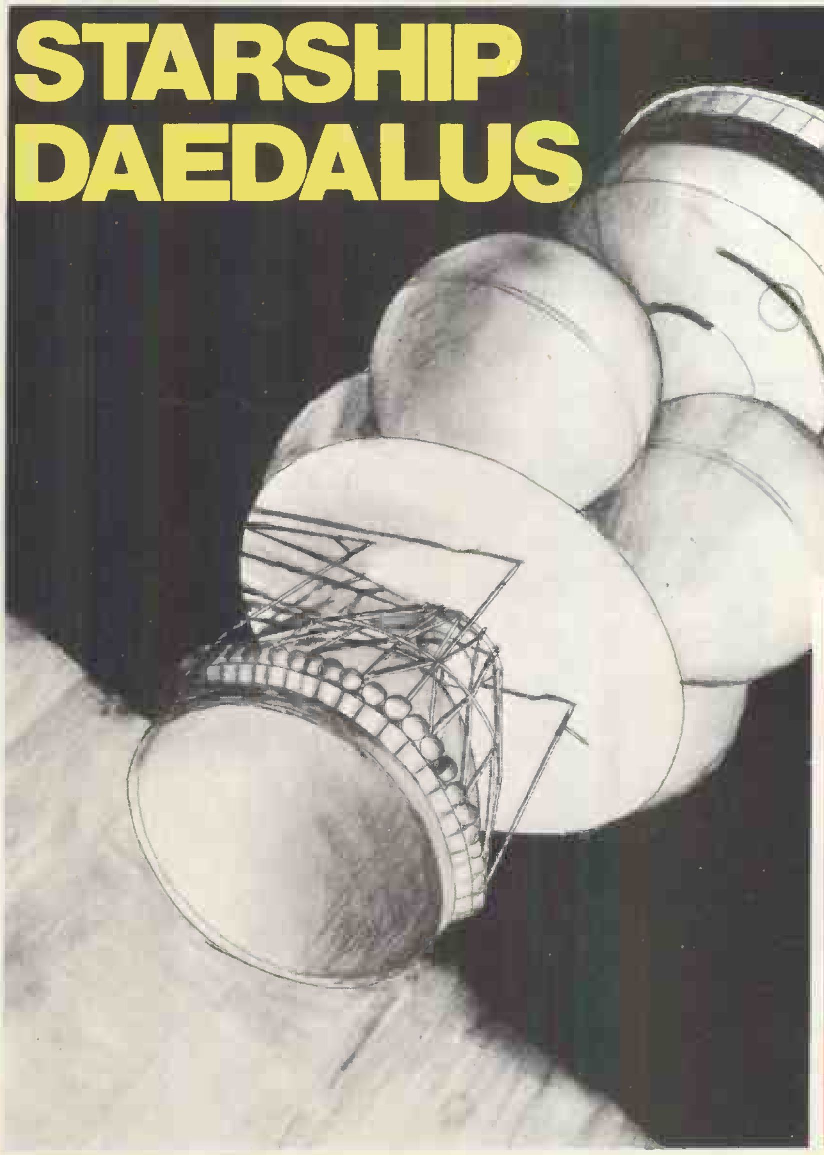
Hobby Electronics

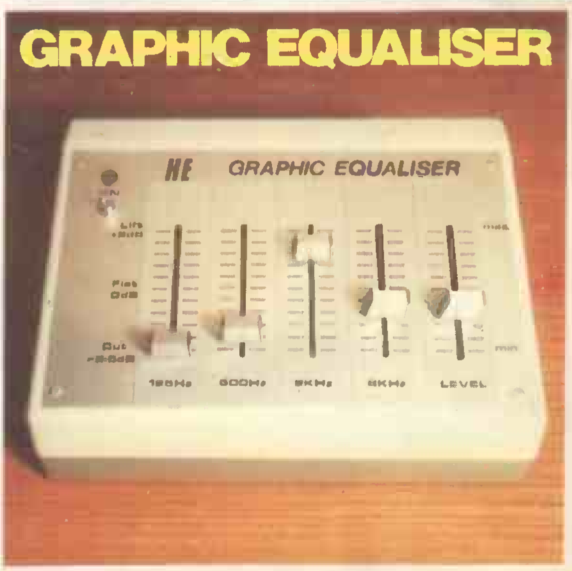
January 79

40p

STARSHIP DAEDALUS



GRAPHIC EQUALISER



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Keep your windscreen clean

Viewdata Systems
Coupling your TV to the phone

Touch Switch Project
Fingertip control

Valdemar Poulsen
The early days of tape recording

Slave Flash Trigger
Project for the photographer

Basic Programming
How it's done

Pinball Wizards
A mere bagatelle

Into Electronics
How transistors work

Hobby Electronics

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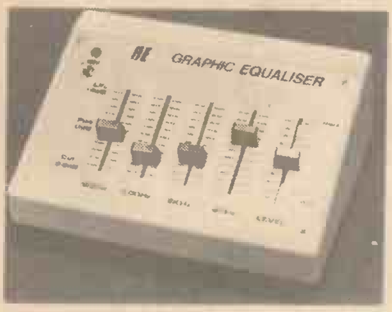

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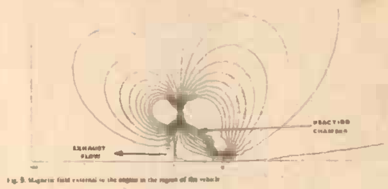

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Monitor

Raspberries To EMI!

A fruity tale this. I assure you we are *not* winding you up. Right? Read on . . . . A team of engineers has been disguising acceleration transducers, accelerometers – which convert force into electrical energy – as Raspberries. And hanging them out on bushes.

The number of comments one could make at this point is truly staggering, so one will say nothing at all.

As anyone ?) knows picking raspberries is a sticky process. When ripe they are soft and fragile and liable to squash flat at the drop of a basket. Furthermore they hide beneath leaves upon brittle and lethal canes.

Automation is called for.

Automation has arrived.

Only problem is the prototypes smashed the berries to a pulp in no time flat. Slim pickings, and this is where our men in white coats with the fake raspberries come in. Hang these little fakers out with the real berries and if the machine doesn't smash them to bits too, you know exactly what forces are being produced at the crucial parts, and can adust your machinery accordingly. Clever eh?

EMI produce the transducers, called Entran, and the Scottish Institute of Agricultural Engineering are the loonies . . . er engineers who produced the model raspberries and went out hanging them full moon?)

The actual accelerometers are only 3.6mm square, and give out 1mV for every 'g' of acceleration they are subjected to. The false fruits are wired up to both magnetic and pen-recorders to give full details of the fall of the raspberries. I didn't believe it first time either . . .)

So You Think You're Nelson?

One of the more interesting games to appear for kiddies (i.e. the entire human race—note the box photo is not an adult!) is this Computer Battleship offering.

The basic game is played in a manner similar to the old paper and pencil game — both players have a fleet cunningly (they hope) distributed across a board upon which the opposition keep dropping bombs. The idea is — of course — to annihilate the enemy while remaining untouched (hah!) yourself.

The machine does all the paperwork for you, and adds little touches like defeaning explosions if you actually HIT anything. Based upon a TMS 1000 microprocessor, Random Access Memory (RAM) is used to store the board as seen by the players, and keep track of 'shots' etc.

It is designed in Britain too (oh for a few Dreadnoughts now eh Callaghan?) and lists around £29, from patriotic toy shops everywhere as they say . . . . .

Our unintentional contributor this month was Pye Electronics Ltd, who have just landed an order for the $6.9 million Nova Scotia mobile radio system. The above photo shows the contract being signed.

News from the Electronics World

Scope For Cost Savings?

A new range of oscilloscopes is on the market, specifically aimed at the home constructor. Calscope is from the House of Scopex as it were, themselves a well-known trace making company. The Calscope 6 is designed to give good performance at a reasonable price. It would make a good instrument for anyone starting to build up a workbench at home.

Sensitivity to inputs can be switched from 50mV to 50V — which means that this is the signal required to produce a trace one inch long on the screen. Bandwidth is quoted at 6MHz — the scope responds to AC between 0 and 6 MHz, and the time base and triggering facilities are claimed as outstanding in this price range.

The Calscope 6 should cost around £160 — it can be bought from Maplin and Marshalls amongst other people.

Oracle Of The Present

Tests will begin next year on the use of Oracle — the ITV's between the lines information service — to provide programme subtitles for deaf viewers. The service could be utilised with a Palantype set-up to give 'real-time' i.e. instant, subtitles while news or sports programmes are being transmitted.

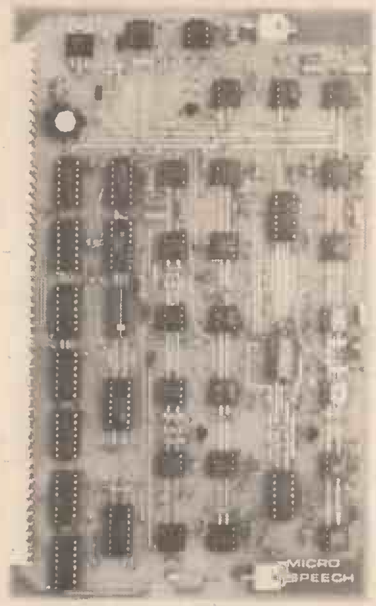
The Palantype produces the shorthand English — mispelt but readable — via a keyboard and processor. Such a system is now in use in the Houses of Parliament by Jack Ashley the deaf MP. Live transmissions will be attempted next year.

The photo shows a typical caption produced by the Palantype/Oracle system.

Technically Speaking

Computer Speech has come a long way since the Daleks first clanked their way across the TV screen. In the USA add-on devices for home systems (peripherals) can be purchased to make the small system talk in a reasonable — at least recognisable manner.

Microspeech is the first such unit to be released in the UK as far as we are aware. As you can see from the photo it is not a massive system at all. The program for the board converts typed in phonetic speech from the keyboard into sets of data which is then transmitted to the synthesiser.



There are nine parameters controlled by the unit which make possible manipulation of the frequency, amplitude and resonance of the final sound, and in this manner male speech can be reasonably imitated.

Microspeech also has an external input which enables it to produce 'talking instrument' effects from guitars and the like. The data coming out is converted back to audio form by an 8-bit digital-to-analogue (DAC) convertor using nine sample and hold circuits which can 'store' information for well over a minute.

Relatively little memory is used up by the system, and any system using BASIC is its language can be adopted to operate with Microspeech. Costronics, 13 Pield Heath Avenue, Hillingdon, Middx.

Projected Index

Now this is one of those ideas that someone should have thought of long ago, and now that someone *has* the rest of us must hang our heads in shame and wonder why we didn't . . . .

A very clever man called M. L. Scaife has compiled a complete index of all electronic projects appearing in all the revelent magazines from 1972-1977. Next year a second listing will appear which will bring the index completely up to the minute.

Some 2500 projects are listed, all with brief description where applicable, a list of how many components are used in each — and what they are — method of construction PCB. Veroboard etc, and source. Our sister magazine ETI is naturally included as are all ETI Specials.

Subjects are sensibly grouped together to make browing easy and the listings clearly and precisely done.

This truly amazing piece of work costs only £1.50 a copy from the patient M. L. Scarfe at: Central Library, Northumberland Square, North Shields, Tyne and Wear. Recommended in the strongest possible terms to all who ever intend to build a project again.

DIGEST

The Christmas laser light show was switched on in London's Oxford Street last month, despite attempts by the Westminster Council to ban it for safety reasons.

French viewdata engineers have protested on 'technical grounds' against the British viewdata character set (which includes £ and $ signs). This is against a background of prospective international agreement on standardisation for viewdata symbols.

Researchers at London's university College are working on the interpretation of the output from acoustic microscopes. These systems use acoustic signals at 3MHz to find a 'map' of the viscosity of plant and animal cells.

The Science Research Council is putting up £1.6M to set up IC manufacturing facilities at the Rutherford Laboratory and four universities.

At a meeting of the Optical Society of America recently, it was suggested that a laser-carrying satellite could provide detailed information on worldwide wind velocities every 12 hours.

ERRATA: —

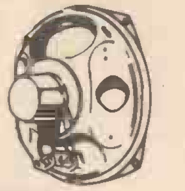
Confession time again. Below are the errors which crept into our projects in our last issue. We apologise to our readers for these and will wear our sackcloth and ashes with abashed dignity.

LED DICE: The pinout given for the LED's is not, unfortunately, universal we discover. When buying LEDs check with the supplier as to polarity. Also a 6V or 12V rated tartalum capacitor can be employed for C4, instead of the 35V type specified with a considerable saving in cost!

LIGHT BEAM TELEPHONE: The battery, B1 on the circuit diagram, should be a 12V type.
SHORT CIRCUITS: The item entitled One-Transistor Amplifier in particular. Referring to the circuit, the resistor from the function of R1 and R2 has a value of 100k, and the current flowing through it is 10 uA.

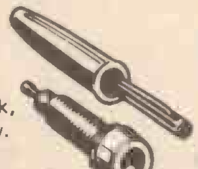
STEVENSON
Electronic Components

LOUDSPEAKERS



56mm dia. 8ohms	70p
64mm dia 8 ohms	75p
64mm dia. 64 ohms	75p
70mm dia. 8 ohms	100p
70mm dia. 80 ohms	110p

PLUGS AND SOCKETS



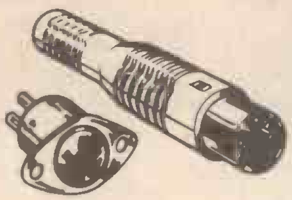
1mm plugs and sockets suitable for low voltage circuits. Available in red or black. Plugs 6p each. Sockets 7p each.

4mm plugs and sockets. Available in black, blue, green, brown, red, white and yellow. Plugs 11p each. Sockets 12p each.

Jack plugs and sockets

	unscreened plug	screened plug	socket
2.5mm	9p	13p	7p
3.5mm	9p	14p	8p
Standard	16p	30p	15p
Stereo	23p	36p	18p

Din plugs and sockets



	plug	socket
2 pin speaker	7p	7p
3 pin	11p	9p
5 pin 180°	11p	10p
5 pin 240°	13p	10p

CABLES

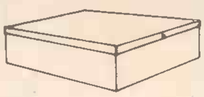
Connecting wire
Available in packs of 8 metres (one metre of each colour) or packs of forty metres (five metres each colour).

	single	standard
Eight Metre pack	16p	16p
Forty Metre pack	76p	70p

Screened Cable
Single screened 8p
twin individually screened 11p

Ribbon cable
10 way 58p metre
20 way 100p metre

ALUMINIUM BOXES



Boxes complete with lid and screws.

	Length	width	height	
AL1	3	2	1	48p
AL2	4	3	1½	58p
AL3	4	3	2	65p
AL4	6	4	2	70p
AL5	6	4	3	85p
AL6	8	6	2	116p

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				ZTX300	16p
				2N697	12p
				3N1302	38p
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AC128	16p	BCY72	14p	2N2907	22p
AC176	18p	BD131	35p	2N3053	18p
AD161	38p	BD132	35p	2N3055	50p
AD162	38p	BD135	38p	2N3442	135p
BC107	8p	BD139	35p	2N3702	8p
BC108	8p	BD140	35p	2N3704	8p
BC109	8p	BF244B	36p	2N3705	9p
BC147	7p	BFY50	15p	2N3706	9p
BC148	7p	BFY51	15p	2N3707	9p
BC149	8p	BFY52	15p	2N3708	8p
BC158	9p	MJ2955	98p	2N3819	22p
BC177	14p	MPSA06	20p	2N3904	8p
BC178	14p	MPSA56	20p	2N3905	8p
BC179	14p	TIP29C	60p	2N3906	8p
BC182	10p	TIP30C	70p	2N4058	12p
BC182L	10p	TIP31C	65p	2N5457	32p
BC184	10p	TIP32C	80p	2N5458	30p
BC184L	10p	ZTX107	14p	2N5459	32p
BC212	10p	ZTX108	14p	2N5777	50p
BC212L	10p				
BC214	10p				
BC214	10p				
BC477	19p				
BC478	19p				
BC479	19p				
BC548	10p				
BCY70	14p				

DIODES

1N914	4p	1N4148	3p
1N4001	4p	1N5401	13p
1N4002	4p	1N5402	15p
1N4004	5p	1N5404	16p
1N4006	6p	1N5406	18p

BZY88 series 2V7 to 33V 8p each.

74LS

		LS95	65p
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		LS125	40p
		LS126	40p
LS00	16p	LS132	60p
LS01	16p	LS136	36p
LS02	16p	LS138	54p
LS03	16p	LS139	50p
LS04	16p	LS151	50p
LS08	16p	LS153	50p
LS10	16p	LS155	80p
LS13	30p	LS156	80p
LS14	70p	LS157	45p
LS20	16p	LS164	90p
LS30	16p	LS174	60p
LS32	24p	LS175	60p
LS37	26p	LS190	80p
LS40	22p	LS192	70p
LS42	53p	LS193	70p
LS47	70p	LS196	80p
LS48	48p	LS251	60p
LS54	16p	LS257	55p
LS73	29p	LS258	55p
LS74	29p	LS266	40p
LS75	44p	LS283	60p
LS76	35p	LS290	55p
LS78	35p	LS365	45p
LS83	60p	LS366	45p
LS85	70p	LS367	45p
LS86	33p	LS368	45p
LS90	45p	LS386	35p
LS93	45p	LS670	180p

LINEAR

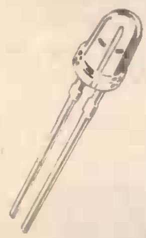
A SELECTION ONLY! DETAILS IN CATALOGUE.

709	25p	LM324	50p	NE556	60p
741	22p	LM339	50p	NE565	120p
747	50p	LM380	75p	NE567	170p
748	30p	LM382	120p	SN76003	200p
CA3046	55p	LM1830	150p	SN76013	140p
CA3080	70p	LM3900	50p	SN76023	140p
CA3130	90p	LM3909	60p	SN76033	200p
CA3140	70p	MC1496	60p	TBA800	70p
LM301AN	28p	MC1458	35p	TDA1022	650p
LM318N	125p	NE555	25p	ZN414	75p

TTL

		7493	34p
		7494	52p
		7495	52p
		7496	50p
7400	12p	74121	25p
7401	12p	74122	33p
7402	12p	74123	40p
7404	12p	74125	35p
7408	14p	74126	35p
7410	12p	74132	50p
7413	25p	74141	56p
7414	48p	74148	90p
7420	12p	74150	70p
7427	24p	74151	50p
7430	12p	74156	52p
7442	43p	74157	52p
7447	55p	74164	70p
7448	58p	74165	70p
7454	14p	74170	125p
7473	25p	74174	68p
7474	25p	74177	58p
7475	32p	74190	72p
7476	28p	74191	72p
7485	70p	74192	64p
7489	145p	74193	64p
7490	32p	74196	55p
7492	35p	74197	55p

OPTO



LEDs	0.125in.	0.2in.	
Red	TIL209	TIL220	9p
Green	TIL211	TIL221	13p
Yellow	TIL213	TIL223	13p
Clips	3p	3p	

DISPLAYS

DL704	0.3 in CC	130p
DL707	0.3 in CA	130p
FND500	0.5 in CC	100p

CMOS

FULL DETAILS IN CATALOGUE

		4029	60p
		4040	68p
4001	15p	4042	54p
4002	15p	4046	100p
4007	15p	4049	28p
4011	15p	4050	28p
4013	35p	4066	40p
4015	60p	4068	20p
4016	35p	4069	16p
4017	55p	4071	16p
4018	65p	4075	16p
4023	15p	4093	48p
4024	45p	4510	70p
4026	95p	4511	70p
4027	35p	4518	70p
4028	52p	4520	65p

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4.7, 6.8, 10uF @ 25V	13p
22 @ 16V, 47 @ 6V, 100 @ 3V	16p

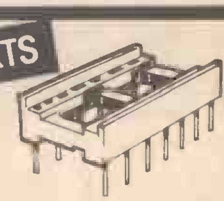
MYLAR FILM

0.001, 0.01, 0.022, 0.033, 0.047	3p
0.068, 0.1	4p

RADIAL LEAD ELECTROLYTIC

63V	0.47	1.0	2.2	4.7	10	5p
			22	33	47	7p
	100					13p
			220			20p
25V	10	22	33	47		5p
	100					8p
		220				10p
				470		15p
	1000					23p
10V		220				5p
				470		9p
	1000					13p
		2200				23p

SKTS



Low profile by Texas

8 pin	10p	24 pin	24p
14 pin	12p	28 pin	28p
16 pin	13p	40 pin	40p

Soldercon pins: 100: 50p
1000: 370p

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Graphic Equaliser

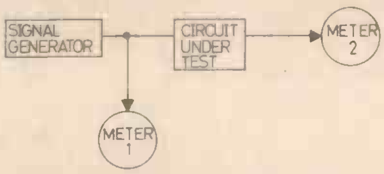
Another project for those interested in audio work, this will make an excellent companion to the HE Mixer in last month's issue.

A GRAPHIC WHAT, you ask? A graphic equaliser is a complex form of tone control. It can be used to smooth out the frequency response of a Hi-Fi, or as a guitar effects unit. In fact, it will prove useful in any audio application.

FREQUENCY RESPONSE

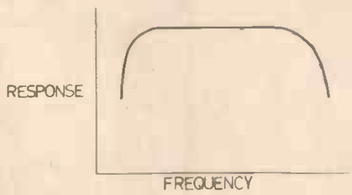
In order to explain how the equaliser works, first a quick explanation of the term 'frequency response'.

Say we take a circuit (any circuit) and set it up like this:



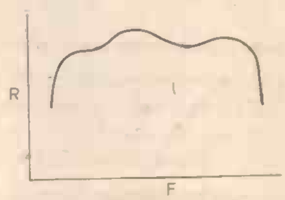
The ratio of the reading of meter 1 to the reading of meter 2 is called the response of the circuit. If the frequency of the signal used is varied, the response varies — because the circuit behaves differently when fed with different frequencies. A graph of response against frequency is called — you guessed it — the frequency response.

The frequency response of a typical amplifier looks something like this:



The central section is fairly 'flat' but when it comes to the very high or very low frequencies it loses power — the reading on meter 2 drops and so the response becomes less.

Once the signal from the amplifier has been passed to the speaker (which has its own frequency response as well), the response of the system overall may look like this:

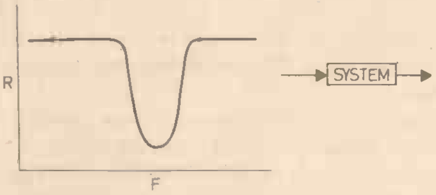


This will be further modified by the response of the room that the Hi-Fi is in — even your curtains have a response curve! By the time the signal finally reaches your ears the overall response will be fairly well mangled.

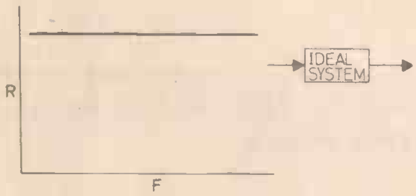
An equaliser is a device for correcting (equalising) the frequency response of a system.

IRONING OUT THE BUMPS

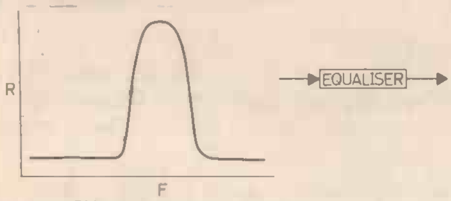
Say, for instance, that the frequency response looked like this when it reached you (rather exaggerated, perhaps!):



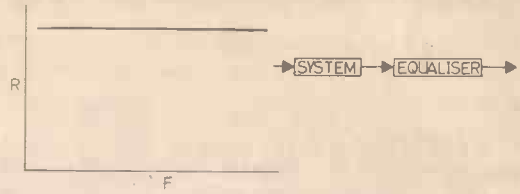
and we would of course like it to look like this:



If we have a device (called an equaliser) which has a response like this (the opposite to the one we wish to correct):



and we put it in series with the system, the overall response would be the sum of the two responses:



In this way we can take any system, be it a microphone, a telephone line or a Hi-Fi system, and 'iron out' the variations in its response.

