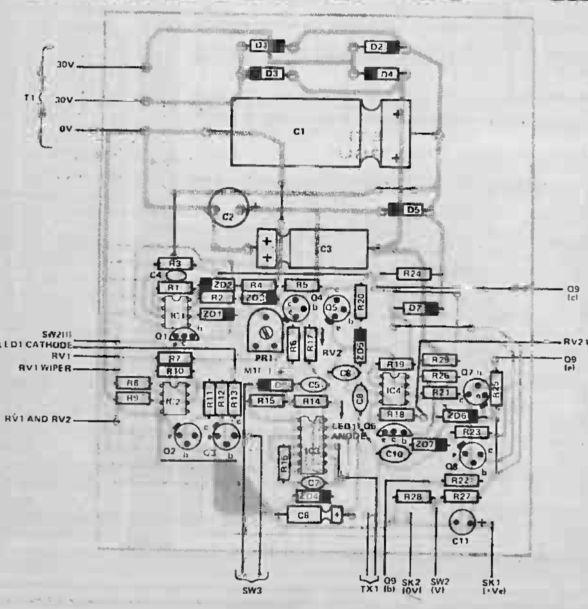
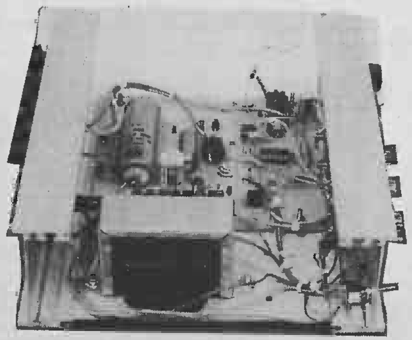


Fig.3 Component overlay for the Laboratory PSU. Don't miss the off-board connections in the centre of the PCB — the ones to M1(−), LED1 anode and RV2.



An internal shot of the case showing how we fitted everything in. The piezo-electric buzzer mounts on the right-hand end cheek. The case comes apart into several sections to make drilling and construction much easier.

HOW IT WORKS

At the outset of the design of this project it was decided that the PSU would be required to span the full 0-30 V output range and have semi-precision current limiting that is fully variable from 20 mA to 1A2. These requirements precluded the possibility of using reasonably-priced regulator ICs as the basis of the design, hence the use of a relatively large number of discrete transistors and IC op-amps in our project.

The main circuit can be broken down into a number of distinct blocks, as follows. ZD3-R5-Q4 and RV2 act as a variable reference-voltage generator, in which the slider voltage of RV2 is fully variable from zero to 32 V. IC4-Q8-Q9 act as a high-power voltage follower, with the output voltage across C11 closely following the voltage set on RV2 slider: Q9 has short-circuit protection provided by R25 and Q7, which automatically limit the peak output current of the circuit to about 1A8. To protect IC4 against excessive supply rail voltages without impairing its operating capabilities, the supply to this IC is provided via the Q5-Q6-ZD5-ZD6-ZD7 'sliding voltage generator' network, which holds the negative terminal of IC4 (pin 4) at roughly 9 V below the C11 output-terminal value and the positive terminal (pin 7) at 22 V above that of pin 4. All of the above circuitry comprises the variable voltage regulator section of the PSU.

The variable current-limiting part of the project is designed around R24-IC1-Q1 and RV1-IC2-Q2, with audio-visual over-current alarm indication given by the Q3-LED1-IC3 network. These sections of the PSU operate as follows.

The output current of the voltage regulator is monitored by R24; a voltage of 1 V/A is generated across this resistor. This voltage is integrated (to eliminate the effects of transients) by C4-R3 and the resulting voltage is fed to the input of the IC1-Q1 DC level translator, which has a gain of 10 and causes a voltage of 10 V/A to be generated across R9. This voltage is fed to one input of uni-directional differential amplifier IC2; the other input of this amplifier is derived from the slider of RV1, and the output of IC2 is coupled to point 'X' of the voltage regulator circuit via Q2.

The overall action of IC2 is such that, if the current-related R9 voltage is below that set via RV1 slider, Q2 is cut off and the voltage regulator acts in the normal way, but if the R9 voltage is greater than that of RV1 slider Q2 is driven on linearly and pulls point 'X' towards ground (0 V), thereby reducing the output voltage (and hence the current) of Q9. IC2-Q2 and the associated components are effectively coupled into a current-sensitive negative feedback loop with the voltage regulator, causing the output current of Q9 to self-limit at a mean current level (variable from 20 mA to 1A2) that is set using RV1.

Note that the output of IC2 is also coupled to Q3 via R12. Consequently, when the current-limiting circuitry becomes active, Q3 is driven on and causes LED1 to illuminate, giving a visual indication of the over-current state. Simultaneously, if SW3 is closed, the IC3 audible over-current alarm circuit is activated: in this circuit, IC3b-IC3c form a gated astable, with its output fed to the PB-2720 acoustic transducer via buffer stage IC3d and with gating provided from Q3 collector via the IC3a peak-detecting network.

Note that the complete PSU circuit uses a total of three supply rails. The 42 V negative rail is used to enable pin 4 of IC4 to swing negative when required; this rail is required to provide only 20 mA or so of current. Two positive supply rails are used in the circuit: the +42 V (A) rail drives most of the low-power sections of the circuitry and is required to provide only a few tens of milliamps. The +42 V (B) rail powers IC1-Q1 and the high-power Q8-Q9 sections of the circuit and is required to provide mean currents up to 1A2. The use of the two positive supply rails enables power losses to be minimised and enables the main smoothing capacitor (C1) to be given a relatively low value.

BUYLINES

The case used in this project is one from the Swift range offered by West Hyde Developments and costs £11.96 including postage and VAT. The high power resistors are available from Electrovalue, the PB-2720 is stocked by Ambit, and the LF355 can be obtained from Marshall's. None of the other components should cause any problems.

The PCB for this project will be available from our new PCB service — see page 45 for details.

DESIGNER'S NOTEBOOK

This month Ray Marston takes an in-depth look at constant current generator applications and circuits.

A constant current generator circuit can be simply described as being electrically equivalent to a voltage generator with such a high output impedance that the current fed to an external load is virtually constant, irrespective of wide variations in the load resistance value. Figure 1a illustrates this description by showing the simple equivalent of a 1 mA constant current generator, with a basic source voltage of 100 V and an output impedance of 100k: as you can see, varying the load impedance from zero to 1k0 causes the load current to change by a mere 1%. In practice, of course, a true constant current generator can use electronic techniques to simulate these high source voltage and high output impedance characteristics. Figure 1b shows the circuit symbol that is used to represent a practical constant current generator.