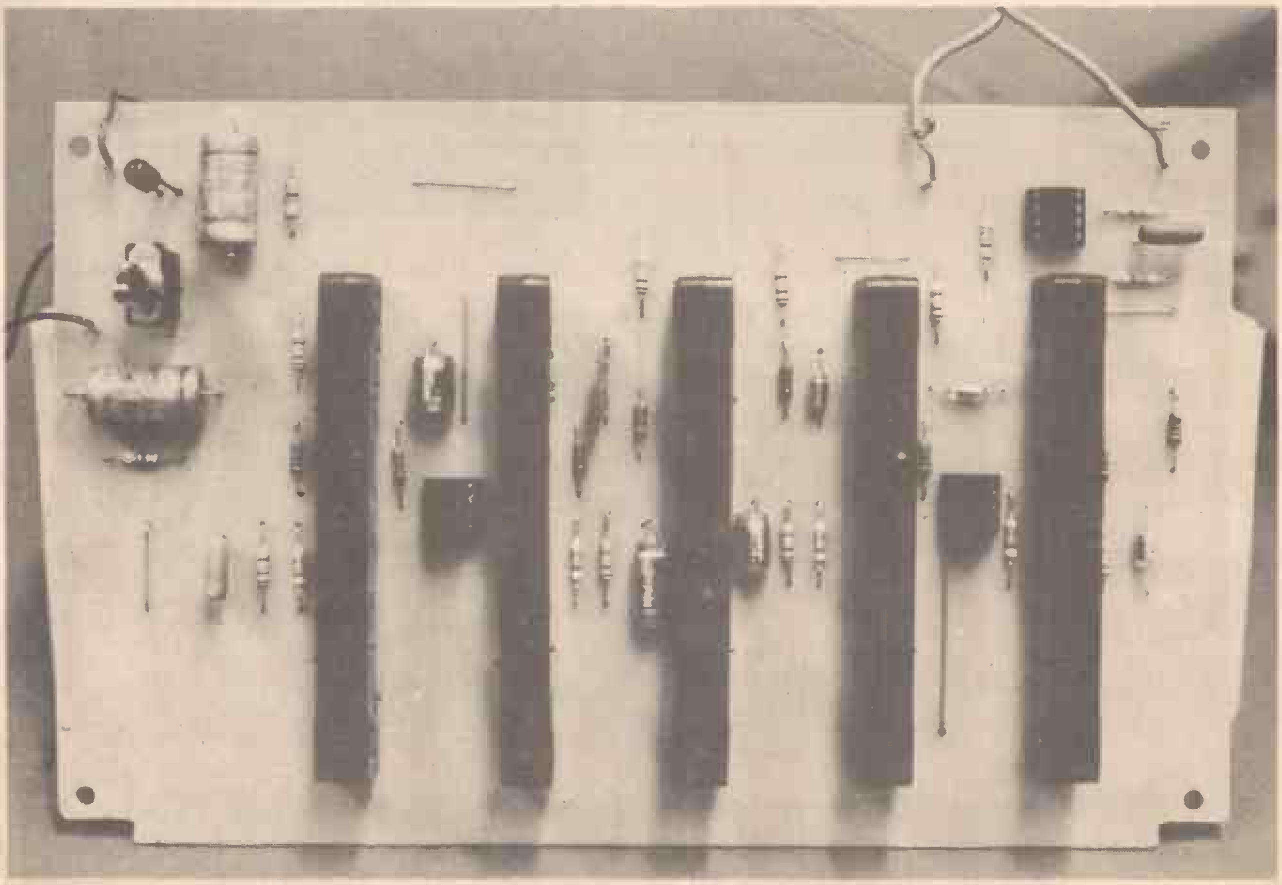
There are two ways of finding the right equaliser response — directly or indirectly. The indirect method involves measuring the system curve and then designing an equaliser to fit it. This is fine if you are prepared to do all the sums and build a complete new unit for every application you run across.

The direct method is to build a device which has a variable response, connect it to the system and then vary the equaliser curve to give the desired effect.

The way this is usually done is to build a unit which will split the incoming signal into a number of frequency bands and then remix these in the desired ratios. This will give the device a number of plateaux on its response curve, all of which can be moved up or down independently of each other to give an approximation to the desired shape.

An equaliser of this type is called a graphic equaliser if the controls which determine the positions of the plateaux are of the 'slider' type. The positions of the

The board. Note the IC sockets and the electrolytic capacitor orientation.



control knobs will then look like the frequency response graph of the equaliser.

The amount by which the HE Equaliser can vary the level of a particular frequency band is about 8 dB boost or cut.

The dB is a measure of voltage ratio — it measures the response in terms of the output divided by the input.

8 dB should prove sufficient for most applications.

CONSTRUCTION

The equaliser should be fairly easy to build — the only difficult part being the front panel.

Take care to mount all the electrolytic capacitors, the ICs and the LED the right way round and you should be okay. We suggest you use IC sockets to be on the safe side — these solder directly onto the board and the ICs plug into them.

Don't forget the wire links on the PCB, by the way!

We stuck the batteries on with double-sided adhesive pads (useful things!). The PCB will mount into the case we've specified with the aid of some plastic 'spacers' to increase the distance between the front panel and the board.

After constructing the board, use the positions of the potentiometers, the LED and the switch to mark out the front panel.

The holes for the LED and switch can be drilled simply enough. The holes for the potentiometers can be fairly sloppy as we're using stick-on bezels which go onto the front panel and have cut-outs the right shape for the shafts to run in. Make sure there are no burrs sticking out of the front panel.

Parts List

RESISTORS (all ¼W, 5% tolerance)

R1, 2	47k
R3, 4, 8, 9, 13, 14, 18, 19	18k
R5, 6, 10, 11, 15, 16, 20, 21	1M
R7, 12, 17, 22, 23	47k
R24, 25	4k7

CAPACITORS (all polyester unless otherwise specified)

C1	0u1	
C2	33n	
C3	3n3	
C4	8n2	
C5	820p	
C6	2n2	
C7	220p	
C8	470p	
C9	47p	
C10, 11	220u	16V electrolytic

SEMICONDUCTORS

IC1, 2, 3	1458
LED1	any red LED

POTENTIOMETERS

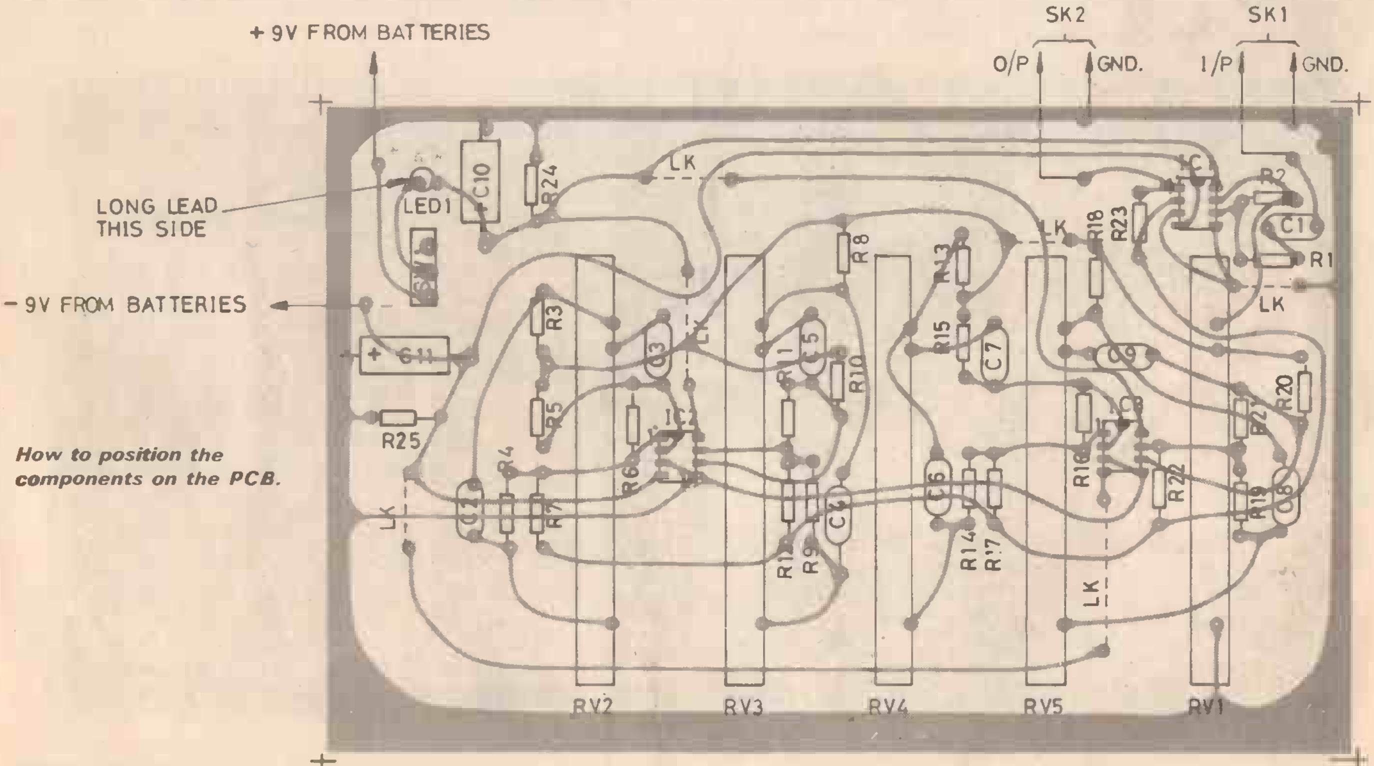
RV1	10k logarithmic slider
RV2, 3, 4, 5	100k linear slider

MISCELLANEOUS

One panel-mounting switch (single pole, double throw); Two sockets (see text); Three 8-pin IC sockets; Vero case; PCB; 2 off PP3 batteries with clips.

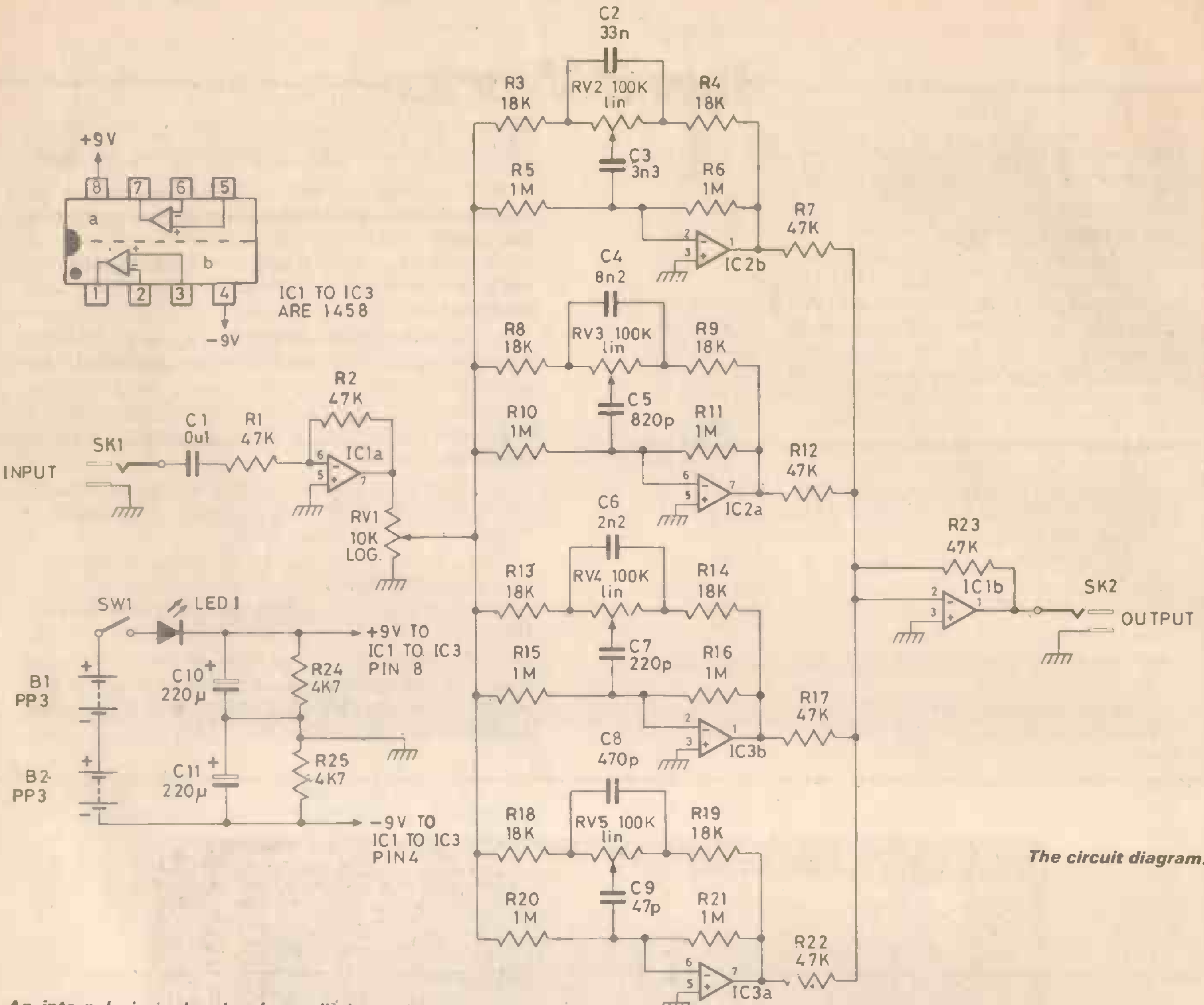
All of the components in this project should be available from decent stockists. The slider potentiometers we used ar RS stereo types — we've only used one channel of each. The box is from the Vero range — in fact it's the same one we used for the mixer last month.

Approximate cost: £20



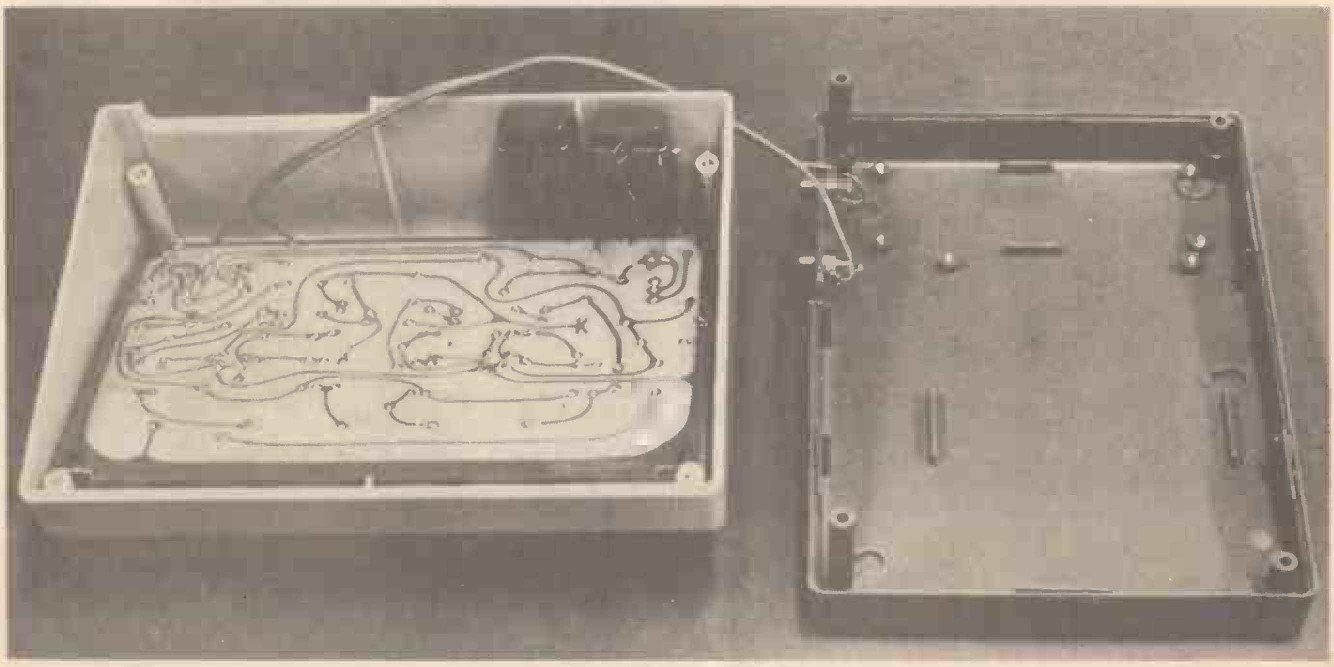
How to position the components on the PCB.

LK = WIRE LINK



The circuit diagram.

An internal view showing how all the main components go together.



How it Works

The input to the unit is decoupled (to remove DC) by C1 and fed into IC1a, which acts as a 'buffer' — it can be driven from a source with a very small current capability, which would be incapable of providing enough input otherwise. The output of IC1a is sufficiently powerful, however, to drive the rest of the circuit.

The output from IC1a is fed (via RV1, which controls the overall volume) to the four filter stages (ICs 2b, 2a, 3b, and 3a). These each respond to a particular frequency band and their output levels are adjustable by means of RVs, 2, 3, 4 and 5. The outputs from these filters are summed by IC1b, which acts as a virtual earth mixer — the "—" input is held at zero volts by virtue of the feedback through R23 and so the output of the unit is the inverted sum of the voltages at the outputs of the filter ICs.

The individual filters work as follows: the feedback effects will cause the output to be equal to the input times ($-Z_f/Z_{in}$), where Z_f is the impedance from the output to the "—" input and Z_{in} is the impedance from the input to the "—" input.

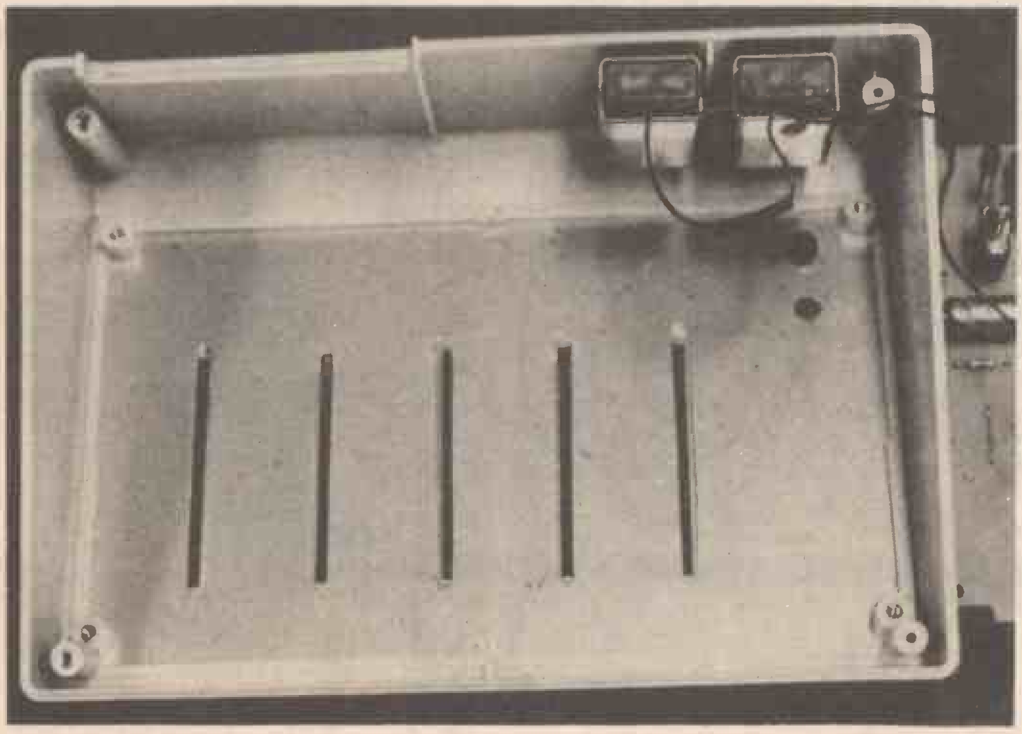
This is the same situation as in the buffer — IC1a. In its case, $Z_{in} = 47k$ and $Z_f = 47k$. Thus the output is —1 times the input (i.e. the signal will be 'inverted' — it will *sound* the same, though).

In the filters, if the variable resistor is at mid-position, with an equal resistance between the wiper and either end, then $Z_{in} = Z_f$. Thus each filter will pass all frequencies with output = —1 × input when the slider is in mid-position.

When the slider is at the left-hand end on the circuit diagram, however, the impedances of the capacitors will cause the gain of the filter (gain = output/input) to vary with frequency in such a way as to increase the gain in a particular frequency band.

Similarly, moving the slider to the other end of the potentiometer will cause the same band of frequencies to be attenuated.

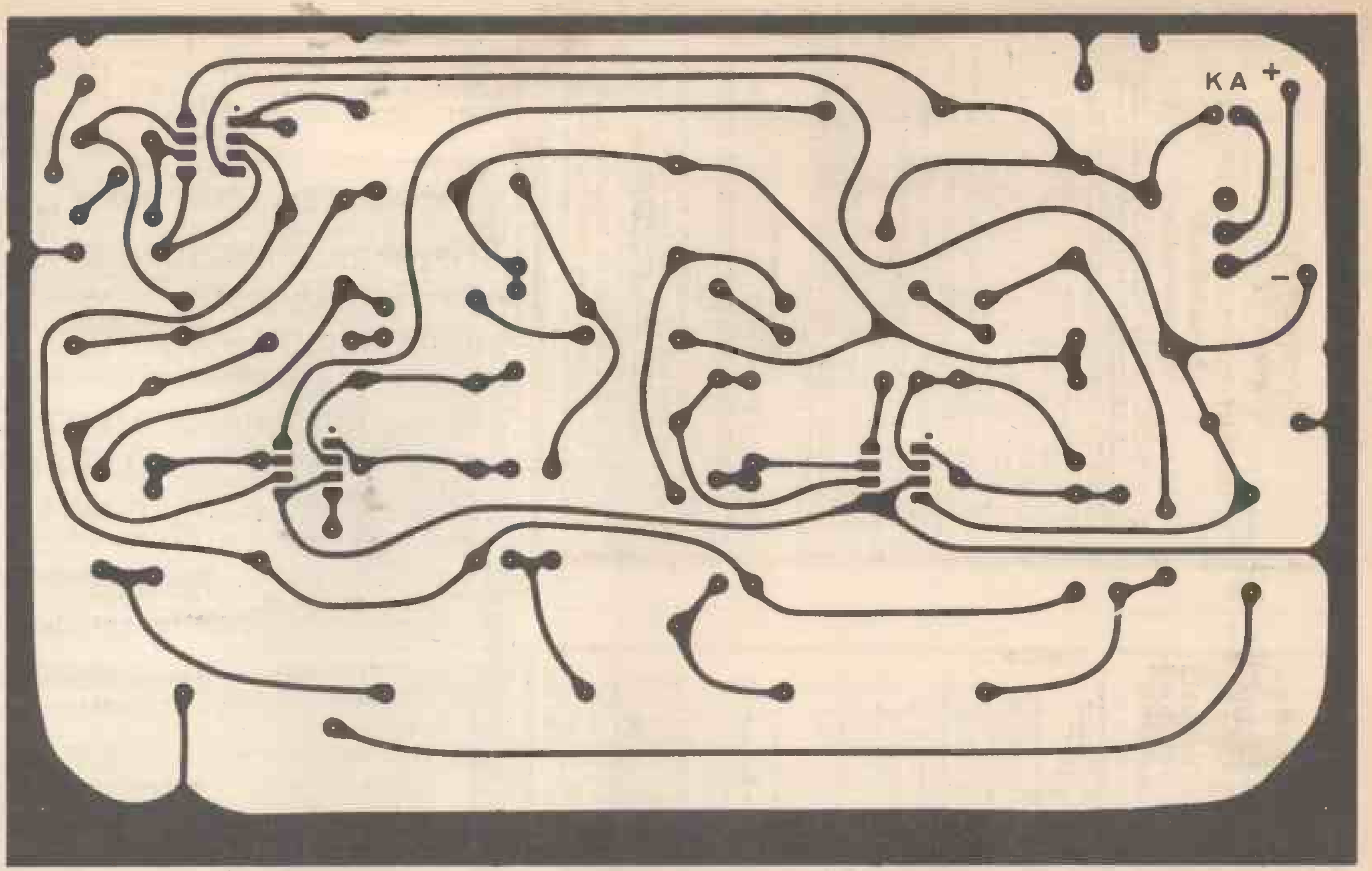
Thus, by moving the slider from one end to the other, the response of the filter to its particular frequency band can be changed. As the output is the sum of all the filters' outputs, the overall frequency response of the unit will follow the shape the sliders make on the front panel – pushing one of them up will boost that particular frequency band.



The back of the front panel, showing the method of connecting the batteries — with the positive terminal of one connected to the negative terminal of the other. The slightly oversized potentiometer holes can also be seen.