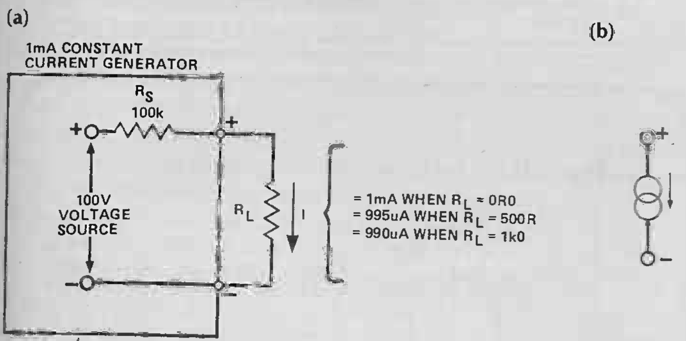


Fig. 1 Simple equivalent circuit of a 1 mA constant current generator (a), and the circuit symbol for a constant current generator (b).

Figure 2 shows some useful basic applications of constant current generators. Figure 2a is the basic circuit of a linear-scale ohmmeter, in which the Rx value is read off on a voltmeter; if I is 1 mA, the output voltage will be 1 mV per ohm of Rx value, if I is 10 uA the output voltage will be 10 uV/R, and so on.

In Fig. 2b, the generator is used to provide linear charging of a capacitor; this circuit is useful in linear timebase generators, for example.

In Fig. 2c, the constant current generator is used as the emitter load of a common collector amplifier or emitter follower, where the high dynamic impedance of the generator gives the follower excellent linearity and a near perfect unity gain.

In Fig. 2d the generator is used as the collector load of a common emitter amplifier, where its high dynamic impedance causes the amplifier to operate with high voltage gain (typically about 70 dB).

In Fig. 2e, the generator is used as the emitter load of a differential amplifier, where its high dynamic impedance causes the amplifier to operate with high gain, excellent linearity and a high CMR ratio.

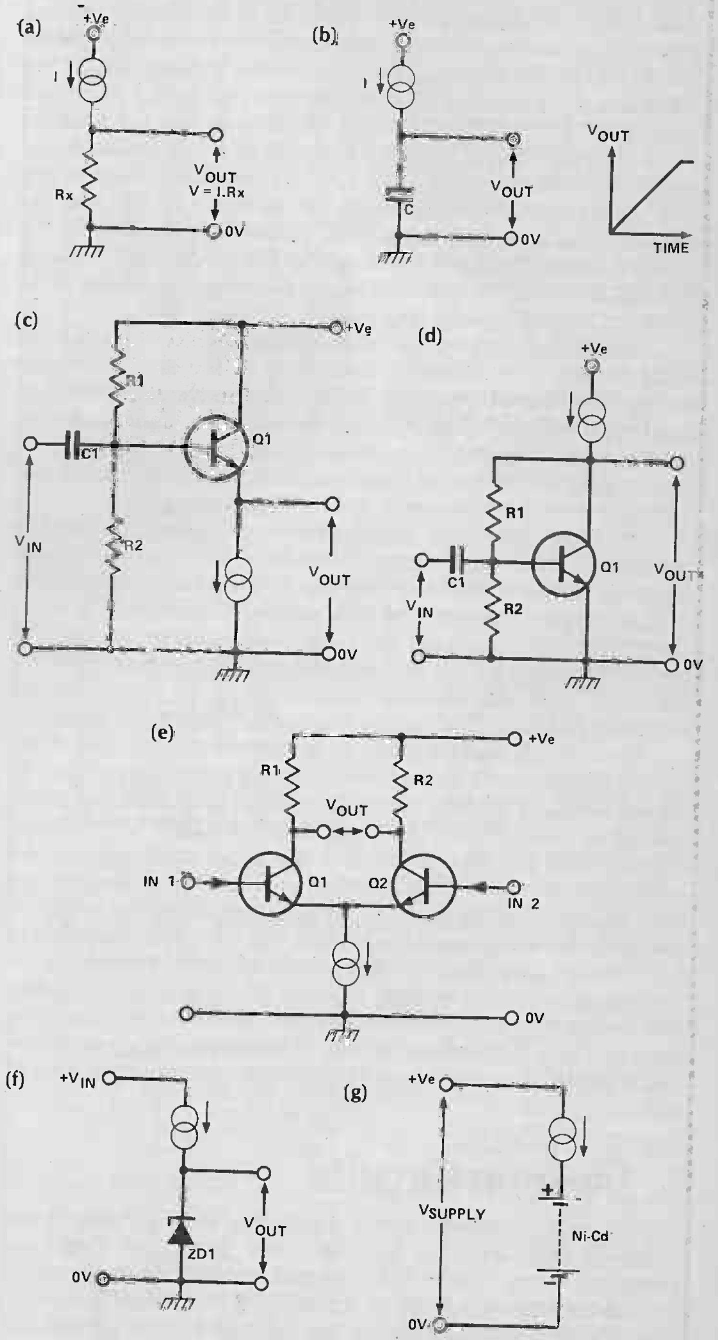


Fig. 2 Typical applications of constant current generator circuits; (a) linear scale ohmmeter; (b) linear charging of a capacitor; (c) unity-gain, highly-linear emitter follower; (d) high-gain common emitter amplifier; (e) high performance differential amplifier; (f) precision voltage source; (g) Ni-Cd charger.

Figure 2f shows a typical power supply application, in which the generator is used to apply a fixed bias current to a zener diode, irrespective of wide variations of input voltage, and thus enables the zener to generate an ultra-stable output reference voltage.

Finally, Fig. 2g shows how the generator can be used as a Ni-Cd charger, in which the charger current is constant, irrespective of the number of cells that are used in the Ni-Cd stack.

Transistor Circuits

Bipolar transistors can easily be configured to act as efficient constant current generators. Figure 3 illustrates an easy way to use an NPN transistor in this mode. Here, R1 and ZD1 are used to apply a fixed 5V6 reference voltage to the base of common emitter amplifier Q1, which uses R2 as its emitter load and its collector as the constant current source. Because of the inherent 600 mV (approximately) base-emitter voltage drop of the transistor, 5 V is developed across emitter resistor R2, so a fixed current of 5 mA passes through this resistor via Q1 emitter. Since the emitter and collector currents of a bipolar transistor are inherently almost identical, a 5 mA current also flows in any load that is connected between the collector of Q1 and the positive supply rail of the circuit, almost irrespective of the load's resistance value (providing that the value is not so large that Q1 is driven into saturation), so these two points serve as constant current source terminals.

From this description, you can see that the constant current magnitude is determined by the values of the base reference voltage and the emitter load resistor (R2), so the current value can be varied by altering either of these values. Figure 4, for example, shows how the basic circuit of Fig. 3 can be 'inverted' to give a ground-referenced constant current output that can be varied from approximately 1 mA to 10 mA using RV1.

In most practical applications of constant current generators, the most important feature of the circuit is its high dynamic output impedance (see Fig. 2). The precise magnitude of the constant current is of only modest importance: in such cases, the basic circuits of Figs. 3 and 4 will satisfy most practical needs. If greater precision is needed, the characteristics of the reference voltages of these circuits must be improved, to eliminate the effects of supply line and temperature variations.

One simple modification to improve the Fig. 3 and 4 circuits is to replace R1 with a 5 mA constant current generator, as shown in Fig. 5, so that the zener current (and thus the zener voltage) is independent of variations in the supply line voltage. If really high precision is needed, the zener reference should have a temperature coefficient of −2 mV/°C, to match the base-emitter coefficient of Q1; an easy way round this problem is to use a forward biased LED in place of the zener, as shown in Fig. 6. In this case the LED voltage is roughly 2 V, so only about 1V4 appears across emitter resistor R1, which has its value reduced to about 270R to maintain the constant current output level at 5 mA. An even better way of obtaining high precision is to use an op-amp version of the constant current generator circuit.

Op-amp Circuits

Op-amp constant current generators are very easy to implement, as illustrated by the 1 mA to 10 mA precision generator of Fig. 7. Here, IC1 is used as a voltage follower with a variable reference voltage of 560 mV to 5V6 applied to its non-inverting terminal via RV1, but has the base-emitter junction of Q1 included in its negative feedback loop. Thus the R2 voltage precisely follows the reference voltage, but has its current sup-

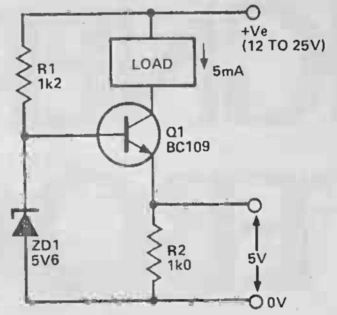


Fig. 3 A simple transistor 5 mA current generator.

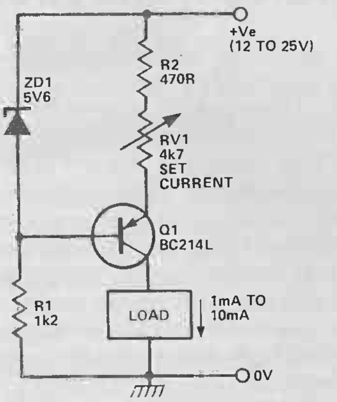


Fig. 4 A simple variable ground-referenced constant current generator (1 mA — 10 mA).

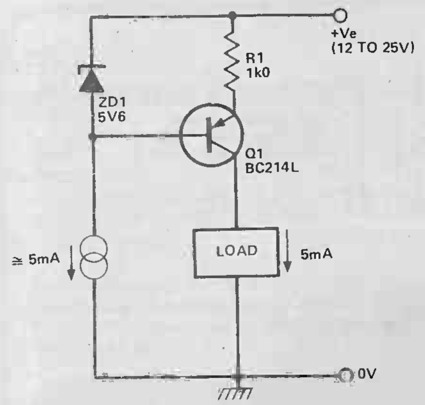


Fig. 5 A precision constant current generator, with precision voltage reference.

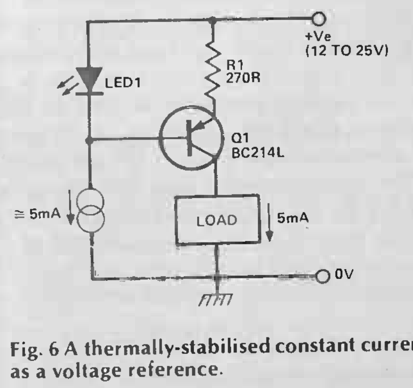
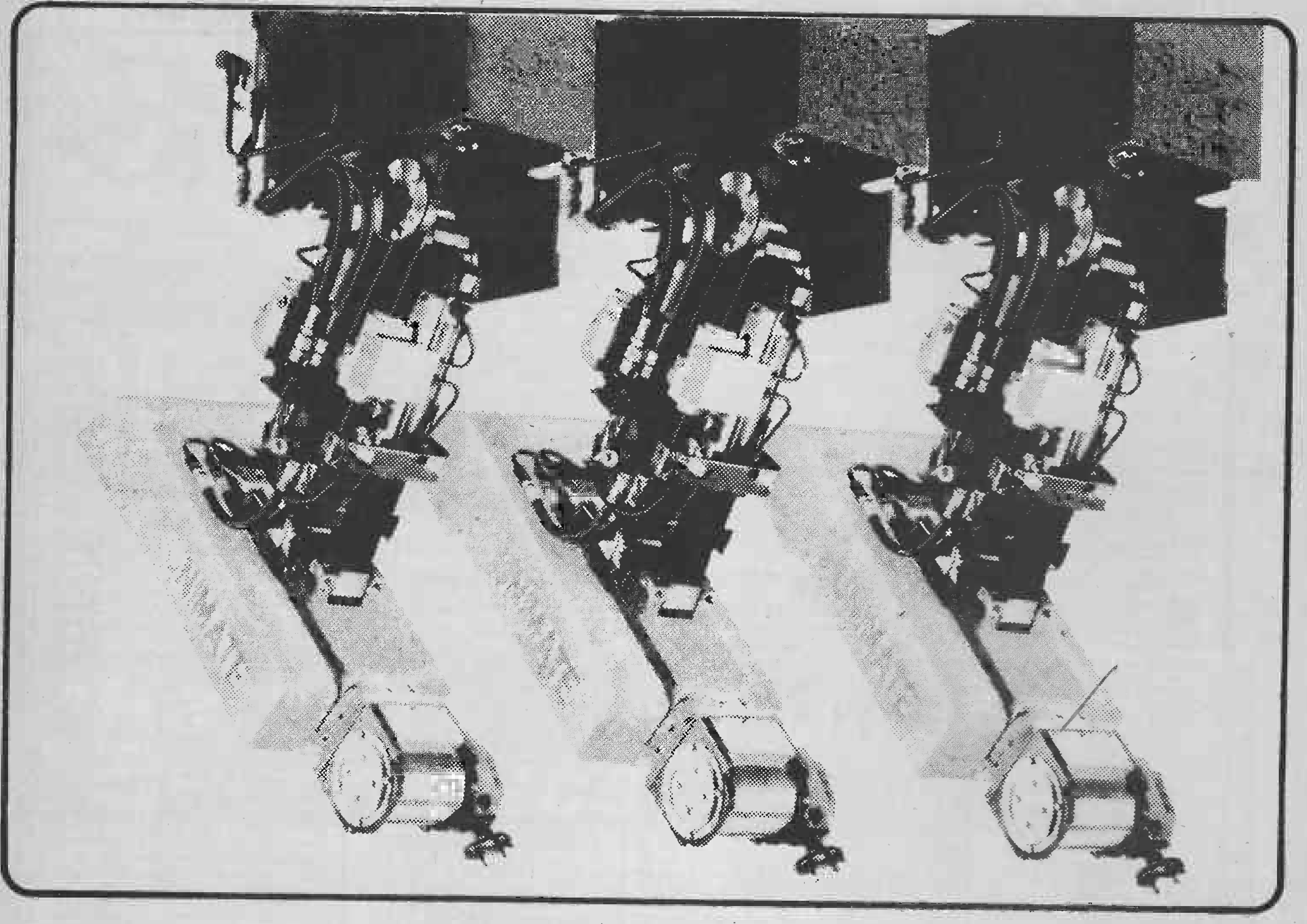