We used phono sockets for the input and output but there's no reason why any sockets suitable for audio signals shouldn't be used if there's room.

Having built the unit, you're now ready to use it — but how?



The printed circuit board foil pattern — as viewed from the opposite side of the board to the one the components are mounted on.

EFFECTS UNIT

The input to the equaliser should be of a fairly high level — a microphone or guitar will not do. The output of the HE Mixer would be ideal, however!

Any audio output from a device which either a) requires batteries or b) plugs into the mains should be of a high enough level.

The output from the unit should go wherever the input was going before you built the unit! This could be a PA amplifier or your Hi-Fi or tape recorder.

The sort of effects you can get from this unit are: a telephone line (with the 500Hz slider up and the rest down), a shout from a long way off (with the 8kHz slider up and the rest down), or just a simple bass boost (with the sliders forming a diagonal up at the left).

Of course, by trying the unit yourself, you can adapt it to new applications or use it in conjunction with other effects units to provide a versatile addition to your effects equipment.

HI-FI SMOOTHER

Naturally, if your Hi-Fi is stereo, you'll need two of these units, but that shouldn't prove too much of a stumbling block to a hardened Hi-Fi perfectionist!

The unit should go between your pre-amplifier and power amplifier. The simplest way to adjust it is by ear, although it's not the most accurate method. You can reduce that annoying 'boominess' your speakers have always had, or boost the bass and treble and cut the middle from the signal from your tape recorder.

If you want to do it properly, however, you will need a signal generator (see the kit review in this issue!), a good microphone and an oscilloscope, with the equaliser connected as described above. Assuming the microphone's response is absolutely 'flat' (i.e. the same at all frequencies), you should be able to measure the output of your Hi-Fi at a particular frequency by measuring the signal level with the oscilloscope. Merely adjust the equaliser until the system's response to all frequencies is the same. Make sure the amplifier's tone controls are in mid-position.

This sounds simple enough — but remember that the room's response will change if you move the sofa or open the curtains — so first adjust these to their normal position. Also remember the neighbours! **HE**

Valdemar Poulsen

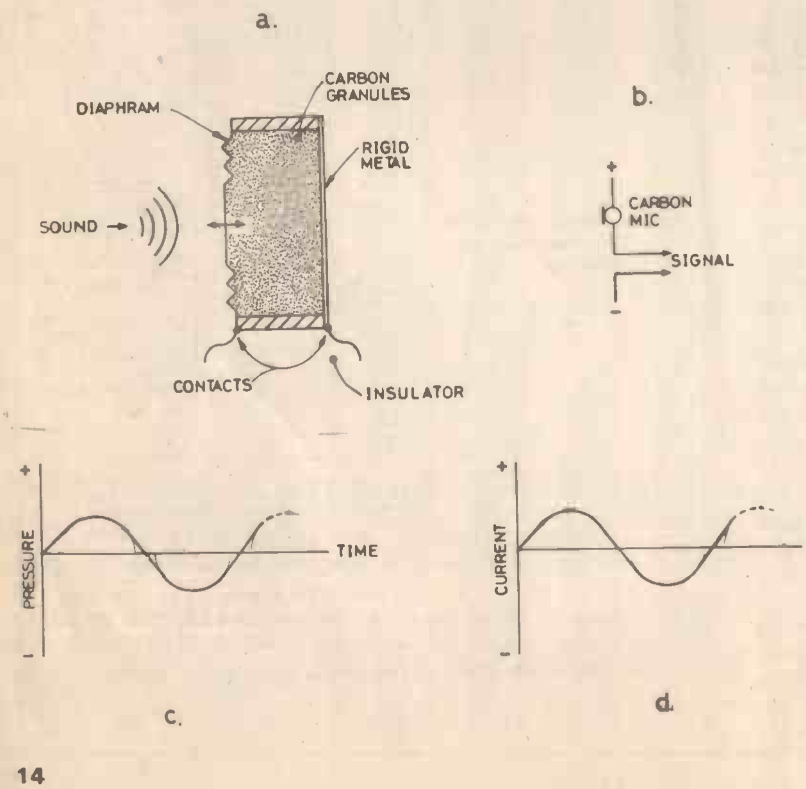
Although he receives rare credit, Poulsen did much to bring about the tape recorder. We take a look at his experiments carried out at the turn of the century.

ONE OF THE ODDITIES in the history of science is the names that we remember in connection with various inventions. Practically everyone, for example, associates television with Baird, despite the fact that Baird's system was out of date before it was built and had no connection with the TV system which we use. Anyone heard of Campbell Swinton, of Zwrykin, or Blumlein? These were some, just a few, of the people who really made the modern TV system, yet only a few professionals know these names.

Valdemar Poulsen is another of these less well known names which deserve to be better known. What he invented was the tape recorder, a device which is in use pretty extensively all over the world, yet for many years his work was unknown, his invention a curiosity that was almost forgotten. Poulsen, like many 19th century inventors, was fascinated by electromagnetism, a topic which was well understood by the second half of the century in theory, if not in practice. The basic principles which Poulsen made use of were:

1. A current passed through a coil of wire causes the coil to become a magnet. If the current is an alternating current, the magnetism also is alternating.
2. Some materials, called hard magnetic materials, can be magnetised by being held near a magnet, and will remain magnetised when the magnet is taken away.
3. When a magnet is moved past a coil of wire, a voltage is inducted in the wire.

All of these principles had been known in the 1840's, but there's always a gap between discovering a principle and making use of it. Before anyone could think about tape-recording, a method of converting sound-waves into electrical signals had to be invented, and this was achieved by Alexander Graham Bell in 1876; his invention was the telephone. Bell's telephone used a carbon microphone, which makes use of grains of rough carbon held between a conducting plate and a thin metal diaphragm. The two metal plates linked by the carbon grains form part of a circuit in which most of the resistance is the resistance of the carbon grains. When these grains are compressed by pressing the diaphragm, the resistance of the carbon decreases, and more current can flow. When the diaphragm is pulled out, the grains loosen, the resistance increases, and the current de-



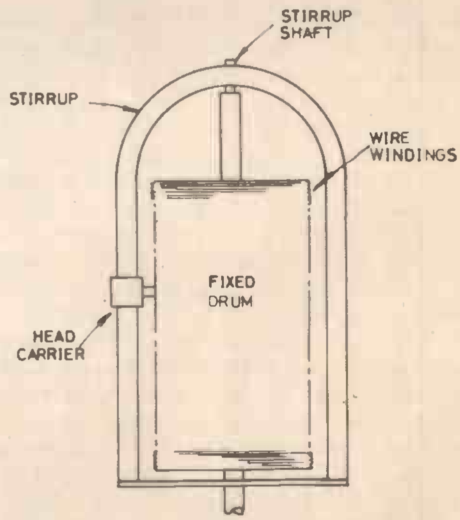


Fig. 1. (left) Carbon-granule microphone (a) Cross-section. (b) Connection in circuit. (c) Sound wave, (d) Corresponding current wave.

Fig. 2. (above) Telegraphone diagram — simplified.

creases. The effect of a sound wave on the diaphragm is alternately to compress and pull out the diaphragm, so that the sound wave is converted into a wave of current (Fig.1). The invention of the carbon-granule microphone was the last link in the chain which was needed before Poulsen could devise a working magnetic recorder. The carbon granule microphone is nowadays almost a museum-piece and is being replaced even for telephone use by modern electret types.

EARLY DAYS

We know very little of what Poulsen was aiming at, or about his early experiments. What we do know with certainty is that he filed a patent in 1898 for a device which seems like an automatic telephone answering machine — well ahead of its time. Almost every feature of tape recording is present in this machine — except for the tape. The technology for manufacturing tape took a lot longer to develop and Poulsen used steel wire, a material which was still used in dictaphones until quite recently.

Poulsen called his invention the Telegraphone, and Fig.2 shows a diagram taken from the original patent. Let's take a look at how he claimed it worked. Unlike the modern machine in which the tape is reeled past the recording or replay heads, Poulsen's machine used a head which was moved along the wire. This was done by winding the steel wire onto a drum, and revolving the head around the drum. The head was held on a stirrup-shaped arm, which revolved around the drum, and the head assembly was free to slide up and down one arm of the stirrup. Why such a peculiar arrangement? Well, Poulsen seems to have realised that to get enough recorded signal on steel wire he would have to use thick wire and that made it impossible to wind the wire from one reel to another. The drum idea looks very similar in mechanical detail to another wonder of the age, Edison's Phonograph, the original wax-cylinder gramophone which was by then appearing in homes all over the western world.

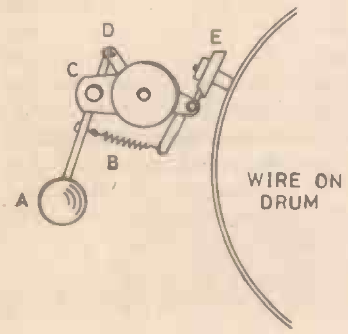


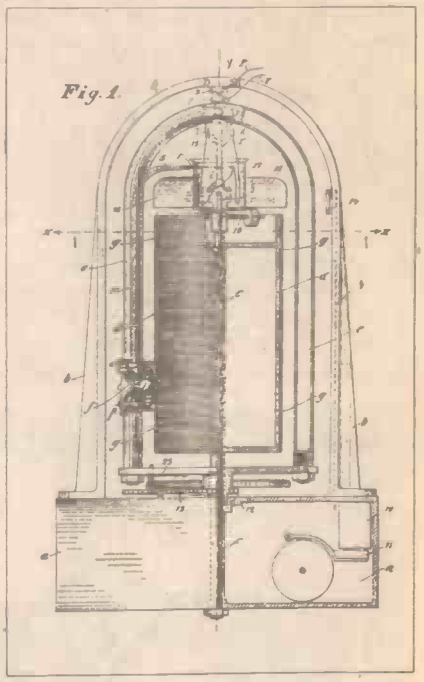
Fig 3. Detail of head construction of Telegraphone.

The mechanical action of the Telephone is rather ingenious (Fig.3.). When the stirrup starts to revolve, the weight A tries to keep moving in a straight line (the action that used to be called centrifugal force until someone realised that there is no such force), so that the weight flies outwards, stretching the spring B. As the weight A flies out, the pawl on the end of the hinged arm C pushes the arm D, which in turn presses the recording/replay head, E, against the drum. The head appears to have consisted of a rod of soft iron with a radius machined at the end to match the radius of the recording wire, so that the head was a good fit against the wire. A winding on the soft-iron rod constituted the recording/replay coil, and the wire connections to the head were led through the hollow stirrup to a shielded container above the drum in which one wire was earthed to the frame, and the other made a connection through a slip-ring and brush to the lead-out cable. The drum could be turned out at a fairly constant speed by means of a clockwork motor.

Poulsen's original tape recorder built in 1900.

FOR THE RECORD

The use of the machine was straightforward. For recording, a carbon microphone, with energising battery, was connected to the recording head. The drum was allowed to rotate, so that the head contacted the wire. As the recording was made, the screw action of the wire winding pulled the head assembly steadily higher up the stirrup. At the end of the recording, the machine was switched off, whereupon the head was pulled back from the drum by the spring B, and the whole assembly then fell down to the bottom of the stirrup again — a most



British Patent No. 8761 of 1899, Poulsen's original drawing.

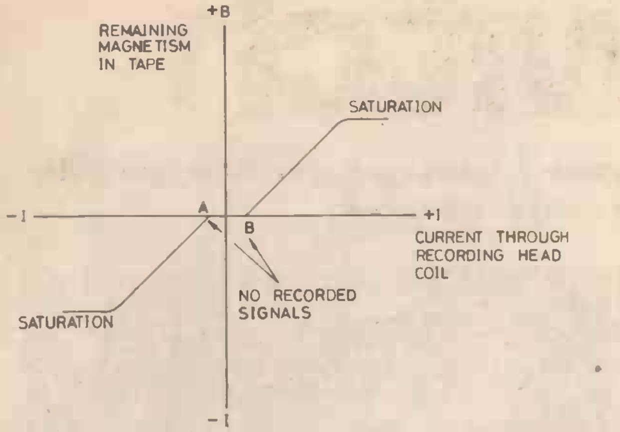


***Fig. 4.** Graph of magnetism retained by tape plotted against recording head current.*

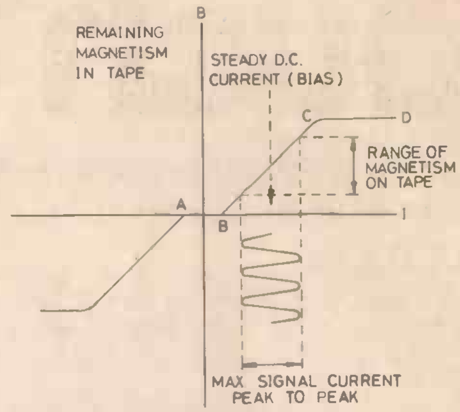


***Fig. 5.** Use of steady bias current to avoid distortion.*

effectively simple type of rewind operation.

For replay, a telephone earpiece was connected in place of the microphone, and the machine was started again. The head would engage the wire again at the start of the recording and the listener would hear the recorded voice.

It was a simple device, like the Phonograph, and like so many other simple devices, it had several problems and faults. Surprisingly enough, though, it got round some problems which were to perplex later designers, but the shortcomings of the machine led to it becoming almost forgotten, although steel-wire recordings were made and used in small numbers.

PROBLEMS

The main shortcoming was the volume of signal on replay. Edison's Phonograph used purely mechanical methods, with the fluctuations of the recorded groove vibrating a diaphragm, and the sound produced by this vibration being considerably 'amplified' by the use of a horn. The replay signals from the Telegraphone were decidedly feeble, and could only just be heard using a sensitive telephone receiver, so that there was no market for the Telegraphone as a method of family entertainment. As a telephone recording machine, it was not sufficiently developed, nor was there any demand for such a machine at the time, when a clerk could be employed to answer telephones for a couple of quid a week. Poulsen's invention looked set to disappear from memory.

Poulsen's early work led to the tape recorder. This one was one of the first production models, the 'Magnetophon' made by AEG in Germany in 1935; the tape was made by BASF.

The principle was rescued by two other devotees of the magnetic recording principle, Blattner and Stille. In the early part of this century, the Blattnerphone was an acceptable office dictating machine, selling steadily, and using reels of steel wire. The invention of thermionic valves, making it possible for the first time to amplify the weak replay signals provided at last the missing link for which magnetic recording was waiting. Amplification, on recording and also when replaying, overcame many of the disadvantages of the early machines. Blattner machines, using steel tape, were, in fact used by the BBC for programme recording in the 30's, and were abandoned only when the onset of war made it impossible to import the special steel tape from Sweden. All that was needed for Stille to construct the first 'modern' tape recorder in the 30's was the invention of coated paper (later plastic) tape.

BIAS

Oddly enough, Valdemar Poulsen had solved one of the great problems of any magnetic recorder. Fig. 4 shows what that is — it's a graph of the retained magnetism of the tape plotted against the current through the recording head. The shape of this graph is the problem. Recording is fine so long as the current in the recording head causes the magnetism of the tape to trace out the straight-line part of the curve. At low recording currents, there's no magnetic signal recorded on the tape or wire at all, and at high recording currents, the tape or wire saturates — it's as magnetised as it can be, and changes of current through the head produce no effect. December's HE article on Bias goes into this in detail.

Poulsen had solved both of these problems by using a carbon microphone. The fact that a carbon microphone passes a steady current even when no voice signals are being converted means that the current through the recording head is never zero. That, in turn, means that Poulsen never had to worry about the section of the graph marked AB(Fig.5). He, had, in fact, invented bias and it may be that he was the first to use bias in any shape or form. Also, because he used no amplification, the output from the microphone was never enough to magnetise the material to the saturated region, CD, of the recording graph.

Later workers had to grapple with both of these problems — the modern solution to the bias problem is the use of AC bias. Modern, you say? AC bias was invented in 1918 . . . but that's another story, another inventor. **HE**

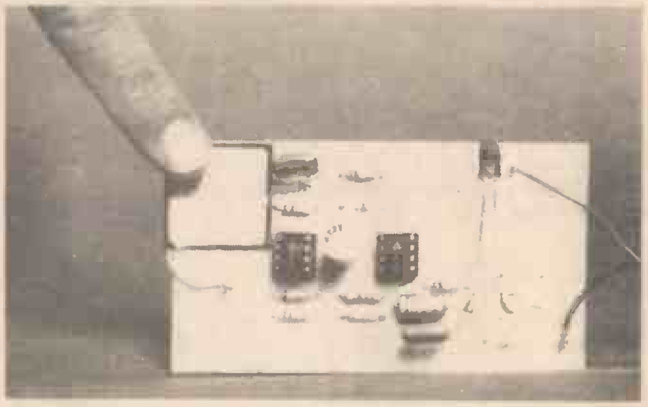
Touch Switch

For turning on equipment sensitive to vibration — photographic enlargers for example — or even just for a doorbell, this circuit is a boon

IF YOU'VE EVER got involved in repairing a transistor radio, you will probably know the trick of dabbing your finger at the input to the audio stage to see if you can hear the hum and/or increase in noise level to prove that the audio stage is working.

It is also possible to make use of this effect to switch a circuit positively. Switching by touch has become quite common in the last two or three years since the IC manufacturers have introduced devices specifically to perform this function. TV sets and lifts are amongst the common users (though some TV sets make use of your finger bridging two terminals and operate differently).

Touch switches may seem highly extravagant but industrially they are far more reliable, than mechanical types. In TV sets, touch switches have the great advantage of enabling the preset pots which control the varicap diodes in the timer to be put at the back of the set.



Above: the completed PCB. In this version we did not use a relay connecting a resistor and the LED in series across the output.

Parts List

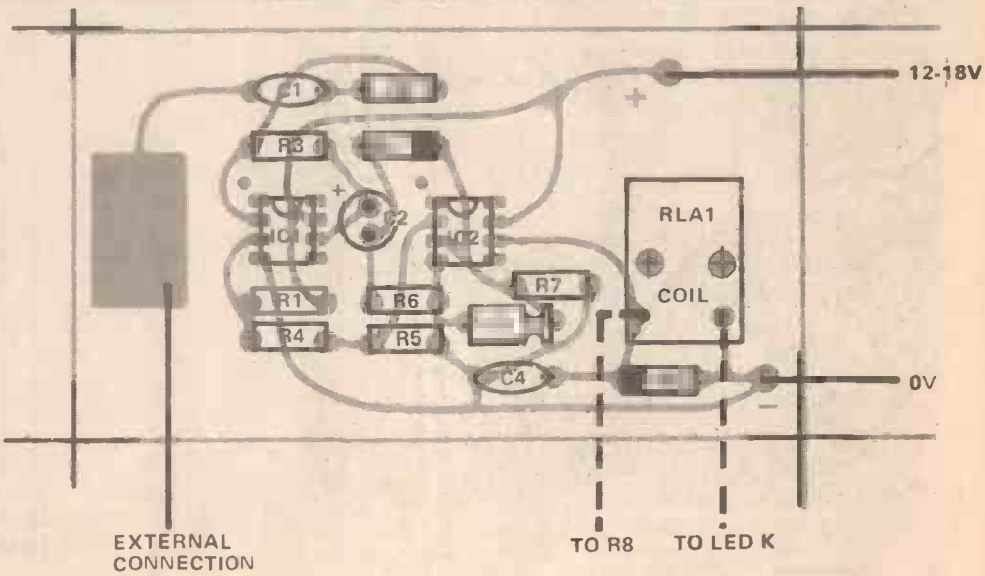
RESISTORS, All ¼W, 5%	
R1	56k
R2	100k
R3	10M
R4	15k
R5	15k
R6	3k3
R7	100k
CAPACITORS	
C1	100n polyester
C2	100uF 25 V electrolytic
C3	2u2 25 V electrolytic
C4	100n ployester
SEMICONDUCTORS	
IC1, IC2	741 Op Amp
D1, D2	1N4148 silicon diode

MISCELLANEOUS

PCB as pattern, Miniature relay (500 ohm or more coil and change-over contacts).

Approximate Cost: £4

On the right is the component overlay for the PCB. Be sure to position the polarised components C2, C3, IC1, IC2, D1 and D2 the right way round. If you're buying a relay get one to fit the holes as shown otherwise extra drilling and soldering may be needed.



How it Works

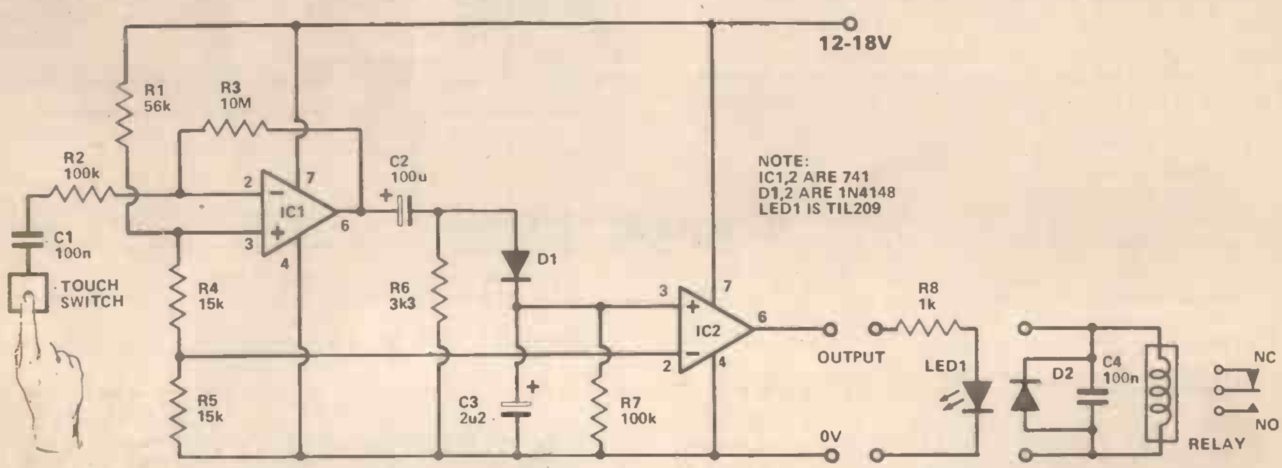
When a finger is placed on the touch contact, a low level of mains hum is introduced to IC1 via the DC blocking capacitor C1 and R2. The gain of IC2 is arranged at a very high level and the hum is thus enormous amplified and switches the output of IC1 to about 7 V peak-to-peak. The signal passes through C2 which blocks the DC to diode D1.

When the signal is swung positive, D1 conducts and charges up C3. When the voltage at the non-inverting terminal of IC2 (pin 3) exceeds the voltage at the inverting terminal(pin 2) the output of IC2 goes high and switches the relay.

IC2 acts as a voltage comparator. When the finger is removed, R7 discharges C3 and the output of IC2 goes low and the relay switches off.

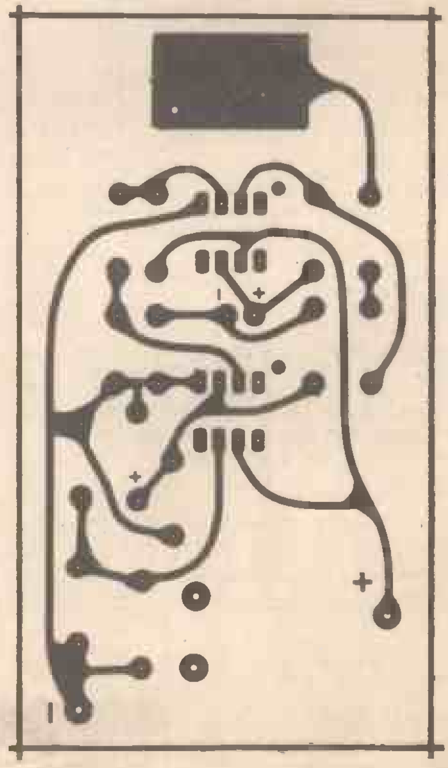
D3 and C4 are included to protect IC2 from the very high voltages caused by abruptly turning RL1 off.

If used to switch mains equipment, great care should be taken to isolate the switched mains from the rest of the circuit. R2 and C1 give only a margin of safety and are no substitute for taking care. The power for the circuit itself should only be derived from batteries.



Above is the circuit diagram, showing, on the right, the connections for either an LED (as in the photo on page 17), or a relay.

On the right is the copper foil pattern for the PCB we used, printed actual size.



CONSTRUCTION

We have designed our PCB so that the touch contract is on the board itself but have also allowed a terminal for taking the touch contact to somewhere more remote.

Small relays don't normally come in standard types and for that reason we have only left a general area showing the coil contacts, though these may have to be changed. We have not even attempted to show the switch contacts but there is plenty of room to run the contracts to terminals sited between the supply connections.

Apart from the obvious precautions to ensure that the ICs, diodes and the two electrolytic capacitors (C2, C3) are connected the right way around, construction is easy.

For safety reasons, we strongly recommend that the circuit is battery operated. If it is used to switch a relay, the contacts of the relay can be used to switch a mains supply on.

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TECHNICAL SPECIFICATION

- Shock resistant ABS case.
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- Size: 260mm × 200mm × 50mm.
- Batteries: 4 × HP7 (Not supplied).

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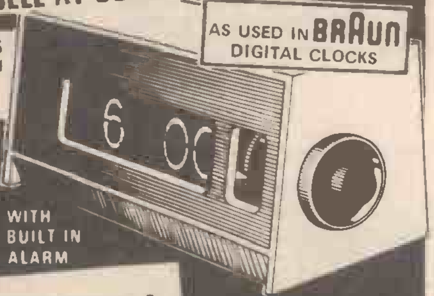

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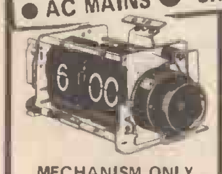

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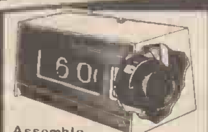

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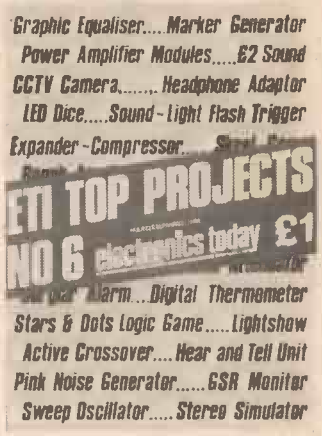

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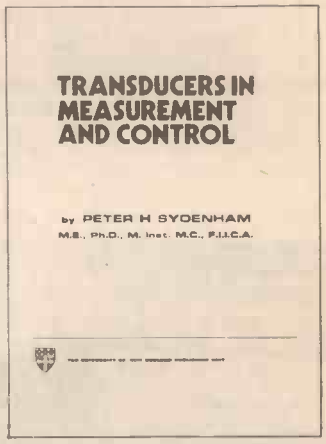

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Basic Programming

What exactly is involved in computer programming? The easy answer is to say: "Try it and see", but if you don't have access to a computer this can be a trifle difficult. Instead, Jim Perry takes you through the whole thing bit by bit.

THE ENGLISH LANGUAGE contains about 650 thousand words but most people only know a tiny percentage (the average is about 12,000). Even more surprisingly, in conversation we only use a couple of thousand or so words. By learning as few as 200 words in any foreign language, you can make yourself be understood in most situations — but obviously the words need to be carefully chosen. The main difference between a *computer* langugage and any other is that you must obey the grammar rules — otherwise the computer will not understand. English people will smile, but understand, if a foreigner asked "Cinema is you know where?"; bad grammar is not a total barrier to communication.

Computer languages are based around a very small vocabulary, usually less than 100 words — but if a word is misspelled, or the grammar not obeyed, the computer will either reject the instruction or do something totally different. There are dozens of different computer languages in use, the most common on small computers being called BASIC. The name is an acronym for Beginners All-purpose Symbolic Instruction Code and it was developed by researchers at Dartmouth College in the USA in 1964. BASIC may not be the best computer language, but it can be learned in a few hours and is reasonably powerful (we use the term powerful in relation to computer langugages to mean versatile).

Just like any other langugage BASIC has several, slightly different, 'dialects'. Different computer specialists have developed their own versions of the original Dartmouth BASIC, usually adding extra words and using slightly different grammar rules. As an introduction to the wonderful world of BASIC this article will deal with the dialect spoken (and understood) by Commodore's PET computer.

PARLEZ VOUS BASIC?

To communicate with a computer you need to speak (or rather type) in a lnaguage it can understand. The instructions that you give it form a 'program', which the computer will execute when instructed to do so. The instructions (or program) are divided into seperate lines (sentences), with each line having an indentification number allocated to it.

When the computer is told to RUN the program, it starts at the line with the lowest number and works up in sequence. To help in modifying programs, the line numbers are usually allocated in multiples of ten — as the computer will only accept whole line numbers, and you may need to insert extra lines as the program is developed.

The line number also tells the computer that you are entering a program, any instructions without a preceding line number will be forgotten after they have been executed. At the end of each program line the 'return' key is pressed, this tells the computer that you have finished the line. The return key is the most used key on every computer, without it every line would have to be the same length so that the computer would know when a line was finished.

WHAT GOES IN . . .

So how can you tell the computer to perform a simple, repetitive, calculation? Suppose you need to calculate the square of any number, a simple enough task! First you need to tell the computer what number you want to square so type in:

10 INPUT X (then press RETURN key)

The 10 is the line number, the word INPUT is a BASIC instruction meaning 'Ask the outside for a number, call it X, and then go to the next instruction line — but remember the number X'.

20 A=X*X (RETURN)

An equals sing is a BASIC instruction, as is the * which is the same as a multiplication sign. X times X is the same as X squared.

30 PRINT A

The PRINT instruction is telling the computer to display the value of A on the screen, as A is X times X (line 20); the number displayed will be the answer we want.

To start the program the instruction RUN is typed into the computer, followed by the return key. The computers response will be a question mark, which is its way of asking for an input. If you type in a 4 and then press return the answer 16 will appear instantly, followed by READY.

What has happened is that the computer has started at line 10, asked for a number a number, multiplied it by itself (squaring it), and has assigned the result to a letter A, then moved to the next line. After printing the value of A the computer has found no further instructions and so says that it is READY for more instructions. The screen will look like this:

```
10 INPUT X
20 A=X*X
30 PRINT A
RUN
?4
16
READY
```

This will be followed by a flashing white square on the next line, this is the CURSOR which shows the position of the next position on the screen, anything typed will move the cursor to the next position. If you want to RUN the program again you have to type in the command RUN again, and the program will repeat. To keep the program running an extra line can be added.

```
40 GOTO 10
```

GOTO instructs the computer to jump back to line 10, it is an unconditional instruction — the computer will change the operation sequence to give:

```
RUN
?4
16
?
```

With line 40 the computer will continue to square any number typed into it, if you had told the computer to GOTO a line that had not been allocated it would object — any instruction must be valid.

On a simple program like ours anybody would be able to read it and inderstand what was happening. However as soon as programs get any longer it can be difficult deciphering them after a period of time, to help the programmer a BASIC instruction REM is used. REM is short for REMark and is used like this:

```
0 REM A PROGRAM TO SQUARE A NUMBER
5 REM ASK FOR A NUMBER
10 INPUT X
15 REM SQUARE THE NUMBER AND CALL IT A
20 A=X*X
25 REM PRINT THE RESULT
30 PRINT A
35 REM GO BACK AND DO IT AGAIN
40 GOTO 10
```

It is very rare that a program would be as well REMed as this example, but REM statements should be used whenever a program goes off from the normal sequence. Another way of squaring a number is as follows:

```
20 GOSUB 100
100 A=X*X
110 RETURN
```

All the previous lines are the same, but in this example the actual squaring operation has been made into a 'subroutine'. The GOSUB instruction is one of the most useful commands in BASIC, without it you would have to include certain sections of program many times. With every GOSUB there must be a RETURN (not the same as the return on the keyboard), the RETURN makes the computer go back to the line after it went off to the subroutine. As with GOTO, any GOSUB must have an allocated line number that exists. If you had told the computer to GOSUB 99 it would have replied 'UNDEFINED STATEMENT', the modern way of saying 'DOES NOT COMPUTE'.

To demonstrate how precisely you need to tell the computer what to do, line 40 could be missed out (deleted). The computer response would be:

```
RUN
?4
16
RETURN WITHOUT GOSUB IN 110
```

The computer does not like to find RETURNS on their own, without line 40 the computer has 'fallen through the bottom' of the program.

Both X and A are variables, and can be manipulated in any way that numbers can be on a sophisticated calculator. Standard functions that are available in BASIC (arctan) and even exponentiation. By using the exponentiation function (written as X↑Y) line 100 could be written:

```
100 A=X↑Y
11 INPUT Y
```

Line 0 should also be changed to indicate the new nature of the program, as should line 15. The program will now run as follows (if line 40 is END):

```
RUN
?4
?3
64
READY
```

If the original line 40 is put back in we now get:

```
40 GOTO 10
RUN
?3
?2
9
?
```

We now have a much more useful program that can find any power of any number, within the limits of the computers highest number and lowest number. On most BASICs the largest number is 1.70141*10↑38 which is rather large, and should be enough for most programs!

By using more sophisticated PRINT instructions the answer can be made clearer:

```
30 PRINT A;"IS";X;"↑";Y
```

The semicolon instructs the computer to continue printing on the same line, all text enclosed in quote marks will be printed exactly as shown. All variables will have their current value printed.

```
RUN
?4
?2
16 IS 4↑2
?
```

In the program example we have used A, X and Y as variables but we can use any combination of letters and numbers as a variable. The computer however only looks at the first two characters and the first one must be a letter. Also any variable cannot contain a BASIC command word.

For example, instead of A we can use OFFENCE but

cannot use OFFEND as the BASIC command END is in it. Another common word that cannot be used is TO, which is also a BASIC command word. All the BASIC reserved words are listed below:
ABS, AND, ASC, ATN, CHR$, CLOSE, CLR, CONT, COS, DATA, DEF, DIM, END, EXP, FN, FOR, FRE, GET, GOSUB, GOTO, IF, INPUT, INT, LET, LIST, LEFT$, LEN, LOAD, LOG, MID$, NEW, NEXT, NOT, ON, OPEN, OR, PEEK, POS, POKE, PRINT, PRINT#, READ, REM, RESTORE, RETURN, RIGHT$, RND, RUN, SAVE, SGN, SIN, SPC(, SQR, STEP, STOP, STR$, SYS, TAB(, TAN, THEN, TO, USR, VAL, VERIFY, WAIT.

Now suppose we want to find the square, cube and fourth power of a number, we could use our existing program — but would have to keep entering the values for X and Y (2, 3 or 4). A BASIC command DATA can be used to make the job simpler:

```
10 DATA 2,3,4
20 INPUT X
30 READ Y
40 PRINT X↑Y; "IS;X;"↑";Y
50 GOTO 30
```

Each time that Y is read it takes the next item of DATA as its value, when run this program would act as follows:

```
RUN
?2
4 IS 2↑2
8 IS 2↑3
16 IS 2↑4
OUT OF DATA ERROR IN 30
READY
```

Whoops! Not quite what was wanted! As soon as the DATA has been read the computer has no more to use and assumes that you have made a mistake — which you have!

To reuse the DATA another statement is used, the RESTORE command. When a program needs to reuse the DATA, the RESTORE makes it start at the first item again. But if RESTORE is used with the program as it is shown where will it go? The answer is simple, nowhere! With the GOTO in line 50 it cannot come after (it would never get reached), and if placed before 50 the answer will always be the same:

```
RUN
?2
4 IS 2↑2
4 IS 2↑2
```

Etc.

The program will only stop if the BREAK key is pressed. A way round the problem is to check the value of the DATA, IF the DATA is 4 THEN RESTORE:

```
10 DATA 2,3,4
20 INPUT X
30 READ Y
40 PRINT X↑Y;"IS"; X; "↑";Y
50 IF Y=4 THEN 70
60 TOTO 30
70 RESTORE
80 GOTO 20
```

Now the computer will print the 2nd, 3rd and 4th powers of X, then ask for a new value for X. The IF, THEN is a conditional statement and will be ignored if the condition is not met, a GOTO is not needed at the end of the statement — BASIC assumes you want to GOTO the line number after THEN. You can place a GOSUB or other command after THEN if you want to. DATA can be placed on any line in a program, for example

BASIC COMMANDS

Command/Statement	Example	Description
ABS	10 A=ABS(X)	Gives the absolute value of the expression X.
AND	10 IFA=1 AND B=1 THEN 100	If both A and B are 1 then branch to line 100.
ASC	10 PRINT ASC(X$)	Gives the ASCII numeric value of the first character in X$
ATN	10 A=ATN(X)	Gives the arctangent of angle X, expressed in radians.
CHRS	10 A$=CHR$(N)	Returns character corresponding to the ASCII code number N.
CLOSE	10 CLOSE N	Closes file N.
CLR	CLR	Clears all variables to zero.
CONT	CONT	Continues program after a break or Stop command. No alterations allowed in the program.
COS	10 A=COS(X)	Cosine of angle X evaluated, X in radians.
DATA	10 DATA 1,2,3, "CAR"	Specifies data to be read from left to right, any strings must be in quotes.
DEF	10 DEF FNA=B+C	Allows user to define a function.
DIM	10 DIM A(N)	Specifies number of elements in an array or matrix.
	10 DIM A(P,Q,R,S)	Specifies the dimensions of an array.
	10 DIM A$(N)	Dimensions string array.
END	100 END	Stops program execution.
EXP	10 PRINT EXP (X)	Gives the constant 'E' raised to the power X.
FN	10 DEF FNX=B+C	Allows user defined function like, functions already in BASIC.
FOR	10 FOR I=1 TO 10 20 NEXT I	Performs all instructions before NEXT I as many times as specified by index.
FRE	PRINT FRE(O)	Returns amount of empty memory.
GET	10 GET X 10 GET X$	Accepts single number from keyboard, the return key does not need to be pressed.
GOSUB	10 GOSUB 100	Moves program execution to line specified, will come back to next line when subroutine finished (RETURN instruction met).
GOTO	10 GOTO 100	Moves program to line specified, will not return automatically.
IF . . . GOTO	10 IF X=1 GOTO 100	Equivalent to an IF THEN statement, but must be followed by a line number.
IF . . . THEN	10 IF A=B THEN CD 10 IF AB THEN 100	Conditional statement, can transfer program line or execute new statement.
IF . . . GOSUB	10 IF A=BGOSUB 100	Same as IF . . . GOTO, but will return to next line when RETURN encountered.
INPUT	10 INPUT A	Prompts with question mark and accepts numeric input.
	10 INPUT A$	Accepts string input.
INT	10 PRINT INT(X)	Returns the largest integer, less than or equal to X.
LET	10 LET NN+1 10 N=N+1	Assigns value to a variable, is optional and may be omitted.
POS	10 PRINT POS(O)	Displays the next available position for printing.
POKE	10 POKE X,Y	Puts byte Y into memory location X.
PRINT	10 PRINT X	Displays the value of X.
	10 PRINT	Prints a blank line.
	10?	? is a shorthand for PRINT.
	10 ?"YES";XS,Y	Strings of alphanumeric must be enclosed in quotes, defined strings do not need quotes, variables do not need quotes either. Without a; or, a line feed will happen, a comma causes the printing to tablulate over 4 columns — a semicolon makes separate print statements appear next to each other.
PRINT#	10 PRINT#1,J	Write to a file.
READ	10 READ X,Y,Z	Takes DATA statement as source of X,Y,Z.
REM	10 REM THIS IS A REM	A reminder about what you were doing in the program.
RESTORE	10 RESTORE	Sets the READ back to the start of DATA.
RETURN	100 RETURN	End of every GOSUB, send the program back to the line after where it came from.
RIGHT$	10 PRINT RIGHT$(X$,A)	Prints the A characters from the right of X$.
RND	10 PRINT RND(X)	Displays a random number between 0 and 1, if X is less than 0 a new sequence of numbers is generated each time RND is used.
RUN	RUN	Starts program at lowest line number.
	RUN 100	Starts program from line 100.
SAVE	SAVE SAVE"BASIC"	Dumps copy of program onto tape, if named the name is recorded on the tape as well.
SGN	10 A=SGN(X)	Gives +1 if X is positive, 0 if X is zero, —1 if X is negative.
SIN	10 A=SIN(X)	Finds the sine of variable X, which must be in radians.
SPC	10 PRINT SPC(I)	Prints I spaces.
SQR	10 A=SQR(X)	Makes A equal to the square root of X.
STEP	10 FOR I=1 TO 10 STEP X	Increments the value of I by X.
STOP	10 IF A=B THEN STOP	Breaks the program, may be restarted with CONT.
STRS	10 A$=STR$(A)	Gives character represented by A.
SYS	10 SYS 10000	Sends program off to memory location given.
TAB	10 PRINT TAB(X);A	Prints A at position X from start of line.
TAN	10 A=TAN(X)	A becomes the tan of angle X.
THEN	10 IF B THEN 100	End of a conditional argument.
TO	10 FOR I=1 TO 10	Part of a FOR loop statement.
USR	10 USR(X)	Transfers control to a machine code program.
VAL	10 A=VAL(AS)	Returns numeric value of string.

LIST	LIST	Displays current program.
	LIST 100	Displays line 100.
	LIST 100-	Displays line 100 onwards.
	LIST 10-100	Displays 10 through 100.
	LIST -100	Lists up to line 100 only.
LEFT$	10 PRINT LEFT$(X$,A)	Extracts the leftmost A characters from string X$.
LEN	10 PRINT LEN(X$)	Prints length of X$, counts spaces as characters.
LOAD	LOAD	Loads program from cassette into the computer memory.
	LOAD "XYZ"	Loads named program, ignoring all others.
LOG	10 A=LOG(X)	Gives the natural logarithm of X.
MIDS	10 PRINT MID$(X$,A,B)	Prints B characters from string X, starting A characters from the left.
NEW	NEW	Wipes out existing programs from the computer's memory.
NEXT	10 NEXT I	Marks the end of a FOR loop.
	20 NEXT	Without variable ends most recent loop.
	30 NEXT I,J	Equivalent to NEXTI:NEXT J.
NOT	10 IF NOT X THEN 100	X must be false to transfer to 100.
ON	10 ON X GOTO 20,30,40	Branches to line indicated by X, if X=1 will branch to 20, etc.
	10 ON X GOSUB 20,30	The same as GOTO but with a return.
OPEN	10 OPEN1,1	Opens file, numbers indicate what device.
OR	10 IF A OR B THEN 100	Transfers line if either is true.
PEEK	10 PRINT PEEK(X)	Prints the contents of memory location X.
VERIFY	VERIFY	Checks a program on tape to see if it has any errors.
WAIT	10 WAIT I,J,K	This will read the status of location I, exclusive OR it with the status of K and then AND the result with J. When the answers is zero the program will restart.
%	10 A%=INT(X)	Designates an integer variable.

BASIC Mathematics

You don't have to be a mathematical genius to program a computer in BASIC. The computer obeys strict rules when it evaluates any expression, and all you have to do is learn the rules.

Formulae enclosed in brackets are evaluated before anything else, if there are two or more sets of brackets then they are worked out from left to right — this rule also applies to any situation where there is equal priority. As an example 6—3+5 gives 8 as the answer, not —2. As division is more important than addition the expression 5+3/4 gives 5.75 not 2 — if you want to add 5 to 3 and divide the result by 4 you must use the following format (5+3)/4.

The list of precedence is as follows:

1: Formulae in brackets
2: ↑ or exponentation (X'Y)
3: Negation (—X as a negative number)
4: * and / (multiplication and division)
5: + and —
6: = equal
<> not equal
< less than
> greater than
<= less than or equal
>= greater than or equal

10 DATA 2
11 DATA 3,4

Will give exactly the same result as the previous single line. But

10 DATA 2
11 DATA 4
100 DATA 3

will produce the answers out of order, with the 2nd, 4th and then 3rd power being printed.

The equals sign in the IF THEN statement can also be one of the following <, >, <>, =<, =>, =<, =>. Two variables can also be compared using the IF THEN statement (remember you can use a variable instead of a number in programs).

As well as the standard greater than, less than and equals (with the combinations shown above) logical comparisons can be made with AND, OR and NOT statements.

IF A=1 AND B=2 THEN PRINT "A IS HALF OF B"

FOR OUR NEXT TRICK

Suppose we want a table of squares for each number from 1 to 10, we could use the following program:

```
10 PRINT 1;1↑2
20 PRINT 2;2↑2
30 PRINT 3;3↑2
```

This method would work but it's very inefficient, by using the IF THEN statement the program becomes a lot smaller:

```
10 N=1
20 PRINT N;N↑2
30 N=N+1
40 IF N<=10 THEN 20
```

This program will produce exactly the same result as the previous one. But what is happening in line 30? Mathematically N=N+1 is nonsense, however in this statement the equals sign is a shorthand for "replace the value of the left side with that of the right side". The statement replaces N with the value N+1 every time it is executed. As N starts off with a set value of 1 it changes to 2,3,4,5,6,7,8,9 and 10 as the program operates. But when the square of 10 has been printed N becomes 11 and the condition in line 40 is not met — 11 is not less than or equal to 10. The program cannot go back to line 20 and as no more program exists, it will stop.

The technique used in the program above is called 'looping' or 'iteration', and is used extensively in programming. In fact it is such a useful technique that a special BASIC command exists to do it.

```
10 FOR N=1 TO 10
20 PRINT N;N↑2
30 NEXT N
```

The output of this three line program is the same as the previous ten and four line programs. At line 10 N is set at 1, line 20 prints the value of N and the square of N and line 30 adds 1 to the value of N. This continues until N is 10. The variable following FOR is the same as the variable after NEXT, but both could be any valid variable — as long as they are the same.

If only every second square was wanted, a STEP instruction can be added to line 10:

```
10 FOR N=1 TO 10 STEP 2
```

Now the computer will add 2 to the value of N instead of 1, and only every second value will be printed. We can even get the results printed in reverse order by reversing the FOR conditions and stepping a minus number:

```
10 FOR N=10 TO 1 STEP -2
```

If no STEP is given the BASIC will add 1 to the variable each time. A loop can be placed inside another loop, as long as it is all inside. If two loops overlap then the results are predictable, the computer will say "NEXT WITHOUT FOR" when it has finished the first loop it finds. Putting one loop in another is called 'nesting'.

STRINGS AND THINGS

So far all the manipulation has been with numeric variables, but BASIC can also cope with alphanumeric variables. All sets of alphanumeric are called 'strings' and denoted by a dollar sign at their end.

```
10 INPUT A$
20 PRINT A$
RUN
?BASIC
BASIC
READY
```

All strings can be up to 255 characters in length. The strings can be manipulated in many ways, LEN(X$) gives the total number of characters in X$. LEFT $ (X$, I) gives the first I characters of the string X$, RIGHT$(X$,I) gives the last I characters of X$. The command MID$ is used in a similar way to extract characters from the middle of the string.

```
10 INPUT X$
20 FOR N=1 TO LEN(X$)
30 PRINT LEFT$(X$,N)
40 NEXT N
RUN
?BASIC
B
BA
BAS
BASI
BASIC
READY
```

Strings can also be added together after they have been taken apart, the addition sign "+" can add different strings — this is called 'concateration'.

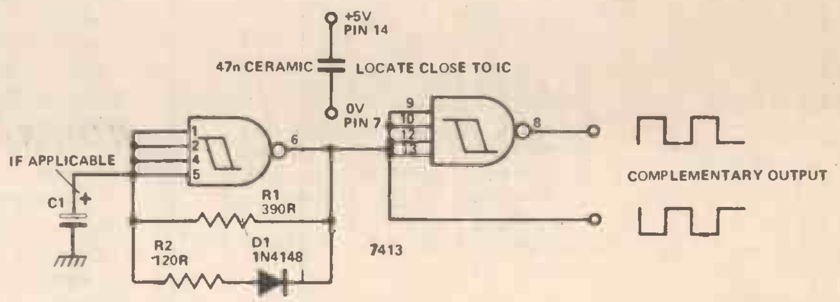
```
10 INPUT A$
20 B$=A$+A$
30 PRINT B$
RUN
?REPEAT
REPEATREPEAT
READY
```

If all this seems like a maze of jargon then there is only one surefire answer, get hold of a computer and try writing a program! All the BASIC instructions are given here with short explanations. Most small computer systems come with BASIC manuals and some are excellent (the Tandy one in particular). A very good book for beginners is Illustrating BASIC by Donald Alcock, available from the HE bookservice for £2.20 (including postage) or most good bookshops; it is published by Cambridge University Press.