Fig. 6 A thermally-stabilised constant current generator, using an LED as a voltage reference.

INDUSTRIAL ROBOTS



ETI is doing its bit this month to further the cause of robotics with the Armdroid — but what's happening in the rest of the world? We asked Peter Matthews to compile this report for us.

The industrial robot first came to public consciousness with the television advertisement by Fiat. Since then a great deal has been said (much of it nonsense) about robotics in industry. The research project carried out by the Industrial Innovation Centre has defined some of the possibilities and limitations of robotics. The first fact that comes from the project is that the first generation of industrial robotics, which incidentally has been around for 20 years, is highly limited. The second is that there is within sight a new generation of robots which is going to offer a much more interesting industrial and even social connotation to the application of the robot.

The industrial robot has been developed as part of the automation of industry and as such is rarely found in isolation in a factory. It is, as it should be, an integrated part of the mass production line. It is the application of automation and not robots by themselves which will cause 'The Collapse of Work' which has been described by the research departments of the union known as The Association of Scientific Technical and Managerial Staff (ASTMS) under Clive Jenkins. The prophecy of the Government's 'Think Tank' that by 2010 (only 30 years' time) all our production demands will be manufactured with the help of only 20% of the country's existing work force, implying an 80% rate of unemployment in the manufacturing sector, is based on the projected use of automated factories. The study of automation and the application of robotics is essential to our industrial future.

Making Sense

Robotics is basically the imitation and use of the senses of man by machines to influence environment. Of these senses touch, sight, vision, smell, hearing (and maybe we should add mobility) are all developed to some extent. The one that has been most used in the industrial robot is a primitive form of touch. This is represented by the pick-and-place devices which plied via the emitter of Q1. Consequently, remembering that the collector and emitter currents of the bipolar transistor are virtually equal, the collector (external load) current of the circuit is almost identical to the R2 current, irrespective of the resistance value of the external load, and can be varied from 1 mA to 10 mA by RV1.

The Fig. 7 circuit, like the circuits of Figs. 3 to 6, acts as a unidirectional fixed-current generator, in which the load current is fixed and can flow only in a single direction. A totally different type of constant current generator is the voltage-controlled bilateral circuit, which can be used to convert an AC input voltage into an AC load current that is virtually independent of the value of load resistance.

A simple example of a bilateral constant current generator is shown in Fig. 8. Here, the op-amp is wired in the inverting configuration, but uses the load as its feedback resistor. The inherent action of this circuit is such that the feedback current (through the load) automatically adjusts to a value equal to that through R1 (ie $V_{IN}/R1$), irrespective of the load value, so bilateral constant current generation is automatically obtained. Note that the output voltage of this circuit is directly proportional to the load impedance.

The Fig. 8 bilateral circuit is useful in applications where the load is fully floating; if the load is not floating, but has one end tied to ground, the alternative circuit of Fig. 9 can be used as a bilateral constant current generator. Here, when the R1 to R4 resistor networks are given the indicated ratios, circuit feedback causes the output load current to be determined entirely by the values of R5 and V_{IN}, irrespective of the value of the load impedance. With the component values shown, the output current has a value of 1 mA per volt of input and the output current is in phase with the input voltage: if the value of R5 is doubled, to 1k0, the output current value will halve, to 0.5 mA/V. Note that, since the AC load current of the above circuit is effectively constant, the load voltage is directly proportional to the load impedance: the circuit can thus readily be adapted for use as an impedance-measuring piece of test gear.

High-current Generators

All of the circuits that we've looked at so far are designed to provide maximum currents of only a few milliamps, which is easily adequate for the majority of applications shown in Fig. 2. If desired, all of the circuits of Figs. 3 to 9 can be fairly easily modified to provide greatly increased current levels. The levels of the Fig. 3 to 7 circuits, for example, can be boosted by simply replacing Q1 with a Darlington power transistor and suitably altering the emitter resistor values. Similarly, the levels of the Fig. 8 and 9 circuits can be boosted by replacing the 741 device with a high-power op-amp and, in the case of Fig. 9, suitably altering the R5 value.

If you need an ultra-simple precision high-value fixed-current generator, eg for charging Ni-Cds, an easy solution is to use an LM317 three-terminal regulator IC in the configuration shown in Fig. 10. The basic action of this chip is such that the output terminal automatically adjusts to a value 1V2 greater than the voltage set on the adjust terminal: consequently, when the IC is used in the Fig. 10 configuration in which the output current flows to an external load via sensing resistor R1, the circuit acts as a constant current generator with a current value of 1.2/R1. When R1 has a value of 1R2 the circuit acts as a 1 A generator, and when R1 has a value of 120R it acts as a 10 mA generator. The circuit can be used with any input (supply) voltage in the range 10 to 35 V.