Computers are not anything to be afraid of, they are as easy to use as a motorcar — you just have to learn to drive them. **HE**

Short Circuit

HF TTL OSCILLATOR



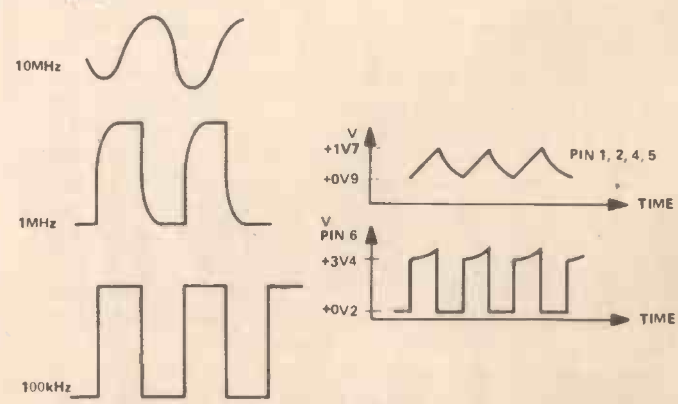
A squarewave oscillator with complementary outputs and with a frequency range of 20 Hz to 10 MHz can be made from one IC, a 7413 which is a TTL dual Schmitt trigger. The oscillator is always self starting and runs from a 5 V supply, current drain 20 to 30 mA. The 7413 is a Schmitt trigger with hysterysis levels (at its input) of +0.9 V and +1.7 V. That is, when the input level exceeds +1.7 V the output jumps to a low condition (+0.2 V). When the input voltage is lowered it needs to fall below +0.9 V before the output jumps back to a high condition (+3.4 V).

When the Schmitt trigger is connected up as shown in the diagram the device will oscillate. Imagine the output is high. C1 is charged up via R1. When the voltage on C1 reaches +1.7 V, the output falls to +0.2 V. C1 is now discharged via R1 in parellel with R2 (D1 is now forward biased) until the voltage on C1 reaches +0.9 V. Then the output jumps to a high state and the process repeats itself. The second Schmitt trigger merely inverts the squarewave output. The frequency of operation is given by the formula:

$$F_{osc} = \frac{2\times10^{-3}}{C1}$$

where F_{osc} is in Hz and C1 is in Farads.

therefore for:
10 MHz, C1=220 pF (polystyrene or ceramic)
1 MHz, C1=2200 pF (polystyrene)
100 KHz, C1=22 nF (polyester)
10 KHz, C1=220 nF (polyester or electrolytic)
1 KHz, C1=2.2 uF (electrolytic)
100 Hz, C1=22 uF (electrolytic)
20 Hz, C1=100 uF (electrolytic)



WAVEFORM DEGRADATION WITH FREQUENCY

Variwiper

This pulsed windscreen wiping circuit can be used on cars fitted with most types of modern wiper motors.

WHEN OPERATING IN heavy rain windscreen wipers often have difficulty providing adequate visability. However, during light rain or mist all that is necessary is an occasional sweep of the blades at intervals of a few seconds.

Turning them on and off repeatedly takes the driver's concentration off the road, and his hands off the wheel, increasing the risk of an accident. Alternatively, if the wipers are kept working all the time in such conditions the blades tend to scrape on dry glass, wearing out the rubber inserts, your nerves, and worst still, the screen itself.

The answer is obvious; have the wipers operate intermittently at a duration which can be varied to suit the conditions.

Figure 1 shows the circuit of a modern wiper assembly. Dynamic braking is achieved by applying a short across the armature, by a cam-actuated change-over switch synchronised with the wiper blades. When the wipers are switched off, the change-over switch shorts out the motor armature via the main wiper ON/OFF switch.

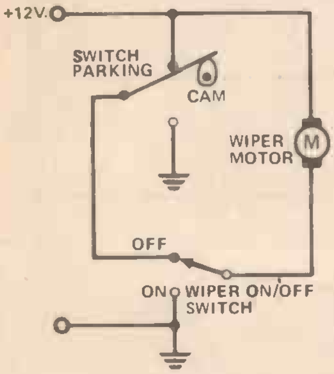


Fig. 1. Circuit of modern wiper motor assembly. Dynamic braking is achieved by applying a short across the armature.

The circuit of Fig. 2 is suitable for use with negative earth cars fitted with permanent magnet motors. Some early model cars are fitted with wound field coil motors and are not suitable for use with this circuit (more about them later).

Some types of permanent magnet wiper motors, especially those on British cars, have a fifth wire extended to the wiper switch. These motors are designed to operate independently of an earth to allow for their use on either positive or negative earth vehicles. The circuit of Fig. 2 can also be used with these motors provided they are fitted to a negative earth car. However, some more cars have wiper motors which are reversed in the parking sequence to lower the blades below the bottom of the windscreen when not in use. The Vari-Wiper unit described cannot be used with these wipers.

Before installing the Vari-Wiper unit make sure that you have one of the types of permanent magnet wiper motors described. If necessary remove the cover of the motor and identify the wire to the centre contact of the cam-operated switch.

NORMAL WIPER OPERATION

Conventional operation of the wipers is obtained by using the vehicle wiper switch in the normal way. Figure 2 shows the sliding contacts of this switch in the correct position for each function. Note that in the OFF position the switch shorts lead B to lead C. In the LOW position the short is removed and an earth is extended to B, while in the HIGH position the earth is removed from B and extended to A. For single speed wipers slide contact A will be omitted.

DELAYED OPERATION

When delayed operation is required, the upper switch is left in the OFF position and the timing circuit energised by operating SW1 which is part of the switch/potentiometer RV1.

After a time which is set by the position of RV1 (0.5-25 secs.) the relay contacts RL1 (1) change over, removing the short circuit from the motor armature before energising the motor by extending an earth via the now closed relay contacts.

As the motor gathers speed the associated cam-operated switch changes over, removing power from the timing circuit (causing the relay to drop out), and extending an earth to the wiper motor via the wiper switch contacts B and C, the now de-energised relay contacts, and the cam-activated switch.

The wipers continue their sweep across the screen, but on their return the cam-operated switch cuts in just before the end of the sweep. This removes power from the wiper motor and places a short across the armature. The motor is thus dynamically braked and remains stationary until the next relay closure from the timing circuit. When this arrives the sequence is repeated.

WOUND FIELD COIL MOTORS

Because wound field motors do not use dynamic braking, the Vari-Wiper can be made without a relay. Figure 3 shows the simplified Vari-Wiper circuit and its connections to either a positive or negative earth vehicle. The same printed circuit is used for both arrangements. Operation is similar to the previously described unit, having an earth extended through the SCR to start the motor.

CONSTRUCTION

Assemble and solder all components on the printed circuit board as shown in Fig. 5. Do not bend the lugs of the SCR too close to its case and ensure all semiconductors are the right way round.

To connect the unit to the wiper motor circuit, the existing lead from the centre pole of the wiper motor change-over switch to the wiper ON/OFF switch (shown in dotted lines in Fig. 2), should be broken at points X and Y and these leads taken to the normally closed contacts on the relay. Ensure that point X goes to the fixed contact and point Y to the moving one.

The potentiometer should be connected to the unit with just enough wire to allow the printed circuit to be mounted in a convenient position under the dash. The potentiometer can be mounted through a 10 mm hole drilled in the facia panel or by attaching it to a bracket mounted in a convenient place. **HE**

Parts List

Relay Output Unit

RESISTORS ALL ¼W 5%

R1 10k
R2 470R
R3 47R
R4 1k
R5 330R

POTENTIOMETER
RV1 1M switch pot

CAPACITOR
C1 22u 16V electrolytic

SEMICONDUCTORS
D1 1N4001
Q1 2N2646 unijunction
SCR1 C106D (400V, 4A)

MISCELLANEOUS
RL1 Miniature printed circuit board mounting heavy duty 12V relay
PCB Variwiper 2
Nylon terminal strip

SCR Output Unit

All components identical, except:
R5 deleted
D1/2 1N4001
SCR2 C106D (400V, 4A)
RL1 deleted
PCB Variwiper 1

Approximate Cost: £6

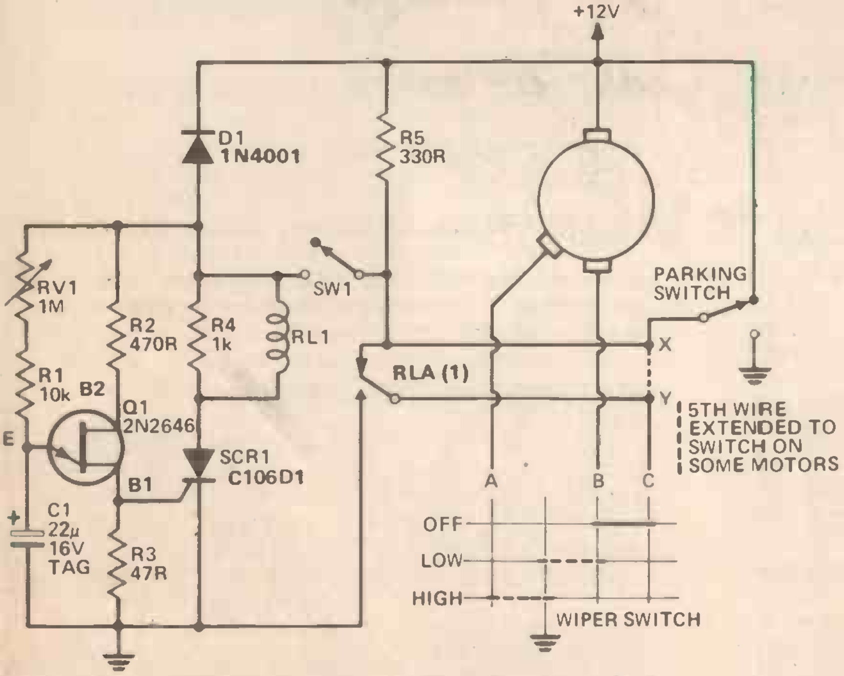


Fig. 2. The Vari-Wiper circuit using relay output for use with permanent magnet motors.

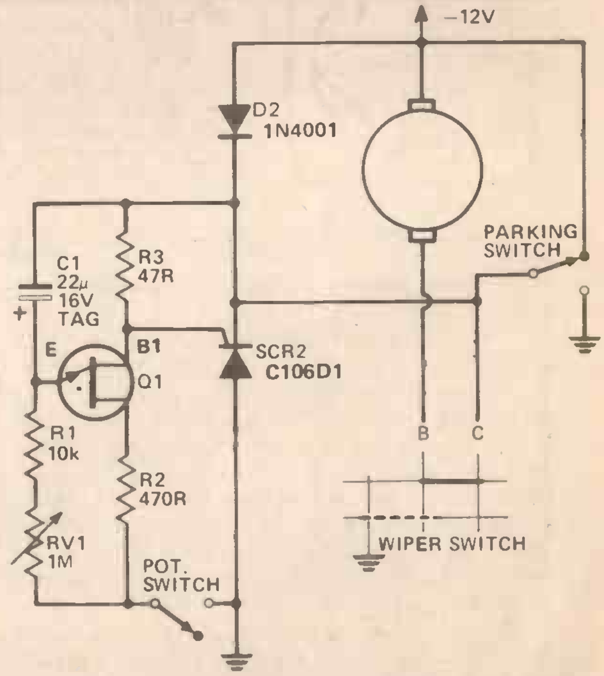


Fig. 3. Simplified Vari-wiper for use with wound field coil motors with positive earth.

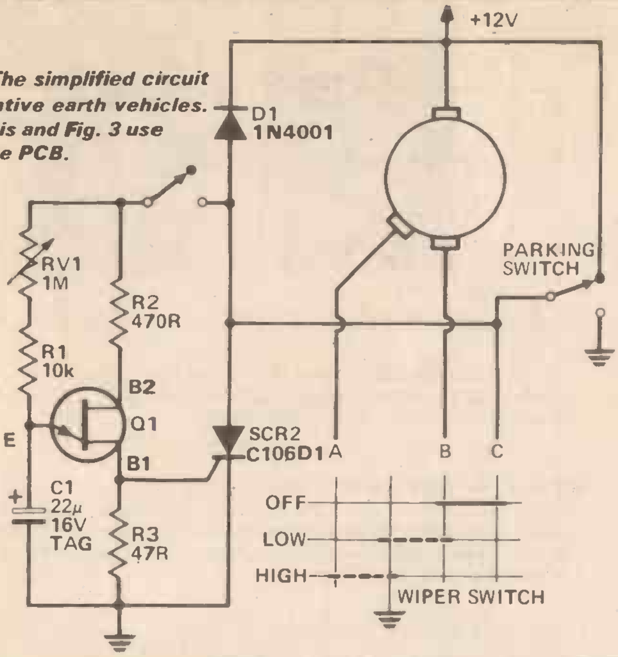
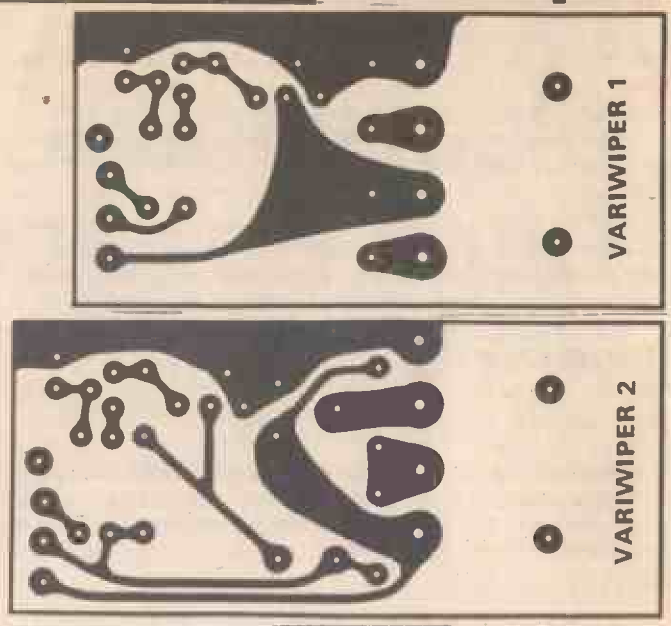
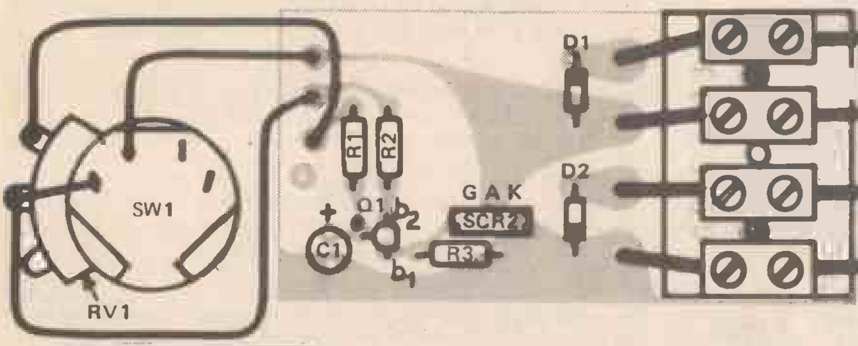


Fig. 4. The simplified circuit for negative earth vehicles. Both this and Fig. 3 use the same PCB.





NEG. EARTH	POS. EARTH
+12V	N.C.
PARKING SWITCH	EARTH
N.C.	−12V
EARTH	PARKING SWITCH

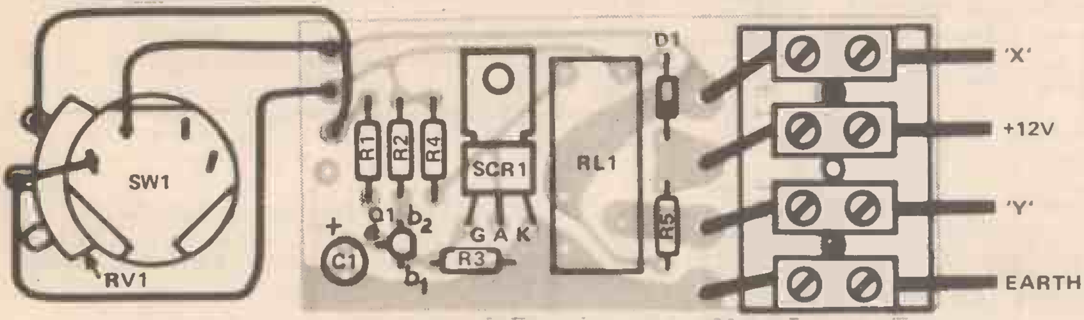


Fig. 5. Component overlays. Note that the same PCB is used for both earth polarities.

How it Works

The timing circuit is energized by operating switch SW1, which is part of switch/potentiometer RV1. This switch applies power to the unijunction/SCR circuit via the still-closed parking switch contacts.

Capacitor C1 charges via RV1 and R1, at a rate determined by the setting of RV1, until the unijunction 'fires', producing a positive going pulse which triggers the SCR into conduction. Resistor R4 ensures that the SCR latches on, thus energizing relay RL1.

Relay contacts RL1 (1) now changeover, removing the short circuit from the motor armature before energizing the motor by extending an earth via the now-closed relay contacts.

As the motor gathers speed, the associated cam-actuated switch changes over, removing power from the timing circuit (causing the relay to drop out) and extending an earth to the wiper motor via wiper switch contacts B and C, the now de-energized relay contacts, and the cam-actuated switch.

The wipers continue their sweep across the screen, but on their return the cam-actuated switch cuts in just before the end of the sweep. This removes power from the wiper motor and places a short circuit across the armature.

Operation of the unit is similar except the motor, which does not require dynamic braking, can be driven directly from the SCR, saving the cost of a relay. Note that either D1 or D2 become redundant depending on the polarity of the vehicle.

Hobby Electronics Book Service

BUILD-IT BOOK OF OPTOELECTRONIC PROJECTS by Charles Adams £4.75
A 48 project learn-by-building guide to the super-practical world of optoelectronics with thoroughly readable instructions on how to create everything from an LED circuit monitor to an electronic stopwatch.

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EASY SPEAKER PROJECTS by Len Buckwalter ... £3.75
Explains how to make speaker systems ranging from simple shelfboard and ceiling-mounted enclosures to more advanced bass-reflex and omnidirectional ones.

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BUILD-IT BOOK OF FUN AND GAMES by Graf and Whalen £3.75
All the projects in this book are designed for fun and game applications. The projects include a sight'n'sound metronome, an electronic football game and stereo balance meter, a sound-activated switch and a metal detector.

IMPROVING YOUR HI-FI £3.50
This book is aimed at the novice who has just purchased his first audio set-up or is about to do so. It begins with details of how to connect the units together to obtain top performance and explains the meaning and proper use of the many control knobs and switches found on modern hi-fi gear.

GUIDE TO PRINTED CIRCUITS by Gordon J. King . £3.50
The Text is angled especially at the keen amateur constructor, the experimenter, the service technician and apprentice.

ELECTRONIC TEST EQUIPMENT by Harry T. Kitchen £5.00
This book is designed to provide interest for almost everyone involved with electronics. The six chapters explore the more general groups of instruments such as test meters of various types, audio and r.f. signal generators, attenuators and oscilloscopes. Each chapter explains the principles and requirements of particular types of test equipment, including typical circuitry, then discusses the choice, care and use of the equipment.

FUN WITH ELECTRONICS by McEntee £3.40
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Describes in seven chapters the working principles of transistor amplifiers and outlines the steps and circuit design using a modern simplified transistor theory.

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ABC'S OF FET'S by Rufus P. Turner £3.05
Describes the field effect transistor (FET) in simple language. Deals in detail with the principles of FET operation and stresses the applications of FETs in practical circuits.

ABC'S OF ELECTRONICS (2nd edition) by Farl J. Waters £4.15
An introduction to the ever-expanding field of electronics. Covers the principles of electricity, functions of atoms and electrons, magnetic forces and their relationship to electronics.

Note that all prices include postage and packing. Please make cheques, etc, payable to Hobby Electronics Book Service (in sterling only please) and send to:

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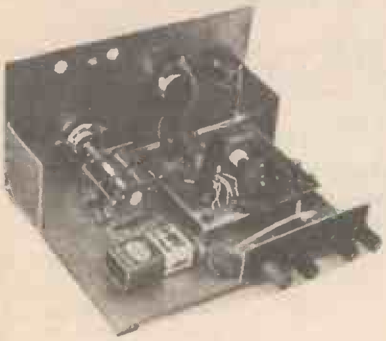
Hobby Electronics

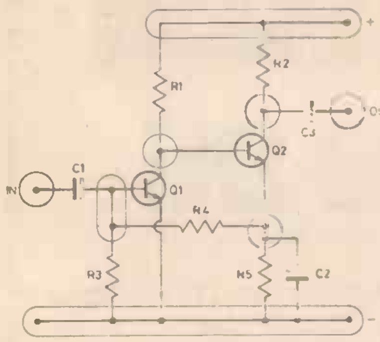
Next Month

Short Wave Receiver



Back in the bad-old-days when there were just valves, and they were expensive, you thought hard before adding another stage of amplification: first you tried to be clever. Our SW radio next month uses just two semiconductors yet will give surprisingly good performance over the range 5.5-25 MHz if used with a reasonable aerial.

Instant Circuit Layout



Do you have trouble getting your brain to translate a circuit into a practical layout? If so you're in good company but next month join the elite by overcoming this. We give you practical advice on how to lay out components from practically any circuit diagram.

Scratch / rumble Filter

An add-on circuit to couple to an existing audio system, this project enables you to select the cut-off frequency of the system at both ends of the spectrum.

Radioactivity

Although most people shudder when they think of radioactivity, there's a lot more to it than fallout from nuclear bombs. Radioactivity is widely used in medicine and in industry and our article describes some of the uses and traces the history of its development.

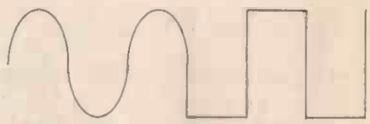
Video Tape Recorders

The age of the Video Cassette Recorder has arrived and soon they'll be common. However, they are the most complex, sophisticated, pieces of engineering that have ever crossed the doormat in reasonable numbers. Next month we explain how they work and take a look at the different systems being offered.

OST Rules, OK?

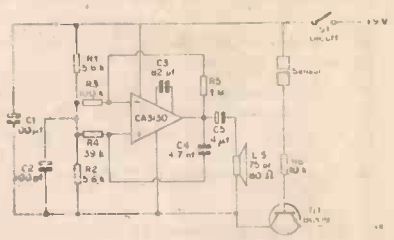
Got the hang of Ohms Law? No problem but the world isn't yours yet — have you ever found a problem it can't cope with? The chances are that you have. However, there are two other approaches to help you solve the nasty ones: Superposition and Thevenin's Theorem. They may sound complex but in reality they make life simpler.

Sine / Square Wave Generator



An essential part of anybody's test gear and our project next month enables you to add one to your workbench at low cost.

Projects Using The CA3130



We publish one chapter from R. A. Penfolds '50 Circuits using the CA3130' (brought out by Babani) and mighty interesting they are too. The projects include an electronic organ, metronome, alarm and latching circuits.

Holograms

Today they are only a curiousity, shown as exhibits and as special effects but much work has been going on behind the scenes. Today's Holograms really make you wonder if you can believe your eyes.

The February issue will be on sale on January 12th

The items mentioned here are those planned for the next issue but circumstances may affect the actual content.

Hobby Electronics

Marketplace

Size: 100mm x 130mm x 60mm.

Over 10% of Electronics Today International's readers have purchased a digital alarm clock from offers in that magazine — the offer is now extended to Hobby Electronics readers. This is a first rate branded product at a price we don't think can be beaten.

The Hanimex HC-1100 is designed for mains operation only (240V/50Hz) with a 12 hour display. AM/PM and Alarm Set indicators incorporated in the large display. A switch on the top controls a Dim/Bright display function.

Setting up both the time and alarm is simplicity itself as buttons are provided for both fast and slow setting and there's no problem about knocking these accidentally as a 'locking switch is provided under the clock. A 9-minute 'snooze' switch is located at the top.

An example of this digital alarm clock can be seen and examined at our Oxford Street offices.

£8·95

(Inclusive of VAT and Postage)

We feel we've got to tell you carefully about this offer which we're introducing for the first time. Why? Because our price is so enormously lower than anywhere else you may suspect the quality.

The exact same watch is currently being offered by another magazine as a special at £24.95 — some of the discounters are selling it at £29.95 the price to HE readers for exactly the same watch is £12.95.

The display is LCD and shows the seconds as well as the hours — and minutes — press a button and you'll get the date and the day of the week.

Press another button for a couple of seconds and you have a highly accurate stopwatch with hundredths of a second displayed and giving the time up to an hour. There is a lap time facility as well — and of course a back light.

Our Chrono comes complete with a high grade adjustable metal strap and is fully guaranteed.

An example of this LCD Chronograph can be seen and examined at our Oxford Street offices.

£12·95

(Inclusive of VAT and Postage)

DIGITAL ALARM

To:
DIGITAL Alarm Offer,
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25-27 Oxford Street,
London W1R 1RF.

Please find enclosed my cheque/P.O. for £8.95 (payable to Hobby Electronics) for my Digital Alarm Clock.

Name ....

Address ....

....

....

Please allow 14 days for delivery.

LCD CHRONO

To:
LCD Chrono Offer,
Hobby Electronics,
25-27 Oxford Street, London W1R 1RF.

Please find enclosed my cheque/P.O for £12.95 (payable to Hobby Electronics) for my LCD Chronograph.

Name ....

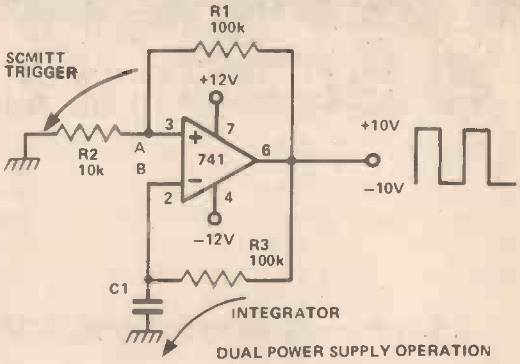
Address ....

....

....

Please allow 14 days for delivery.

A SINGLE OP AMP OSCILLATOR



DUAL POWER SUPPLY OPERATION

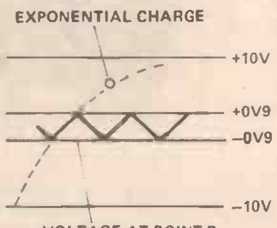
An op amp can be made to oscillate generating a square-wave output. The circuit is a Schmitt trigger and integrator all rolled into one.

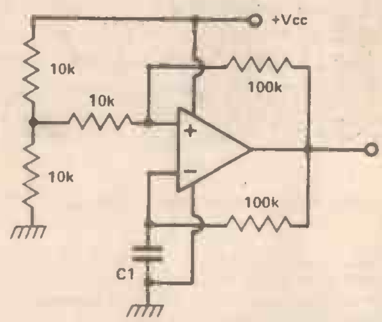
To understand the operation imagine the output is high; C1 is charged up via R3. The voltage at point A is +0.9 V due to the resistor divider network R1, R2. When the voltage at B exceeds this voltage, the output of the op amp flips into its negative (low) state, C1 is therefore discharged by R3. When the voltage on C1 reaches —0.9 V, the reverse process occurs and the op amp output flips back to its high state. Thus the circuit oscillates producing a square wave going from +10V to —10 V.

The frequency of operation can be obtained from the voltage changes on C1. This is the trincated section of an exponential charge/discharge curve, but we shall ignore this and assume that the curve is linear (which it almost is).

The frequency can be obtained from the formula F=I/ΔV×C Hz where I is the charging current (approximately 100μA), ΔV is the charge accross C1 (3.6 V) and C is the capacitance measured in Farads.

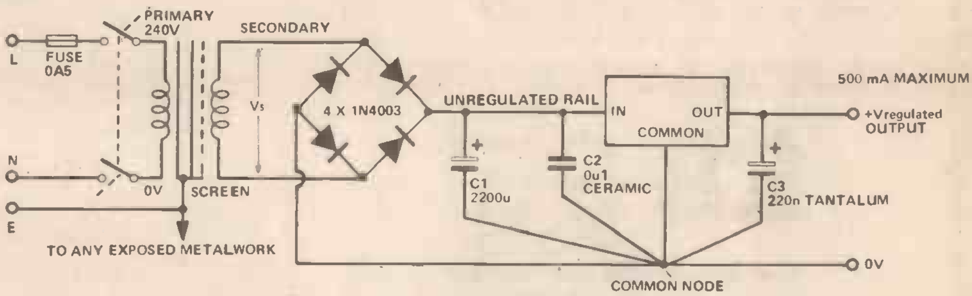
Therefore $F = 10^{-4}/3.6 \times C$ Hz. Thus, if C1=100nF, F=270 Hz; if C1 is 10nF, F=270 Hz and if C1 is 1nF, F=27 000 Hz.

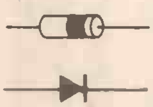


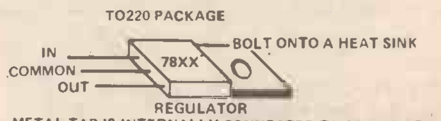


SINGLE SUPPLY OPERATION

POWER SUPPLY WITH IC REGULATOR







METAL TAB IS INTERNALLY CONNECTED TO COMMON PIN (78XX REGULATORS ONLY)

REQUIRED OUTPUT VOLTAGE	REGULATOR 78XX	TRANS-FORMER SECONDARY Vs	CAPACITOR VOLTAGE C1	TYPICAL MAXIMUM INPUT VOLTAGE TO REGULATOR
5V	7805	8 TO 9 V RMS	16 TO 25 V	25V
12V	7812	12 TO 15 V RMS	25 TO 35 V	30V
15V	7815	15 TO 16 V RMS	35 TO 63 V	30V
24V	7824	20 V RMS	35 TO 63 V	38V

A regulated power supply used to require a fairly complex circuit but the introduction of special ICs has made matters much simpler.

The chart shows the various voltage requirements for four types of voltage regulator. The last two numbers of this range of IC indicate the voltage so the 7812 will give 12V. Care has been taken that the voltage ratings of the regulator are not exceeded as this can blow up the IC.

The secondary voltage from the transformer (it must be an isolating transformer but most are) is full-wave rectified by the diodes and then smoothed by capacitor C1. The voltage here is unregulated and has AC ripple superimposed upon it. The IC removes this and gives an almost ripple free, stable DC voltage. C2 and C3 must be sited close to the regulator to prevent any loss of performance due to high frequency instability. Note that the capacitor and common lead from the IC should be wired to the same point, this helps to reduce instability and current hum problems that can occur due to poor layout.

The 78XX series of regulators which come in a TO220 package generally can supply 500 mA of current. Therefore the maximum power dissipated in them is probably going to be 500 mA times the voltage difference between the input and output terminals. This might mean that the regulator has to dissipate 5 W of heat. Therefore an adequate heatsink must be used. The 78XX series is current limited which means that if the maximum current is exceeded, the output voltage drops towards OV. The regulator is thus short-circuit protected as long as proper heat sinking is provided.

Viewdata

Prestel, the British Post Office's viewdata service, becomes publicly available during early 1979. Angus Robertson takes a look at viewdata's background and its future implications.

MOST READERS will by now have come across teletext, the information service transmitted by both BBC and ITV and called Ceefax and Oracle respectively. These services have been widely promoted through both the TV programme magazines and directly on-air — teletext receivers can be seen at most respectable rental and television showrooms. Basically, a special receiver is used which decodes and displays the digital teletext signals which are transmitted on four of the total 625 lines comprising each television channel. Typical teletext services include news, weather, sport, and such topical subjects — however the maximum number of pages is only a couple of hundred, otherwise the transmission cycle becomes rather extended and the waiting time for pages becomes unacceptable. Viewdata uses the same transmission format as teletext, but instead of information being transmitted on the limited spare lines of a TV signal, telephone lines are used.

In Britain there are some 23 022 000 telephones connected to 14 862 000 lines (allowing for PBXs and extensions) and the capital cost of these, together with cabling to exchanges, is £1 548 100 000. The average number of daily calls per line is only 3.36, and obviously if subscribers can be persuaded to make more calls each day, this investment will be better utilised, thus effectively keeping phone charges down. The speaking clock is one such 'traffic generator' receiving around 400 000 000 calls each year — the Post Office hope that their Prestel viewdata service will be another.

The works. This shot shows the innards of a Mullard Teletext unit. The size could be reduced even further to fit inside a TV set.

Viewdata systems can appear in many different forms and guises — you don't have to use a domestic TV set. In fact, there's no reason why the system shouldn't be as an accessory to the telephone rather than the TV.

HOW IT'S DONE

Information is stored at the viewdata centre in much the same way as teletext, using a small computer and bulk disc storage. However, with teletext each page is accessed and transmitted every 30 seconds or so, but viewdata pages are only transmitted when a viewer makes a specific request — which makes it a considerably more efficient system and able to handle many millions of pages rather than teletext's few hundred. More importantly, since a telephone line must be established to the viewdata computer to receive information, the computer can then accept other instructions from the home terminal making it totally interactive — in effect it means a commercial computer terminal in ones living room or office. However, unlike a commercial computer terminal, the protocol required to communicate with it is very simple and can be understood even by children after only a few minutes instruction.

Perhaps I should make the rather important point that unlike the free teletext service, charges are made for accessing viewdata pages and these can accumulate rapidly while one browses through the system. One other important difference is that while teletext information is originated by the BBC and ITV, the Post Office is only offering its Prestel viewdata service as a 'medium' in much the same way as the telephone system. In other words, private companies and organisations can rent a telephone, and then transmit whatever information they so wish — the Post Office will originate no pages itself, other than indexing, although certain PO departments may rent pages themselves for various services such as directories, dialing codes, postal charges or whatever.

Obviously the normal laws of libel and decency apply, but pages will not be vetted as such by the PO. However, subject matter should be within a specific sphere in order that indexing can be provided.

This might appear rather complex, but in practice is very simple and the system is designed to allow rapid access of information without recourse to directories. Basically, each page provides prompts leading toward other pages in the form of a maximum of 10 choices for further information which are then simply accessed by pressing a single digit on the receiver keypad. This new page should in turn provide further prompts until the required information is reached — the final page has a prompt leading back to the route's beginning so one can start again.

In the initial stages at least, Prestel will be primarily providing 'hard' information such as classified advertisements, houses and cars for sale, stockmarket results, entertainment guides, holiday and travel timetables, hobbies and pastimes, cars, education, agriculture and farming, and employment. In addition to information openly available to all users of Prestel, closed user groups can also be created. This is of particular interest to companies and organisations that need to supply rapidly changing information to a large number of outlets widely scattered around the country (or world), such as travel agents, banks, building societies, chains of shops and wholesalers, service departments and so on. In this case, only preselected users will be permitted access to certain pages — these users might for instance have to pay an additional service charge or simply belong to a particular group of companies.

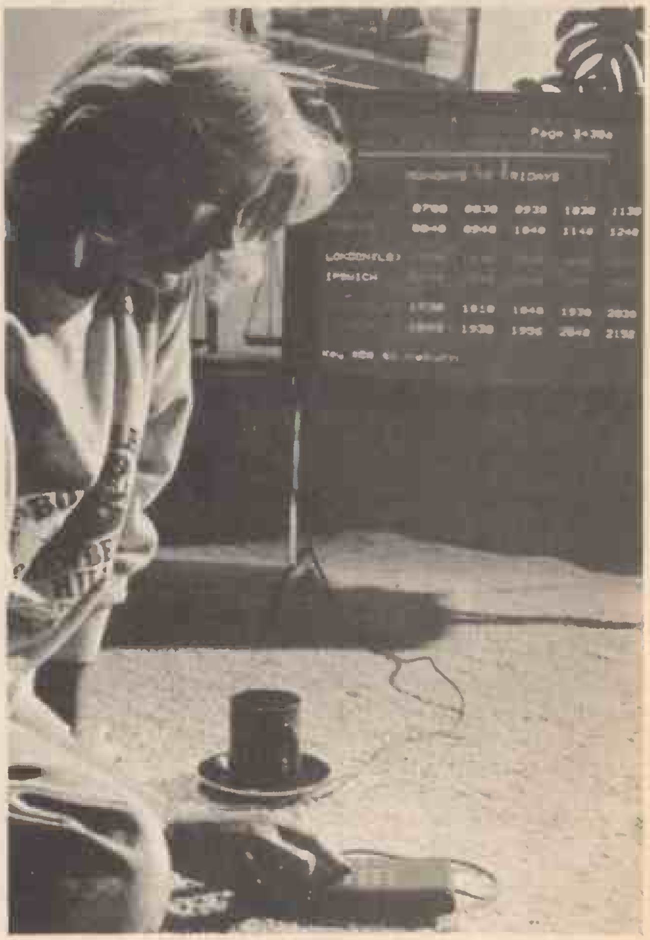
When Prestel is eventually fully operational, the interactive capability will allow information to be passed back from user to the original information provider. For instance, if one has been examining airline reservations, a booking could be completed through the Prestel system and (potentially) could also be paid for using a credit card (whose number Prestel could conveniently also store). Similarly, one could complete a sales transaction and the system could be on-line to banking computers enabling one to examine up-to-the-minute statements and make transactions directly without paper of any form. Prestel can also be used for tasks such as calculating mortages (which requires considerable effort on most pocket calculators). One of the first Prestel pages demonstrated almost three years ago was one of interactive games although these are not being initially provided on the public service. The Maze Games provided mazes of seven different complexities and one has to move a marker around using four digit keys — virtually impossible with the most complex!

TOMORROW THE WORLD

Maybe here I should say that eventually there might be many viewdata services operating both in Britain and around the world — the PO Prestel service is just the first and the PO certainly does not have a monopoly over users of its telephone lines. Mullard Research Laboratories have been privately demonstrating their own viewdata system that uses a radically different indexing system. Eventually, this might be made available to the public. Since one of the principle economic necessities of viewdata is that it should be available countrywide for a local telephone charge, thus requiring a wide network of computers or lines, the PO will have an initial advantage since many different organisations will be using those same computers and lines.

It might be interesting to look at the charges being made for the PO Prestel viewdata service. Users will either buy or rent a viewdata receiver from their local TV shop and this will be plugged into a normal PO jack socket as used for extension telephones. Actual receiver cost is difficult to estimate but will probably initially be about £700 or £18 per month. To contact Prestel, pressing a button automatically dials a special telephone number. The computer answers automatically with a request for the receiver's 'user number', which is stored electronically. When this has been received by the computer, it offers the first indexing page and charging commences.

Apart from the local phone call which works out at 22½p per hour in the evening and at weekends, there is a 2p per minute charge while connected to the computer. Some pages will be free such as indexing and advertisements, while others will carry a charge which is prominently displayed in the top right corner of the screen. This varies between ½p and about 10p although higher charges are possible for valuable information. Most information works out at around ½p to 2p, with only topical news items and such at an extra cost. This charge per page is paid directly to the companies that supplied the information, less a 5% handling charge for the PO. In addition, information providers (as they are



termed), pay additional charges for having their information stored on Prestel in the first place. The 'A' rate applies to regularly updated information and comprises a £4 000 a year service charge with a £4 per frame charge on a one year contract reducing to £2 400 a year and £2.40 per frame on a five year contract. The 'B' rate applies to more archival information that is only occasionally updated for which an annual charge of £1 000 is levied with a £1 per frame storage charge — however, ½p is deducted from each frame access to cover the increased cost of bulk storage. This second rate is appropriate for encyclopedias which might require about 200 000 frames storage and for which a greater waiting time than normal one or two seconds might be acceptable, so that frames could be retrieved from tape or some such system.

IMPLEMENTATION

So how is viewdata actually implemented? The frame format is identical to teletext, 24 rows of 40 characters with seven colours. However, the top line is reserved for page and charging data and the name of the information supplier, while the bottom line is used for computer messages. Information between receiver and computer uses the PO DATEL 600 service which provides a 1 200 baud (bit/sec) frequency shift modulation circuit between computer and receiver (120 words/sec) and a 75 baud link in the reverse direction for keypad commands.

One of the many possible applications for a viewdata type system is the fast dissemination of quickly-changing information. This could be financial, advertising or weather information, although some applications won't even be thought of until the system is in common use!

Although early receivers used standard PO modems, this would have been totally uneconomic for a public service and so the PO has relaxed one of its most stringent rules on the supply of equipment connected to the public switched telephone to allow private industry to develop and sell direct to consumers a vastly simplified modem built into the receiver itself. This change is only part of a broader attitude that the PO has been taking during the past couple of years which should see other items of telephone equipment and new services becoming available over the next few years (and which I shall be writing about shortly in Hobby Electronics).

One of the many possible configurations for a Viewdata terminal. This one would be suitable for someone with the home computing bug!

The computers used for Prestel are GEC 4080 types using 70Mbyte discs (storing about 70 000 pages each) and these operate in pairs at each Prestel computer centre, each with separate memory, but capable of accessing the other. The computer centres will have a large number of 'ports' which comprise telephone line switching answering, modem and a line buffer with a 1Kbyte memory which temporarily stores a page transferred from disc while it is being transmitted to the receiver. It is hoped that each computer will support some 700 simultaneous users engaged only in information retrieval, while this would have to be reduced for

The system which made it all possible — the widespread use of Ceefax and Oracle systems makes the connection to the phone lines a feasible proposition. It's simply a matter of arranging for the system to get its information from the phone rather than the top few lines of the TV picture.

services requiring more processing time such as games and calculations.

Message services will also become available so that users can send written messages to each other — Prestel is even going to be linked to the international telex network so that users will be able to send messages to any telex users worldwide — and vice versa of course (useful for small businesses that cannot justify the £500-odd rental for a telex). Although initially Prestel will operate from a central London computer centre, in the early years of the project this particular centre will become the national update computer which information providers will access to change their information, while further computer centres in the north and south of London will provide the local Prestel service. Other areas getting computer centres (with twin computers) include Glasgow/Edinburgh, Manchester/Liverpool and Birmingham — further centres will be added as demand is generated. Projections vary, but around 1 000 000 Prestel viewers are anticipated by 1985 although in early years business and commercial users will far out number private consumers.

There might be a few stumbling blocks to cross, but viewdata is here to stay. When the various interactive and message services commence operation, demand should increase considerably. I'm even thinking of becoming a customer myself! **HE**

With Viewdata, it will be possible for industrial users to send information to the system for 'publication' via their own terminal.

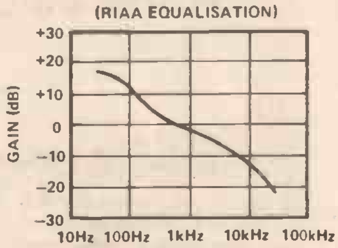
Short Circuit

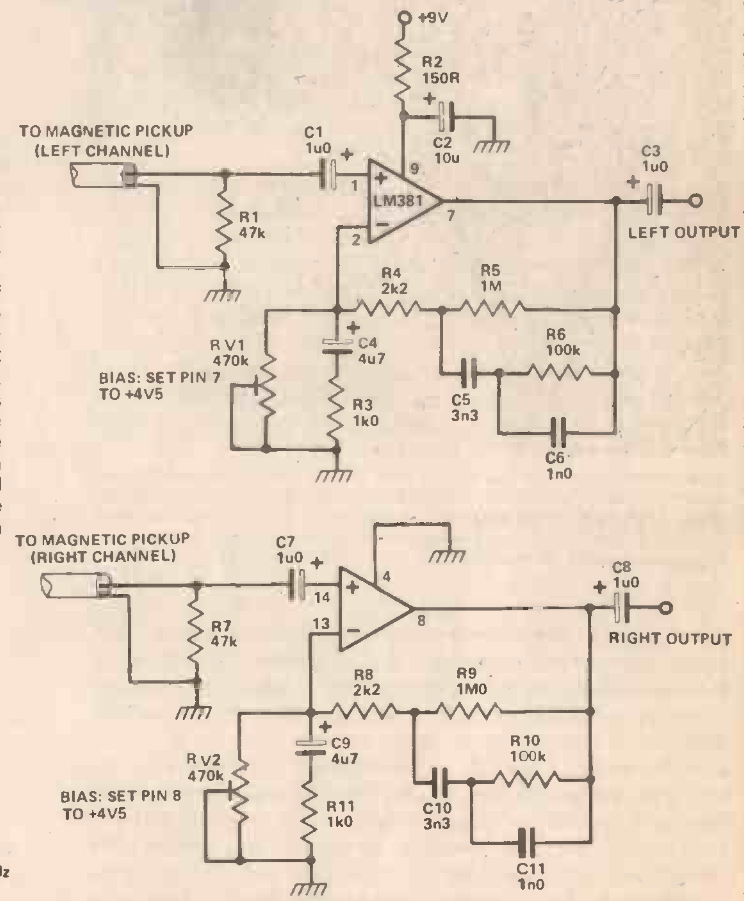
RIAA STEREO PREAMPLIFIER

There are two types of record player pickups, ceramic and magnetic. The first type is the cheapest and generally gives a large output voltage (0.5 V). This type of pickup does not usually require any frequency response correction, but the sound quality produced is not as good as that which can be achieved with a magnetic pickup. Records are cut with a frequency response such that when they are replayed with a magnetic pickup and a preamplifier with a RIAA equalisation (Recording Industry Association of America) the reproduced sound will be as similar to the original as possible.

The disc is cut at constant amplitude, except from 500 Hz to 2120 Hz where it is cut at constant velocity. When this disc is replayed with a magnetic pickup, the relative output voltage rises with frequency, this being due to the fact that the magnetically generated voltage is proportional to the velocity of the stylus as it moves sideways in the groove. To restore the original sound quality, a preamplifier with a frequency response that gives decreasing output with increasing frequency is required. This response curve is known as the RIAA equalisation and it is tailored accurately to fit the cutting and replay processes. The signal level from a magnetic pickup is low, generally 20 mV pp and so a low noise preamplifier is needed.

The circuit shows a realisation of this requirement. The low noise amplifier is the LM381 made by National Semiconductors. A DC bias control is included RV1, 2), and the feedback components generate the RIAA curve. Use screened cable for the wiring to the pickup, keep the circuit away from transformers (and the pickup and its wiring) and connect all the earths shown in the circuit diagram together, near to the IC.





Project Daedalus

Earlier this year the British Interplanetary Society published a report on 'Project Daedalus'. It was nearly 200 pages long and took five years to write. It's packed with detailed calculations for the design of an interstellar craft. These show that the capability is almost within our grasp. Phil Cohen analyses the results of the report.

The DAEDALUS PROJECT is the brainchild of the British Interplanetary Society, founded in 1933 with the aim of advancing the space industry in the UK.

The 'study group' which worked on the project consisted of a small number of professional scientists and engineers from establishments such as the UK Atomic Energy Authority; British Aircraft Corporation, RAF and City University, London. The work was carried out in their spare time over a period of five years and culminated in the publication of a JBIS (Journal of the British Interplanetary Society) report nearly two hundred pages long which contained a *summary* of the results of the study!

The name Daedalus is from the Greek. In legend, Daedalus (meaning 'cunningly wrought') built for himself and his son, Icarus, sets of wings. During their flight, Icarus disobeyed his father's instructions and flew too close to the Sun. The wax holding his wings together melted and he was killed. Daedalus, however, reached his destination without mishap!

The Daedalus craft is an unmanned interstellar probe whose purpose is to gain information about nearby stellar systems — and especially to search for planets, which may contain the first alien life we contact.

THE MISSION

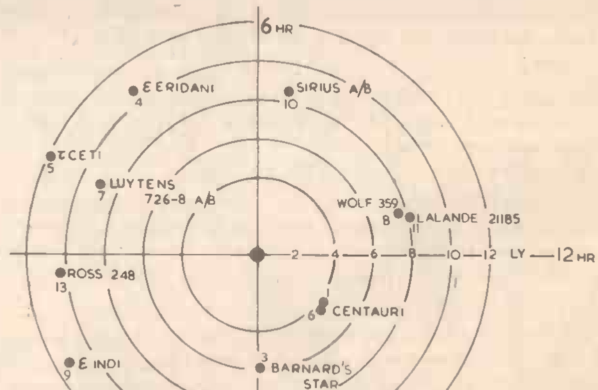
The mission of the probe is to accelerate to about 12% of the speed of light (which works out at 3.6×10^7 m/s, or 20 000 miles per second!) and fly past Barnard's Star (5.91 light years (Ly) away — about 50 years at 20 000 miles per second), dropping probes which will collect data about the star and its (possible) planetary system. This information would then be transmitted back to Earth.

Barnard's Star is not definitely known to have planets. Recent observations have shown that the star 'waltzes' slightly — suggesting that its 'dancing partner' is a massive planet somewhat similar to Jupiter. This 'waltz' is, however, not pronounced enough to prove with any degree of certainty the existence of a planetary system.