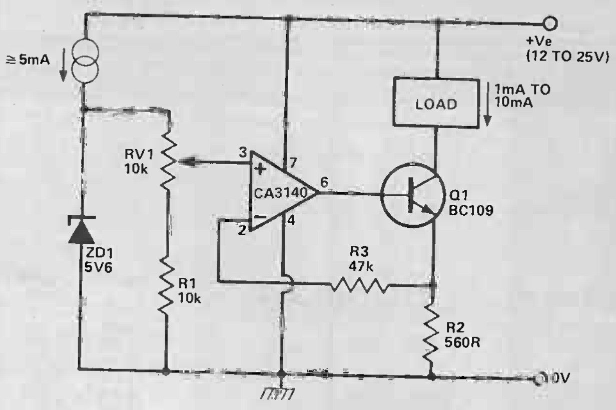


Fig. 7 A precision 1 mA — 10 mA op-amp constant current generator.

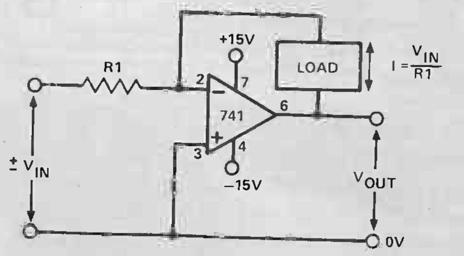


Fig. 8 A precision 1 mA — 10 mA op-amp constant current generator.

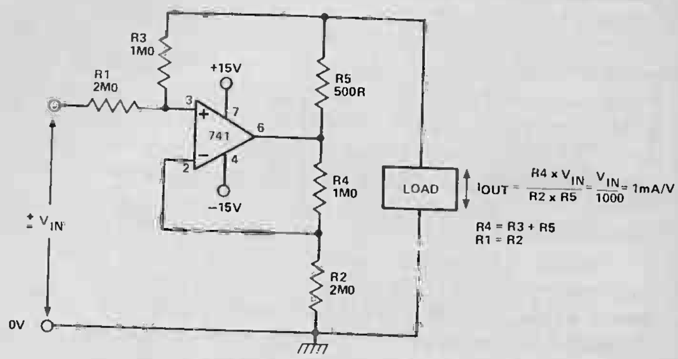


Fig. 9 This bilateral constant current generator has a grounded load. Note that the component values shown do satisfy the equations when component tolerances are taken into account.

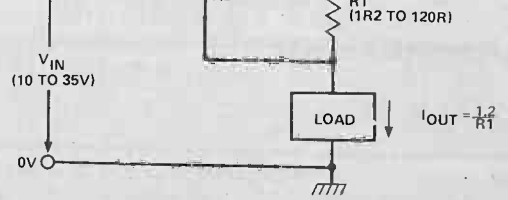


Fig. 10 A precision high-value (10 mA — 1 A) constant current generator.

ETI

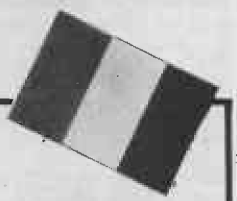
are manufactured by a number of fairly well-known companies. They perform a number of functions; welding, spray painting, subassembly, handling and even fettling metal castings, some of which can be very hot. The handling of items either too heavy or too hot for the average man is an important application; use in hostile environments such as those found in spray painting, nuclear fissionable material and underwater manipulation of, for instance, offshore oil rig equipment is also important. However, the use of devices to replace boring repetitive tasks in industry is the big market for robots, and is not an area where Britain is doing very well.

Undoubtedly the lack of use of robots is mainly the fault of management. In almost all areas of industry there has been a reasonable acceptance of robots by unions. Robots are becoming cost-effective, with costs after maintenance and depreciation being about £2.20 per hour above wage levels in the engineering industry. As wage rates increase at about 10% to 15% a year the cost comparison becomes more favourable to the robot. In one of our study cases the payback period of the robot installation was 22 months. It is generally thought that in production lines handling £3 million worth of input a year soft automation (the mixing of robots and men) is more cost-effective than total, or hard automation. The throughput of items to handle is a critical factor as long as the work piece and its manipulation is right. At present price levels a robot becomes viable at handling rates of 200,000 items per year and reaches its optimum at half a million units per year.

The world market for the industrial robot is relatively simple to define (mainly because of the lack of numbers sold), although there is some difficulty in defining what a robot is. For the purposes of this study we have defined it as being a manipulating device for industrial purposes which is programmable. This knocks out many of the inflated figures that there are for robots in some countries, in particular the one that we have seen for Japan which is estimated at 40,000 and probably includes visual/manual glove manipulators for use in clean rooms, and so on.

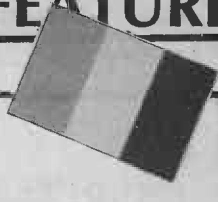
WORLD ROBOT POPULATION

	1975	1980	1985
WESTERN EUROPE			
France	30	260	770
Italy	93	400	1700
Sweden	180	1200	5000
United Kingdom	90	230	1000
West Germany	150	1100	5622
TOTAL	543	3190	14092
USA	1200	4000	16170
JAPAN	1500	7000	29900
USSR	400	150+	7000
WORLD TOTAL	3643	14340+	67162



FRANCE

The figures show that the French have less interest and investment in robots than any other country in the league. There is increasing interest at Government level but it is thought that this will not affect French management and their low level of investment. An area of development which is emphasised by the French is underwater salvage and engineering. There is, however, little research and even product involvement in France.



ITALY

The robotics industry in Italy is, surprisingly, one of the most advanced in Europe. It also has an incredibly popular public image with a following as hysterical as football. Nearly all universities and polytechnics have some R and D in robotics and private research bodies like RTM, CELM and CEMU have access to considerable Government funding. All this is backed up by SIRI (Italian Society for Industrial Robots), UCIMU (Association of Italian Machine Tool Manufacturers), symposia and exhibitions. The latest were the International Convention for Industrial Robot Technology and the 10th ISIR (Robotics Symposium), as well as a plethora of fairs and exhibitions.

All this activity is based upon solid achievement from a wide base of manufacturers who produce almost 20% of Europe's total robot output, second only to West Germany who produce almost one third. The main domestic makers are COMAU, ELFIN, OLIMAT, AISA, BASFER, CAMEL, NORDA, SLS, SPERONI, OLIVETTI, OSAI AND RAFRA with major internationals like UNIMATION, ASEA, DEA, DE VILLBISS and ISE enjoying this exciting marketing. The emphasis is mainly on export to the rest of Europe.