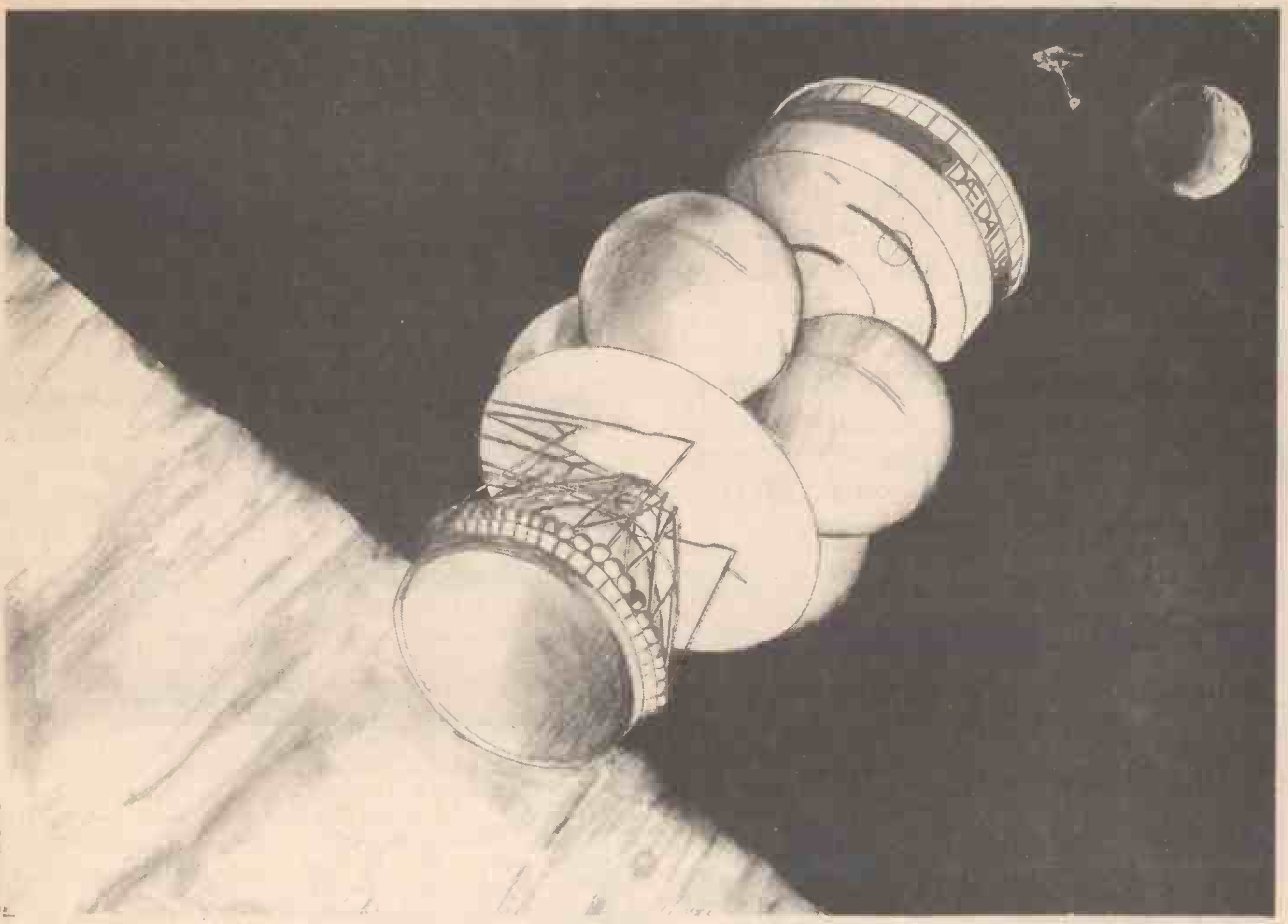
Why Barnard's Star, then? There are two other stellar systems closer to us — Proxima Centauri at 4.3 Ly and Alpha Centauri A/B at 4.4 Ly. Alpha Centauri A/B is a double star and must surely be as interesting as Barnard's Star?

The answer is that the Daedalus Project is an attempt, not to design a probe completely, but to provide a design framework for further studies. The design team considered that if it was possible to use a Daedalus-type craft to reach Barnard's Star, it should be possible to get to Alpha or Proxima Centauri also.

One major consideration in deciding on the actual 'mission profile' chosen was that it had to yield some sort of results within a human lifetime. This was because it was considered unlikely that any state would undertake a longer-term project!



The positions in space of the stars closest to the sun. The figure beside each star is it's 'interest' ranking. These were arrived at by taking into account the distance, the 'uniqueness' of the star (how frequently similar types occur) and the probability of habitable planets. The obvious choice for a mission would be Alpha Centauri but the probe was designed to reach Barnard's Star for good measure.



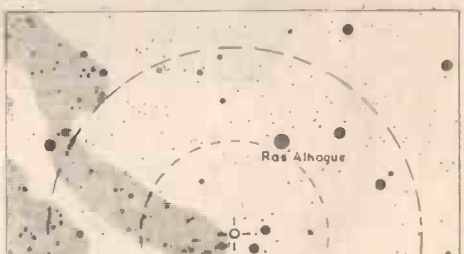
GAVIN ROBERTS

The first twenty years of the project would be spent designing, building and fuelling the craft in orbit around Jupiter (for reasons which will become apparent later). The craft would then accelerate out of the Solar System for 2 years, at which time the first stage would be dropped to save weight. The second stage would then take over for another 1.8 years, accelerating the craft to its final, awesome speed.

There would then come a 40-year wait, with the craft transmitting only data about the interstellar medium — the dust concentration, for instance, which would be invaluable for the design of later craft.

At the end of this period the craft would be close enough to its target to detect the existence of any 'gas giant' planets similar to Jupiter. At about this point it would start to disperse its probes. The dispersal has to take place this soon because it takes a *lot* of power to change course at that sort of speed and the probes would have to fly past the star itself as well as any planets, which may be at wide orbits. The decisions about which direction to send each probe would be taken by the main computer on board the craft. As radio waves would take about 5 years to reach Earth from the ship by this time (and thus a ten-year wait for a reply!), *all* decisions would have to be taken by the ship's computer.

As the craft reached the outer limits of the system, the probes would begin to send back information to it. It would relay the information back to Earth, the total transmission time being about 3 years — the beginning of the message would still only be half-way home when the craft stopped transmitting!



Barnard's Star as seen from the Earth. Unfortunately it's not visible to the naked eye. It appears in the constellation of Ophiuchus.

THE CRAFT

The Deadalus probe has a two-stage engine, the first stage being dropped to save weight when its fuel is finished. These two stages propel the payload of smaller probes, computers for controlling the mission, communications and other equipment.

The first stage weighs over 40 000 tonnes fully fuelled and is about 150 metres long and 190 metres wide. It consists only of a giant motor and six spherical fuel tanks. It 'burns' for about two years continuously at the start of the mission. The designers also took into account which materials would be used for the craft's construction — the materials used for the engine's reaction chamber, for instance, have to stand temperatures from 3°K (3 degrees centrigrade above absolute zero) to 1600°K. This means using an exotic alloy. The one chosen was molybdenum with titanium, zirconium and carbon, internally nitrided — you don't come across alloys much more exotic than that!

The fuel tanks are dropped during the course of the 'burn' to save weight. As they weigh over 16 tonnes each this is quite a saving. Remember, the fuel is being used up also — the first stage itself, without fuel and tanks, weighs only 100 tonnes.

The second stage is almost the same as the first, except that it's about 1/10th of the mass and about ½ the size. It has four fuel tanks which are also disposable and carries the payload bay. This is about 30 metres long and about 50 metres diameter. It holds (starting at the front) an erosion shield to protect the craft from interstellar dust erosion, the eighteen disposable self-propelled probes, the main telescopes, the communications equipment and computers and the 'wardens'.

As the craft will be on its own for some decades, and as only the most optimistic would expect there to be no failures on board during all this time, it is necessary to have some form of automatic repair. This is where the wardens come in. Controlled by the main computers, they are multi-purpose self-propelled robots, flexible enough to perform any repair or replacement necessary (within reason). The ship would also carry a large complement of spares — hopefully, the wardens wouldn't have to build anything from scratch.

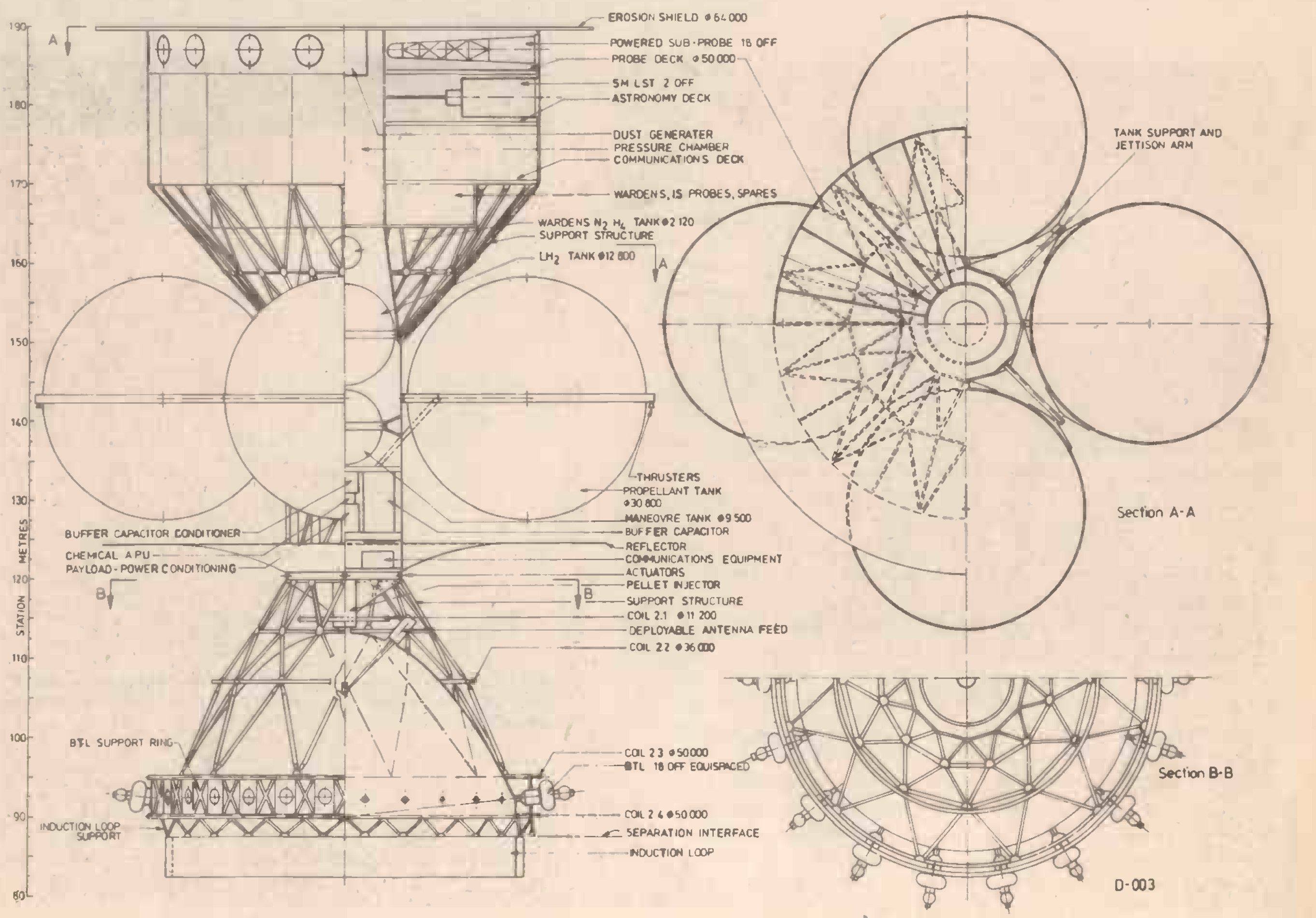
The ship would be 190 metres long at launch and would weigh over 54 000 tonnes — that's a lot of mass to get moving!

THE PROPULSION SYSTEM

The starship is propelled by a series of very small nuclear fusion explosions, occurring at a rate of 250 per second.

Earlier systems had been proposed by other groups which suggested using conventional atomic bombs ejected from a craft carrying an immense 'pusher plate'. The momentum from the explosions would be transfer-

A diagram of the second stage. This is similar to the first stage but carries the payload — a package of smaller probes to be deployed near the end of the journey.



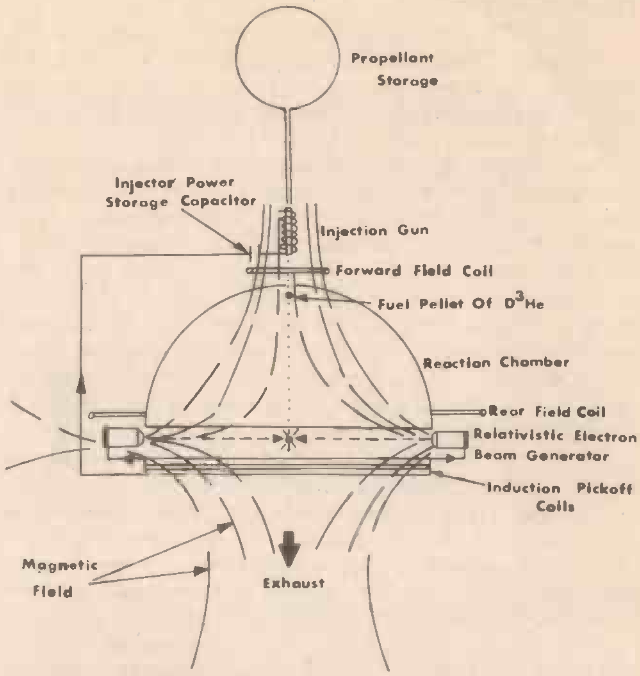
red from the pusher plate to the craft at a reasonable rate via a pneumatic spring system. This type of system was dropped because of the required size of the vehicle, "the limitations imposed by the nuclear test-ban treaty and the difficulty of testing the system."!

The Daedalus propulsion system contains the energy of the explosions in a very strong magnetic field and releases it between explosions by squirting out the explosion products at an exhaust velocity of about 10^7 m/s.

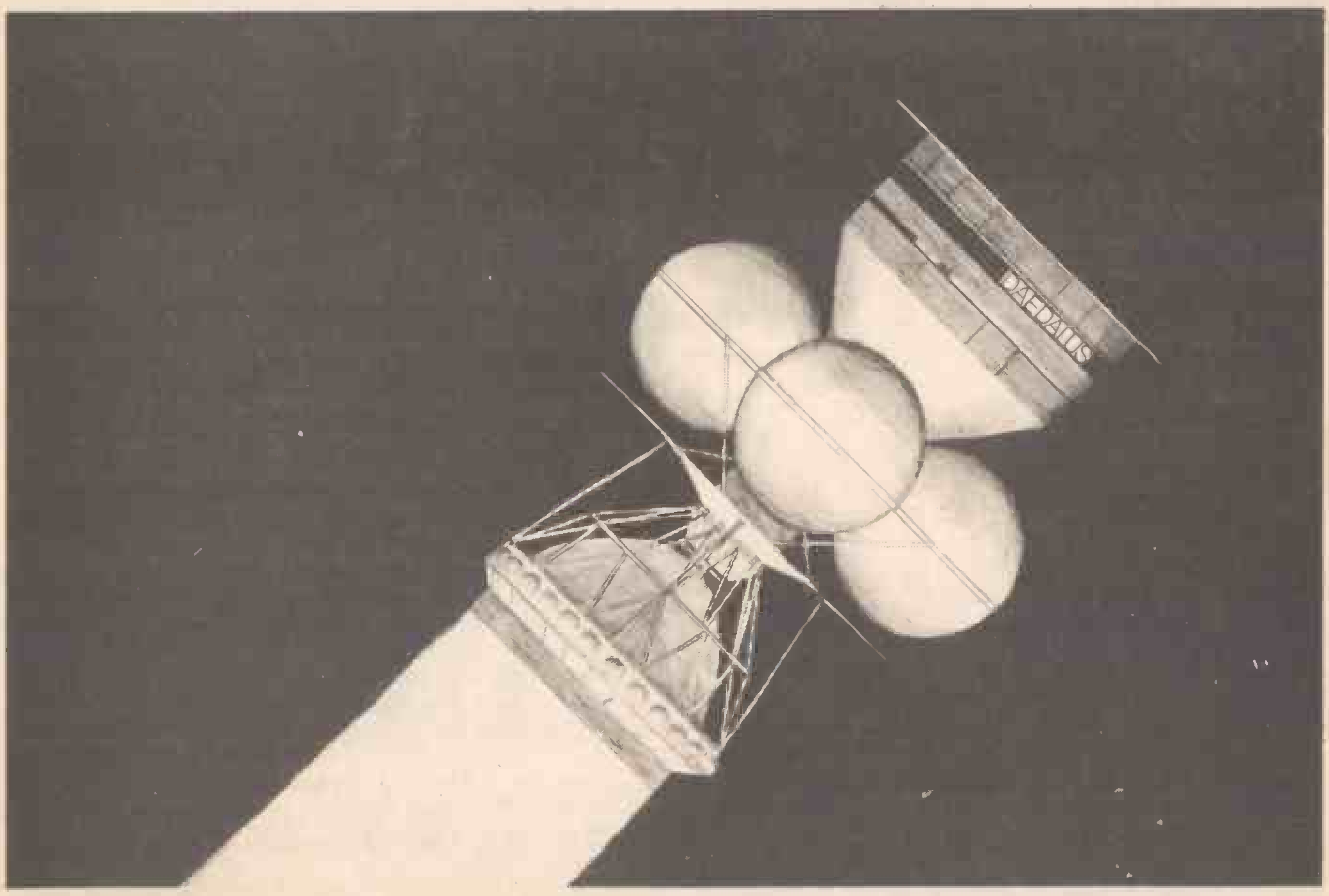
The fuel for these explosions is a mixture of isotopes of hydrogen and helium in a solid fuel 'pellet' about 10 to 20 mm across. These are stored in fuel tanks at a temperature of 3°K (3°C above absolute zero) to keep them from melting!

The pellet structure is rather similar to a particular brand of sweet — a thin hard coating and a honeycomb centre. The coating is not made of chocolate, however, but of a superconducting material. This makes it possible to shoot the pellets into the reaction area by magnetic means at an acceleration of about 10^6 g. This phenomenal acceleration is necessary so that they can cross the gap between the pellet ejection system and the ignition point between the time when the last explosion has died down and the next one is required to start. As this happens 250 times a second, this crossing has to be fairly fast.

Once at the ignition point, beams of high-energy electrons are shot at the pellet. This vaporises the outer shell instantaneously, which increases the pressure and temperature of the centre to the levels required to ignite



The Daedalus propulsion system. This works by controlled nuclear fusion explosions. Solid pellets of a hydrogen isotope mixture are fired on by electron beams and a magnetic field contains the blast. See the text for a full description.



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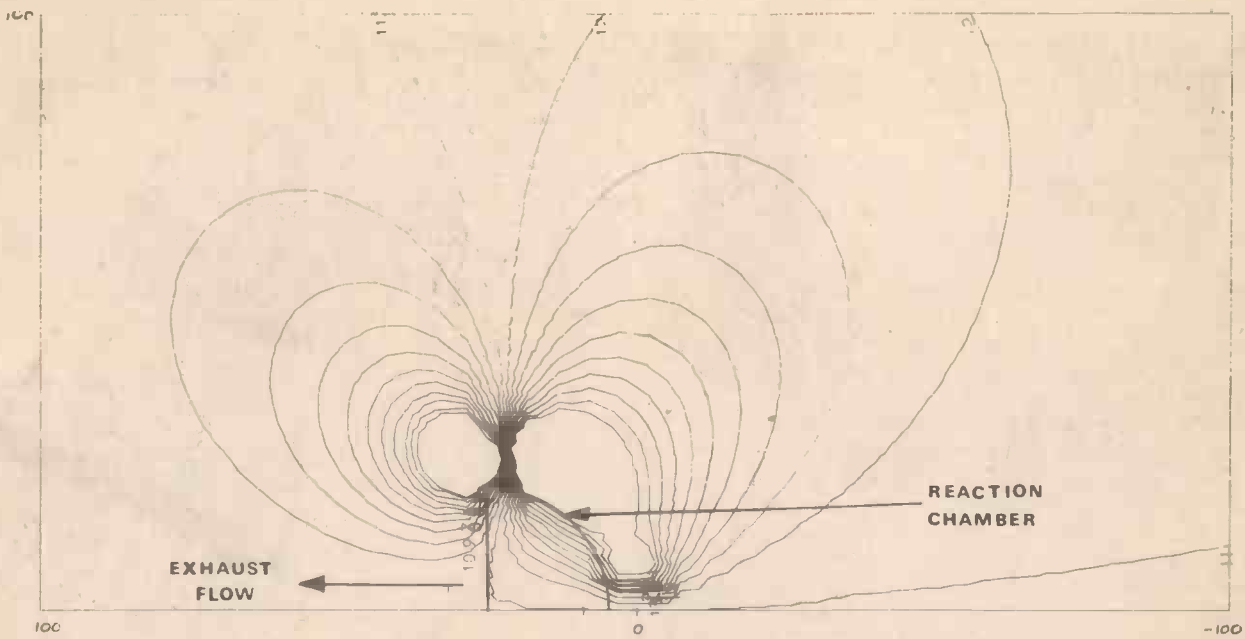
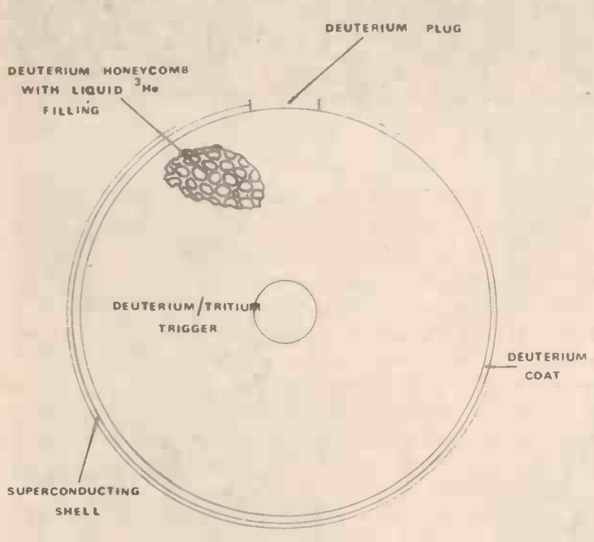


A computer-generated cross-section of the area around the reaction chamber, showing the magnetic field profile. The peak field generated in the coils would be about 14 Tesla.

The fuel pellet structure. The superconducting shell enables the pellet handling system to fire the pellet into the reaction area, where the boiling of the deuterium coat generates enough pressure to detonate the 'trigger' pellet. Each fuel pellet is 1 to 2 cm in diameter.



fusion. The ignition is helped by a 'trigger' particle in the centre.

The expanding plasma is trapped by immensely strong magnetic fields set up by two coils surrounding the engine. The coils generate a peak field intensity of around 14 Tesla and are cooled by liquid helium flowing through the hollow conductors to keep the temperature down to 4 K. The field is deformed by the explosion and (hopefully!) contains it and keeps it within the reaction chamber — exactly like the 'magnetic bottle' which can be used to contain nuclear fusion reactions in terrestrial fusion power generating stations.

One of the reasons for choosing the particular fuel used is that very little of the reaction energy is released as neutrons. This means that the engine is relatively 'cold' (in radioactive terms only!), as the electrons and protons from the reaction can be trapped magnetically, whereas neutrons cannot. This lack of neutrons means that very little shielding is needed to protect the rest of the ship — a weight saving.

Unfortunately, the fuel is rare on Earth and this brings its own problems. For the entire mission, about 3×10^{10} fuel pellets would be required — with a total mass of around 50 000 Tonnes. This would consist mainly of 30 000 Tonnes of helium-3 and 20 000 Tonnes of deuterium. As these are both very rare they have to either be produced artificially on Earth or 'imported' from elsewhere.

MINING JUPITER

One possible source of suitable fuel — the largest such source in the Solar System — is the atmosphere of the planet Jupiter.