The Italian market may have tremendous popular appeal, but what it does not have is a broad base. Nearly all the robotic devices are in three companies, and of the 400 estimated robots installed 250 are in Fiat. Italian robot manufacturers will have to work at getting their robots into smaller companies to maintain the growth in the market and keep up with the present promising market position.

THE UNITED STATES OF AMERICA

The US Government has proposed an ambitious seven-year programme through its Automation Research Council for a support of $300 million for robotics development. This is part of the rescue operation to put America back in the forefront of the technology. The States is the home of robotics; it was said to have started in conversation over cocktails (where else?) in the 1930s, which caused Joe Engelberger to form Unimation Corporation, probably one of the most influential and largest robotic companies in the world. Unfortunately the initiative has been lost to the Japanese in much the same way that America lost the market for transistors a couple of decades ago.

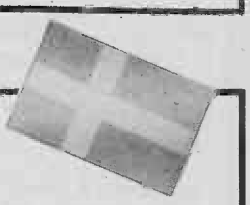
Much of the R and D into manufacturing technology has been directed by the National Science Foundation (NSF) through programmes at Stanford Research Institute, the Charles Stork Draper Laboratories and elsewhere. These projects are in collaboration with industrial companies using automated assembly in manufacture of relays, compressors, contactors, switches and other light assemblies and subassemblies. Special manipulator arms are being developed with force and tactile sensors of a sophisticated nature for use in conjunction with vision and image recognition systems, many of which have looped intelligence controls to monitor present states of work and make judgements for future actions.

The development of robots in the USA has an emphasis in automated small batch production, which has led to a surprising development in the American market. Companies such as Unimation Inc (the first main company in the field), Cincinnati Milacron Inc, Auto Place Inc, Eutectic and many others have developed a wide-based robotic industry in the material industrial handling sector. There is, however, a growing interest in robotics among hobbyists. This has led to a fast developing market in devices which do not necessarily have a direct industrial application although it will be a rich and fertile ground for experimentation by production engineers for industrial use.

The expansion of this market could have similarities to the development of the microcomputer by hobbyists and original equipment manufacturers. It may be that robotic technology will be hobbyist-led in the same way that microcomputers were — at least in the beginning.

USSR AND EASTERN EUROPE

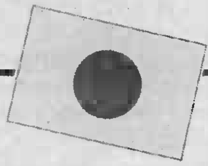
The figures contained in the table for the USSR for 1975 and 1985 are from Soviet sources. We do not believe them!! The figure for 1980 is based upon known exports to the Eastern Bloc generally, plus the home-built ones which are quite frankly anyone's guess. We have watched a number of films depicting factories which are said to be the most advanced in their field in the USSR. None of them seems to have a robotic device in them or even much in the way of automation.



SWEDEN

The Swedish robotic market is amazing with more robots per head than any other country in the world but this is in line with the principle that robots are to be found in the most affluent economies. The total existing robot population is higher than other Western European countries and although the 1985 estimate shows substantial growth in conjunction with the expected growth of GNP, it is expected that there will be a slow down due to the simple fact that the population (8.3 million people) and therefore the industrial opportunities are not as plentiful as, for instance, West Germany.

The robotic R and D effort has linked to the industrial group cellular technique first developed in Sweden and the robot products which have been developed have been very successful. The ASEA robot with the third largest sales in the world next to Unimation and Cincinatti is internationally known, as is the MHV Electrolux device. There are also Retab AB and Erkstrom Industri AB as well as SAAB who have now built a tele-operated submersible for oil rig work.



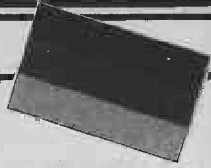
JAPAN

The Japanese Government (through its Ministry of Trade and Industry — MITI) has underwritten robotic and automation research to a greater extent than the rest of the industrialised world put together. The Robotics and the Methodology of Unmanned Manufacturing (MUM) project is the second largest Government-supported programme in the Japanese industrial sector, the first being energy generation and conservation. The Japanese robotics industry is, as a result, the largest, fastest-growing and most important sector of world robotics.

The number of devices in use in Japan (see our table) is almost equal to all those in the rest of the world, showing the tremendous advance that the Japanese have made compared with other industrialised countries, including the United States. The Japanese advantage will be maintained unless the next generation of robots has a breakthrough in sensing, image recognition and artificial intelligence. This breakthrough is unlikely but the driving force of robotics, ie the silicon chip, will probably remain American-dominated for the foreseeable future.

The Japanese are very advanced not only in product marketing but also in the application of robots. There are advanced programmes concerned with totally unmanned factories in textiles, light electronics and several other applications. These appear to be unique projects and do not compare with, for instance, Fiat's factory which is partially manned.

The Japanese are being inscrutable about their achievements and plans but there is no doubt about their being world leaders in the field. A proliferation of companies such as Mitsui, Mitsubishi, Yanmar Diesel, Hitachi Fujitsu Fanue, Kawasaki and Nassan and almost 100 others are actively working in robotics. They have signed licences with large companies in other countries but at this moment the Japanese robot has a low key image in the international market. This has always been the Japanese tradition, to wait for others to break the ground in foreign markets and then use marketing and production expertise to capture the market.



WEST GERMANY

A Government programme under the title 'The Humanisation of Life at Work' deals with the development of automated devices and robots, and is concerned with protecting the worker from hazardous environments as well as the development of technology. Additional support comes from federal funding mainly based on artificial intelligence in data processing. These projects are mainly directed through academic institutions such as the Machine Tool and Technical Management Laboratory of Aachen University and the Institute of Production Engineering and Automation at Stuggart. A much closer relationship is maintained between senior management of industry and these institutions than in most other European countries. The Germans often use senior management as part-time teaching and research staff and this has enabled this programme in particular to become very effective in the transfer of robotic technology.

West German development is well organised and aggressive and it is expected that this country will be the centre of robotics in Western Europe. This is partly because of Volkswagen's early interest in robotics for car production. Other aspects have been the interest of German management in product development in companies like AEG Telefunken, Robert Bosch, IBP Pietzsch, Iwka/Kuka, Riesa and several other companies in the field. The main reason for this is the high hourly cost of the worker in Germany compared with the UK, for example. The earnings of workers in both countries based on comparative consumer units, ie the number of hours worked to earn comparable goods, shows performances as follows:

	1970	1972	1974	1976	1978
Units					
W. Ger.	1,000	1,090	1,160	1,215	1,300
UK	1,000	1,085	1,150	1,170	1,150

The increase in cost of a German workforce gives impetus to investment in robotic devices while the dropping of worker's time/earnings in the UK holds back investment. The most important aspect of this is that the highly paid worker who presumably has high productivity amplifies the success of his country's economy. Therefore in the industrial sector nothing will succeed like success, with robotic technology acting as a constant bonus.

The Device

The industrial robot's main components are almost invariably in the following modules:

A control system and panel which is mainly used for setting up and controlling a situation. Using the system it is possible to teach a robot to pick up or position an object. It can then give a signal to other robots or automated machinery to co-operate or feed the robot. The robot could then remember the routine and be able to imitate it again and again.

An arm which is generally a piston-driven extended or jointed device representing the shoulder and elbow, for example, plus a twisting movement at the base as represented by the waist of a man.

The hand or manipulator which is potentially the most variable part of the device, using gripping actions with fingers, suction cups, magnets and so on to move and hold an object in a repetitive and distinct manner according to the shape, size, fragility and weight of the object. In addition there can be a rotational motion of the wrist as well as a joint action.

The Arm

The mechanical aspects of a robot are more important than is first realised by those other than a mechanical engineer. The most important capability of the device is to achieve 'degrees of freedom' in its parts. Another is the working space within which a robot can manipulate its allotted task and its accuracy in being able to repeat a movement exactly.

UNITED KINGDOM

The figures for robot population are disappointing although there is a great deal of interest among many manufacturers. The media has generated a good deal of this interest but the conservative British management has not taken up the media's message on robot use.

The existing population of 230 robots is low, mainly because the automotive industry is hardly using robots at all. This does not compare with the use of spraying, welding and assembly robots in the factories of almost every other automotive manufacturer in Europe. As the motor industry is the largest user of robotics, this holds down the figure for Britain. The estimate of 1,000 robots in British industry by 1985 is rather pessimistic but most estimates of British industry's performance are that way. It might be, however, that the British genius represented by the hobbyist which put us in the forefront of European microcomputing could improve our performance in robotics and automation.

There is a considerable amount of research being carried out in the academic institutions of Britain, and the research and development programmes both there and in industry are supported by the Government. There are a number of methods of obtaining support for microprocessor related devices which, of course, includes robots.

There is only one scheme which is specifically for robot related development; the grants are administered by the Science Research Council through the Rutherford and Appleton Laboratories at Didcot in Oxfordshire. The company teaching scheme offers a company involved in robotic development the facility to do its research in a university of its choice, and the costs of the research can be largely paid by the SRC. There is a budget of several million pounds to support this scheme. Some of the universities carrying out research are as follows:

University College	Robot control by microprocessor Image processing Optical sensing
Queen Mary College	Systems of micros for robot control
Edinburgh University	Assembly automation
Hull University	Sensory grippers Optical sensing
Lancaster University	Assembly automation (parts feeder)
Manchester University	Robot served N/C machines
Newcastle University	Control of articulated machinery
Nottingham University	Robot forging manipulators Dynamic modelling of robots
Birmingham University	Application of robots
Napier University	Robotic pallet transfer system
Sussex University	Picture interpretation Scene analysis
Warwick University	Mobile robot
Brunel University	Adaptive pattern recognition
Aston University	Robotic electrical drives

In addition to this there is an initiative by the Production Engineering Research Association (PERA). The Director General, Professor W.B. Heginbotham, has established a department with firm emphasis on robotics and automation which has a national reputation.

This considerable effort in academic institutions has not been reflected in industry. There is only one indigenous, well established company in the field and a couple of other newly launched companies. Nearly all other companies are American-based and are using the UK as a base to exploit the EEC market.

The users such as the AERE at Harwell, the CEGB and the National Coal Board are all experimenting with tele-operators and master-slave manipulators but the use of robots in a normal production line is rare.

The minimum degrees of freedom needed in an arm to place any object within a point in its workspace is three, although five is more usual. The arm movement can be arranged in spherical, cylindrical or Cartesian co-ordinates (see Fig. 1). The cylindrical and spherical workspaces allow a robot to work round a central pillar or base while the Cartesian configuration is designed to manipulate work on a continuous belt, for example.

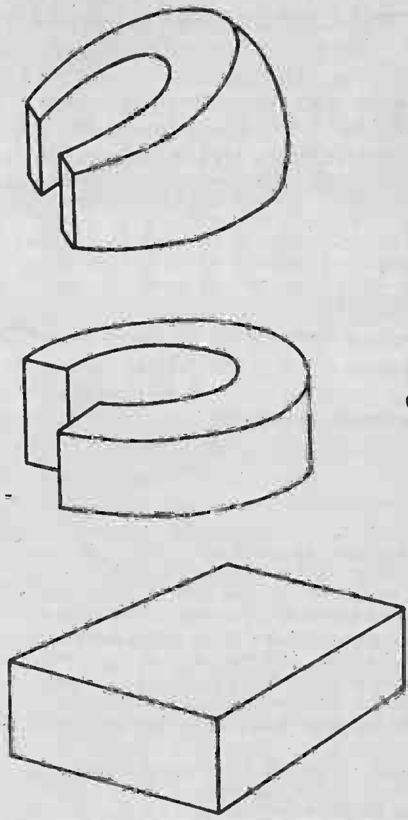


Fig.1 A robot arm can be designed to move in one of the three co-ordinate systems shown above.

Many robots have only a point-to-point control (PTP) and are unable to co-ordinate several simple movements which would create a random arc in the workspace. This is a limitation in placing a workpiece into a machine when there is limited access. Most manufacturers are tackling this problem by using a rotational 'wrist action' on the gripper. The actuators in robotic arms are either oil hydraulic or pneumatic using rotary or linear cylinders or motors. There are only a few electric motor and leadscrew drives and even fewer using gears, linkages and cams. This is because the different drives have different capabilities with a specific radius, the mechanical drive being generally used within the 18" reach, pneumatics within 30" and hydraulics beyond that.

Sensors and Feedback

The sense of touch will be a most important part of the next robot generation. It is necessary to know when a hand is touching its work piece if there is going to be any intelligence in the robot. The development of tactile sensors is not very advanced and to be truly capable of robotic handling a sensor or range of sensors needs to measure force, pressure or slippage. It is very difficult to incorporate all these into one or a few small sensors on, for example, the limited area of the tip of a gripper. However, there is now development which is leading to the sensing of these parameters becoming a reality for the next generation of robot.

Once the hand has sensed the object it must then communicate the information to the robot's 'brain', which could then activate the device in some way such as closing the hand. This technique is known as 'open loop' control. 'Closed loop' control consists of receiving the sensor's information and acting on it to cope with a changing situation. For instance, the robot may want to pick up an egg. The hand grips the egg. If it holds the egg too hard it will break. If it holds the egg too lightly it will drop. It must therefore monitor the signal to see that the grip is maintained at a particular pressure so that there is no slippage, and also check that the 'fingers' are positioned to hold the object firmly. This is a fairly simple concept, but remember that the robot is moving all the time. There are aspects of vibration, changing mechanical drives and other things to affect the power and position of the grip. This is going to require a great deal of development of sensors. If the sensing devices are not available (or only available at formidable prices) then the future of the robot is limited.

Artificial Vision

There are several ways of making a robot 'see' — ultrasonics, infra-red and so on — all of which have limitations. The only medium that has universal application possibilities is ordinary white light. There are a number of systems being researched which offer two-dimensional information, making it fairly easy for a computer to recognise the writing on a piece of paper but less easy to recognise a box, particularly if it could be seen from one of several angles. It is possible to recognise three-dimensional items using several parameters such as area of image and edge recognition, and then using this to calculate the area while identifying the centre of the object. Having done that, existing video technology is used to extract information and evaluate the workpiece. When you realise that it all needs to be done in less than half a second, that feedback is required, and that the price should not be much more than £10,000 to £12,000 it becomes obvious how complex the matter is. There is a recently developed light sensitive solid state array which could offer a solution in this area, however.

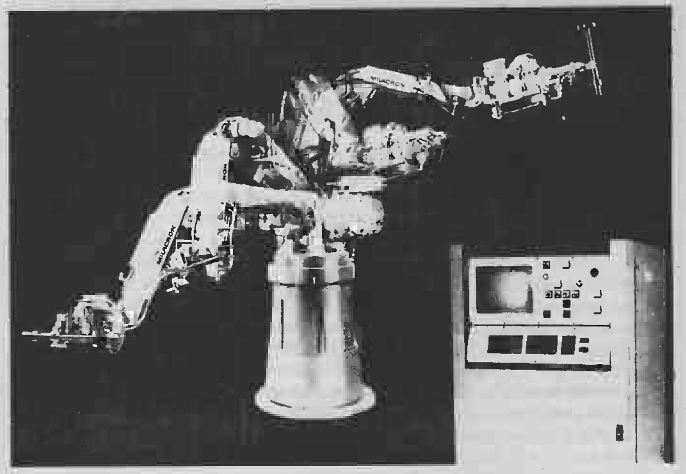
Future Technology

The second generation robot is on the way and will be here when the sensing and visual recognition aspects are solved. This will enable a factory to cope with small batch production but on a continuous production line basis. That factory will also probably be partially manned. The estimate of the arrival of the second generation robot by the American Bureau of Standards is about the middle of this decade. The market for industrial robots at that time is estimated at $200 million in America and about two thirds of that in Europe. The growth rate of both markets is estimated at 30% per annum at that time.

The artificial intelligence aspect of robots is going to provide a most important area of development; it is probably also going to be the growth area of computing in general as a 'spin-off'. The use of computers that can make comparisons and judgements with even a low level of human values is a major step forward in computer technology.

There is a considerable amount of work going on in the field of making a computer (or robot) 'think', whatever that means! Scientists have for some time been using computers to test theories of how humans think. Other R and D has been trying to achieve intelligent behaviour using other methods than human cybernetics. Whichever way they do it, the objective is to achieve Alan Turing's definition of machine intelligence. Briefly, Turing stated that if the computer was out of sight and communicating in some way with a human, then the computer was truly intelligent if the human couldn't tell the difference between it or another human.

Such a confrontation has already happened in a highly structured and limited sphere. The game of chess has had many programs written so that a computer can play with a human being; it is now possible for a computer to beat all but the masters at chess. This does not quite meet Turing's specification. Most chess programs play in their own pattern and humans have a different pattern. However, these patterns are coming closer and closer together, and we are now within sight of a computer that can not only beat a chess grandmaster but keep him guessing as to the identity of his opponent.



This time-lapse photograph shows the T^3 Computer-controlled Industrial Robot flexing its muscles. Built by Cincinatti Milacron, T^3 stands for The Tomorrow Tool — but we need such machines in industry now.

Decisions, Decisions

As already stated, this is a highly specialist application and artificial intelligence (AI) will need to be applied in limited sectors for the foreseeable future. Some of those sectors could, however, be exciting. There is, for instance, a project to simulate the behaviour of a securities analyst making decisions under conditions of uncertainty. One of the more important aspects of AI is the management and interrogation of the huge and growing data bases. At present you can search a data base by putting two, three or four keywords into a computer to see what information exists that mentions any or all of these words. This does not have the freedom of a browser in a library who can flip the pages of a book and pick information or trains of thought which are of importance to him; the closed nature of a computer data bank makes that impossible.

It is becoming possible to have a conversation with a computer for data search projects. You can define what you are looking for in general terms and even mention the peripheral items that could be of interest to you if found. Once your interest is established projects such as the Knowledge Based Management System of Stanford University can use artificial intelligence methods to search huge data bases.

These data bases will recognise that a question is being asked and be more effective than a straightforward retrieval system. They will be able to short-cut the normal condition branching techniques that are now used, re-organising the question and its implications both by what is found in the data base and by fresh input from the person during the search.

Conclusions

So what has this to do with robots? The slightly scary answer is that this technique, which Stanford University calls 'appropriate questions', enables a robot to react with an inappropriate answer to an unexpected emergency or even supply a creative input to its tasks. In fact it might decide to step outside its alloted task to undertake other operations or projects that it has decided to do.

The emergence of a robot with some kind of intelligence is something that will have effects on us in industry, education, medicine and even in the home. One of the things that robots will teach us is the amazing capability of our own bodies. It is obvious that it is difficult to teach a robot to undertake tasks some of which we are able to do without thought or effort. It is almost certain, however, that many of us will live to have social and industrial intercourse with machines that do many tasks as competently as we do.

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