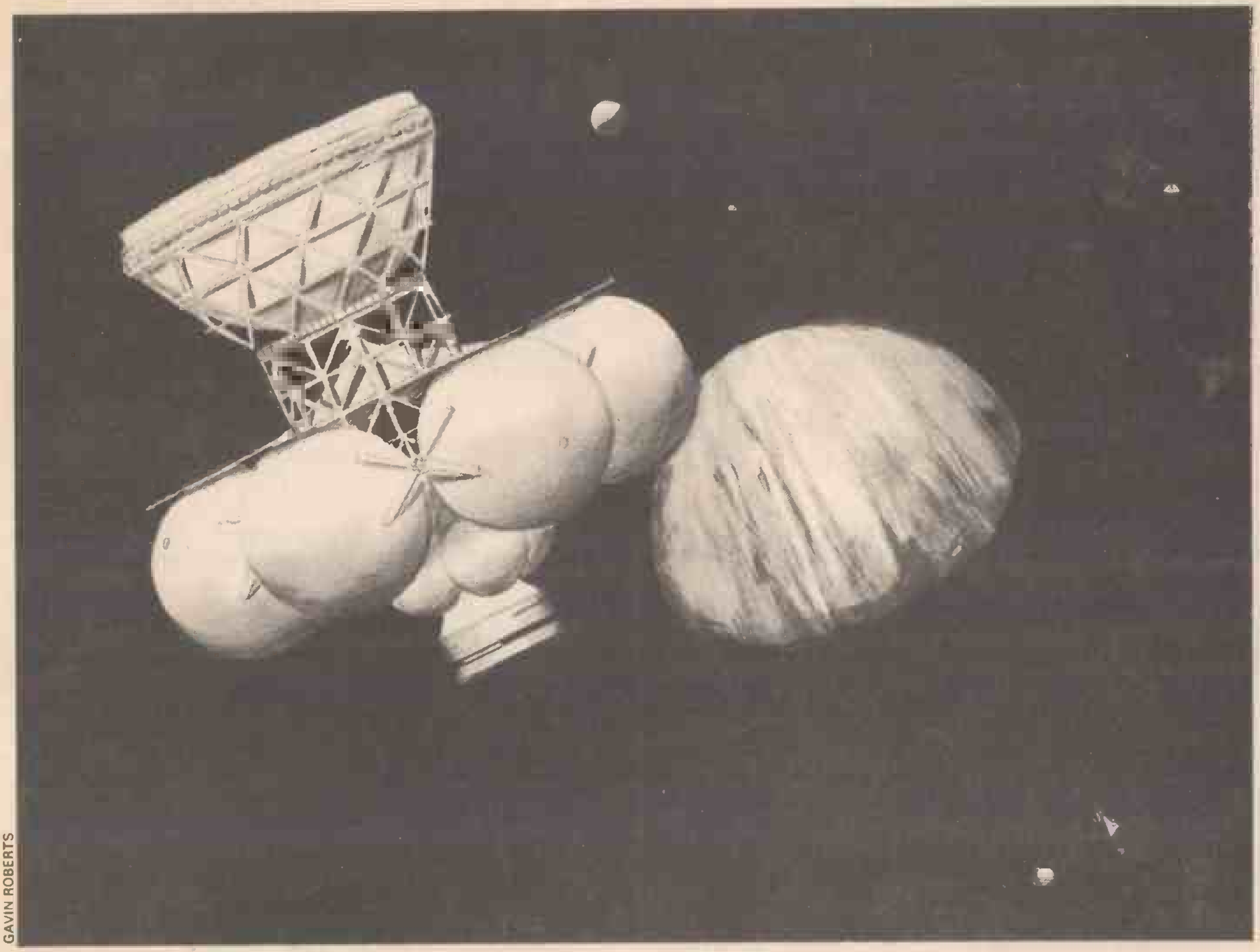
While just *getting* to Jupiter would be a major feat and the prospect of setting up factories around Jupiter to produce 50 000 tonnes of propellant seems daunting the reports points out that once 'mining' had started, the fuel produced could be used to fuel power station reactors on earth. The mining may well have been started due to economic pressures by the time a Daedalus-type probe is built.

As Jupiter has no solid surface, the factories could not be built *on* Jupiter but they could be built *in* Jupiter.

One possible design for such a factory would be a giant 'hot air balloon' filled with jovian atmosphere heated by the factory's waste energy.

The skin of the balloon would be woven of carbon fibres or a similar material. It would be 200 odd metres in diameter.

The factory would float in Jupiter at a level which had


GAVIN ROBERTS

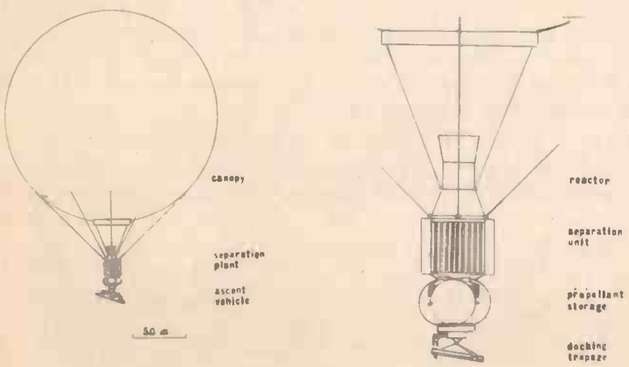
a pressure equal to the pressure of earth's atmosphere. Unfortunately, this would put it in Jupiter's weather, which has been observed to generate 90 m/s winds! Not ideal conditions for a balloon. The *vertical* atmosphere currents are an unknown quantity but may be even worse. The report suggests sending an atmospheric probe to study the conditions — this could probably be done using present technology.

Another little problem is how to inflate the balloon when it is initially dropped into Jupiter. One solution to this would be to fuel it with about twelve tonnes of liquid oxygen — which would burn nicely in the hydrogen-rich jovian atmosphere.

The factory itself would hang free of the balloon, with it's waste heat directed through a funnel into the neck of the balloon. It would weigh over 100 tonnes. About 128 complete factories would be used in total. These would probably be unmanned. With a 12-second communications gap between the factory and an orbiting platform there would probably have to be a fair degree of autonomy in the factory computer's operation.

The alternative—manning the factories—may, if it proves necessary, be the future equivalent of North Sea Oil drilling, with massive wages and long, dangerous shifts. It wouldn't be possible to fish someone out of Jupiter, though, if the factory collapsed!

The conditions encountered in space would provide problems for the Daedalus probe also, as it sped through space at 12% of light speed.



Preliminary design for a vehicle which would float in the atmosphere of Jupiter, allowing it to be 'mined' to provide the hydrogen isotopes required to fuel the Daedalus craft. The same fuel would be ideal for the production of 'clean' fusion energy for use on Earth.

PROBE DEBRIS PROTECTION

The chunks of rock which plagued Dan Dare and his ilk by ploughing through the walls of spacecraft during gaps in the plot are not as numerous in interstellar space as was once imagined.

In the main, the matter which will be encountered between stars consists of ionised and neutral hydrogen clouds and very fine dust grains.

The average mass of the grains is thought to be about 0.1 pg (or 10^{-16}kg). While this is not exactly enormous, the craft will hit quite a large number of them, all at a velocity of 20 000 miles/second!

There are two problems to be countered — the heating effect of the ionised gasses (as large numbers of high energy protons and electrons hit the vehicle) and the erosion caused by the impact of the dust. The designers predict that the erosion shield of the probe will reach a temperature of 193°K — well within reasonable limits.

The material used for the shield will probably be boron and the report concludes that a thickness of 9mm of boron will survive dust erosion long enough to protect the vehicle from the X-rays produced by the impact of protons and electrons (and of course the protons and electrons themselves) during the course of the entire coast period.

When the probe reaches the Barnard's Star System, however, it will encounter the same problem again, but on an entirely different scale.

The target system, if it's anything like our own, will be full of all manner of junk — ranging from material the same size as the interstellar dust all the way up to asteroids weighing up to 10^{12} tonnes! Of course, the likelihood of meeting something large is small, so to speak. The designers of the probe took as a target protection against a 0.5 tonne object.

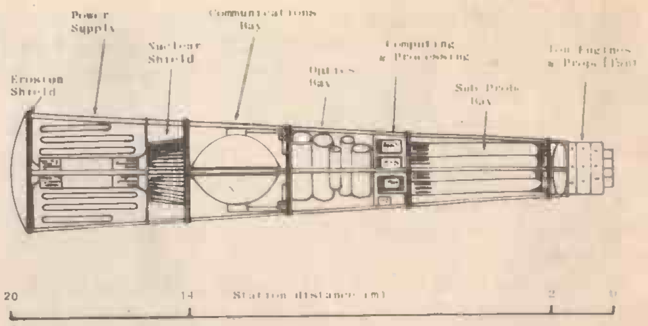
To protect the vehicle against half-tonne rocks coming towards it at 20 000 miles per second is not as difficult as it sounds, luckily! The system used is to fly a small chemically-propelled vehicle about 200 km ahead of the main probe and use it to deploy a smoke cloud about 100m thick and with a total mass of 6 kg. While this seems rather insubstantial, the calculations show that anything under 500 kg will be totally vaporised on meeting this cloud and that the expanding vapor will be too thin to harm the vehicle when it passes through it, 200km behind the smoke cloud and 0.005 seconds later. It seems that you can stop anything if only it's moving fast enough!

A similar method would be used to protect the smaller probes which are shot into other parts of the target system. The probe couldn't really be said to fly past the Barnard system — it punches several holes in it and flies *through* it!

SUBPROBES

Most of the information to be gained about the target system will be via the 220 tonnes of smaller probes the mother ship will carry. These will be 'launched' some distance from Barnard's Star and will follow carefully-planned trajectories through the system, transmitting information back to the main vehicle.

The probes (18 in all) would be designed for specific tasks—3 for terrestrial plants, 5 for stellar physics etc.



One of the subprobes. These would fly through the target system, sending information to the main craft which would relay it back to Earth.

They would each contain a debris protection system similar to the main ship's. In fact, there would be nineteen holes punched in the target systems detritus! There is an important principle in physics which states that you can't study anything without changing it — that's certainly true here.

The Daedalus craft would also carry five 'interstellar medium probes' for finding the shape of variations in dust concentrations, for example. These would be spread around the mother craft (three at a time, with two in reserve) at a distance of 1000 to 10 000 km. When the craft flies through the edge of a cloud of dust, the information from all four sources (including the main vehicle) would give information about the shape of the edge and how the dust varied throughout the cloud.

COMMUNICATIONS

Naturally, it will be useful for the probe to be in contact with the earth at all times — it should be capable of sending information back and receiving major 'policy change' messages.

During the boost phase, a large plume of plasma (dissociated sub-atomic particles) will trail the vehicle, making microwave communications impossible. For this reason the probe will carry a communications laser for use during the early period of the mission. This system will have a bandwidth (frequency response) of 20 kHz and a range of one light year (20 000 miles/second over one year). This requires a laser with a peak power of 1.3 MW, operating in the infra-red (which the plasma would be transparent to).

When the boost phase finishes, the craft will deploy a microwave transmitter/receiver which will be mounted in what was previously the reaction chamber, using the chamber to focus the microwaves. This would operate at 2.24 — 3.02 GHz and would have a data rate of 864 k baud (864 000 bits/second). The range would be about seven light years — sufficient for the 'Post-encounter' transmissions of data about the interstellar medium on the far side of the targer system. One thing which had to be taken into account in designing the system was that transmissions would be received at a lower frequency due to the Doppler effect!

Less powerful transmitters and receivers would also be required for communication with the disposable probes and the wardens.

THE COMPUTERS

Perhaps the one aspect of the Daedalus project which will require the greatest extension of present-day capabilities is the self-repair function.

The concept of the multi-purpose 'warden' robots is all very well but these are, after all, only as intelligent as the software (computer programs) which control them.

All the way through the report the wardens crop up as a sort of *deus ex machina* for repair and even improvement of the craft.

As was mentioned before, the speed of radio waves limits the amount of control from the earth to an absolute minimum. The report shows, by extrapolating data from military and commercial aircraft, that a long flight without on-board repair is not feasible.

This means, in effect, that before the project is undertaken there must be a major advance in the state of what is known as 'artificial intellegence'.

The ability of modern computers to deal with predictable repairs — items which will inevitably wear out in a certain way — and such other tasks as will be known in advance is probably adequate when projected to the mission date. However, the complete inability of software as it stands at present to deal with a) un-predictable events and failures and b) failures *in the software itself* is discouraging.

Then again, looking back at the advances in computing in the last few years . . . who knows?

The memory capacity of the system, calculated from the amount of information to be stored during flypast for transmission back to earth, is about 3×10^{10} bits. Using the latest in high density information storage — the magnetic bubble memory — this would require about 200 000 integrated circuits, weighing 1½ tonnes!

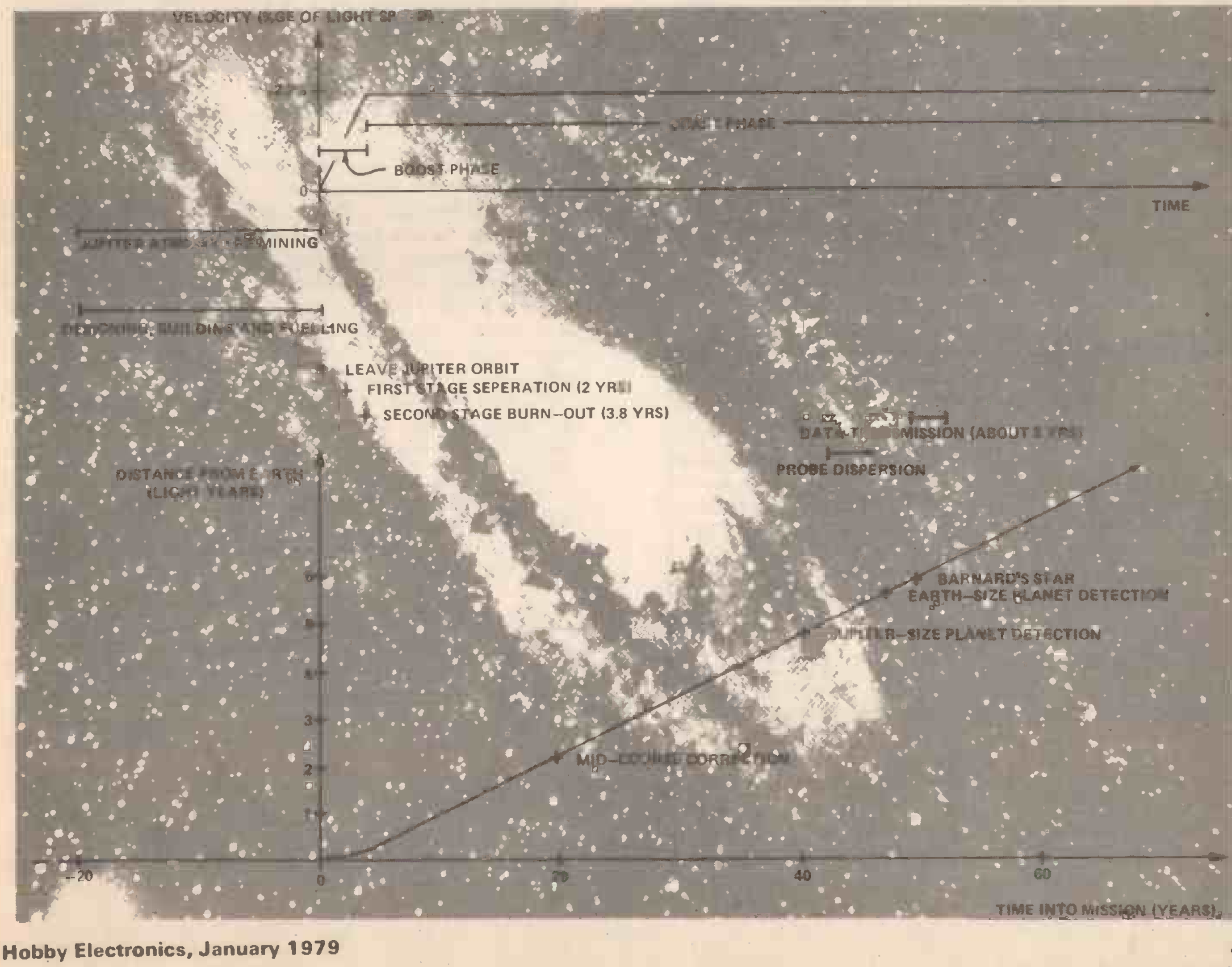
SUMMARY

The Daedalus Project report makes fascinating reading. What is most impressive is the level of *detail* to which everything has been thought out. For instance, the material used for the insulators in the electron beam generators (part of the engine) was chosen to be Berylia, which has the required mechanical and electrical properties. The mere fact that the designers have gone into such detail lends the report much credibility.

The whole thing is written in a clear (if highly technical) manner with references to all sources of data — all in all a very impressive work — but what use is it?

The report will have several effects. One will be to swell the ranks of the British Interplanetary Society — not a bad thing. Another may be the serious consideration at some time in the future of a Daedalus-type project. It's worth noting that the same society produced a feasibility study on a lunar mission some *thirty years* before Appollo 11! **HE**

Further information on the BIS is available from: The Executive Secretary, The British Interplanetary Society, 12 Bessborough Gardens, London, SW1V 2JJ.



Into Electronics

by Ian Sinclair — Part 3

In this part we enter the field of active components: Semiconductors. First we deal with the materials from which diodes and transistors are made from, then we move on rapidly to applications.

ONCE UPON A TIME, folks, life looked simple. We had conductors, which conducted electric current and insulators which didn't. Then we discovered *why* some materials conduct and others don't, and it's not so simple as we once thought. As usual it all boils down to these electrons. The best conductors, metals, have their atoms arranged so that some electrons are loose, about one electron for each atom. These loose electrons can travel through the material, so that the metal is a conductor. We once thought that this was the only way that electricity was conducted through a solid material, but it's not.

Around the turn of the century, a physicist called Hall, who had set up an experiment to test the sign of charge of the current carriers in metals, found that positive charged particles seemed to carry current also. We now know that these positive particles exist only in materials that form crystals and that they are really gaps in the regular arrangement of electrons. These gaps can move and behave like positively charged particles. We call them holes. What convinces us that they are not truly particles is that they cannot be removed from the material as electrons can. Inside a metal, though, the hole is as 'real' as the electron.

TABLE 1
RESISTIVITY AT 20°C

The resistivity figure for a material is a way of comparing the resistance, R, of samples of standard size. For a wire which is s metres long and A m² cross-section, the resistivity is $\frac{RA}{s}$, units ohm-metres. The resistivity figures for some materials of interest are shown below.

Material	Resistivity in ohm-metres
Aluminium	2.7×10^{-8}
Copper	1.7×10^{-8}
Iron	10.5×10^{-8}
Constantan	45×10^{-8}

(Constantan is an alloy of copper, nickel and managanese used to make wire-wound resistors).

Germanium	about 10[illegible]
Silicon	about 10^{4}
Diamond	10^{13}
Perspex	10^{19}
Quartz (silicon oxide)	10^{20}

SEMICONDUCTORS

Between the good conductors, like metals, and the insulators like so many non-metals, there are some curious materials called semiconductors. The difference between semiconductors and other materials is not so much their resistivity (Table 1) but the way in which the value of resistivity can be altered. Take a piece of metal wire, measure its resistance at room temperature, then heat the wire. What happens? The resistance increases by only a few percent. Try the same measurement with an insulator, and the resistance is too high to measure, both times. Now use a chunk of a pure semiconductor material. Whatever value of resistance it had at room temperature, it's a darn sight less when you heat it, not just a few percent but a really big change. A typical result might be a change from 4k to 200R for a temperature rise of 50°C.

That's a very obvious difference, and the other difference is even more important. Compare two bits of wire, one pure copper, the other copper with about 1% zinc. The resistivity values are pretty much the same,

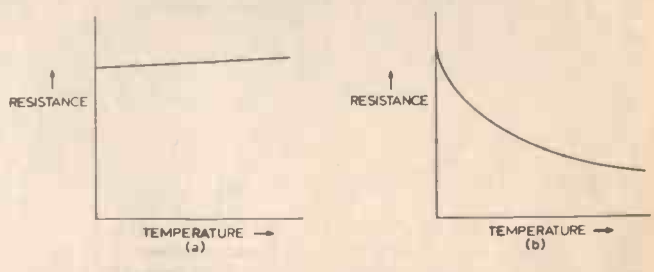


Fig. 1. Resistance/temperature graphs (a) for a metal, (b) for a pure semicondutor.

because the impurity (zinc) has as much effect as you would expect from the quantity — 1%. Try mixing two insulators and you still can't measure any resistance charge.

Semiconductors behave quite differently. Almost immeasurably small amounts of impurity will cause the resistance of a sample of a semiconductor to drop enormously. The amounts of impurity needed are not 1%, or 0.1% but something like one millionth of one percent to make a huge change in the resistance. Difference No. 2, and more to come.

Pure semiconductors, like germanium and silicon, are more like insulators than conductors. Adding other elements to the semiconductors will make them into conductors and we can even choose how they conduct. Elements such as phosphorus make semiconductors conduct mainly by **electron** movement. Elements such as indium make semiconductors conduct mainly by **hole** movement. The addition of impurity is called **doping** and is rather a delicate operation, because we don't exactly operate with bucket loads! Nevertheless, we can now make semiconductors which have whatever resistivity values we want (within reason). What's more important we can make them **N-type** (most of the carriers electrons) or **P-type** (most of the carriers holes) by doping with the appropriate materials. Incidentally because these doped materials have a good supply of electrons or holes, heating them makes little more difference to their resistance value than it does for a metal.

UP THE JUNCTION:

We wouldn't think much of the show so far but for one discovery — one of the discoveries that's changing life around us right now. Take one tiny crystal of silicon or germanium and slice a wafer from it. Now dope it on one side with indium (making P type) and on the other side with phosphorous (making N-type). Heat it up in a vacuum, so that the atoms of the doping materials can spread into the semiconductor and at some stage in the procedure, P and the N bits will meet each other. Logically enough, this meeting place is called a junction. We don't make junctions this way now, but the junction of P and N is the big step forward, because of its behaviour in a circuit.

Try to imagine a junction. Fig 3 is a diagram that helps, showing + and — signs to show which sign of carriers can move. If this junction is made part of a circuit with one wire connected to the P type side of the crystal

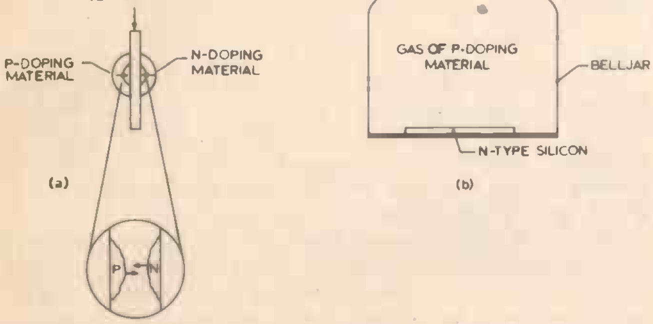


Fig. 2. Creating a junction (a) Diffusing solid material into both sides of a thin crystal, the old-fashioned method. (b) Modern method of diffusing the impurity atoms into oppositely doped material from a hot gas atmosphere.

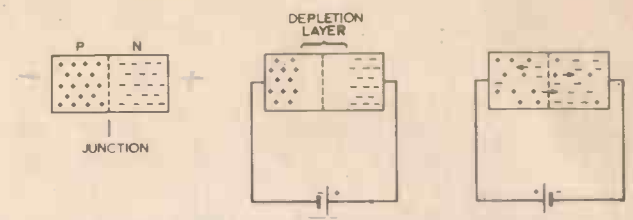


Fig. 3. Junction action. (a) Diagram showing the signs of the mobile charges (b) Action under reverse bias, carriers are drawn away from the junction. (c) With forward bias carriers cross the junction, so that the junction conducts.

and another wire connected to the N-type side, the action of the junction will depend on which way round the circuit is connected. With the N-type side connected to battery + and the P-type side to battery —, no current flows. Why not?

Good old-fashioned 18th century electrostatics, that's why. The battery + attracts the loose electrons of the N-type material away from the junction, and the battery attracts the loose holes of the P-type material away from the junction. Nothing moves right round the circuit, so no current flows. The junction is depleted — drained of electrons and holes, just a chunk of non-conducting material. This connection is called the **reverse bias connection.**

DIODES

Now, think of the battery connected the other way round. This time it's a very different story. The battery + pulls loose electrons across the junction from the N-type side. The battery — pulls loose holes across the junction from the P-type side. Everything is moving, it's all happening, current is flowing; the bias now is **forward.** The whole arrangement of P and N materials meeting at a junction is called a **semiconductor diode.**

The P-type part of the diode is called the **anode**, and the N-type is called the **cathode**. The diode is forward biased when the anode is more positive than the cathode. A germanium diode will just start to conduct when the voltage between anode and cathode is about 0.15 V, a silicon diode will just start to conduct when the voltage between anode and cathode is about 0.55 V.

When the bias is in the reverse direction, there are so few electrons and holes (called the minority carriers) left in the junction that the diode is almost an insulator. A reverse current of only a few nanoamps ($1 nA = 10^{-9} A$) is typical.

We use diodes, as described above, in great quantities; in power supplies, in radio reception, in computing. Details later, folks, but most of the uses for diodes stem from one thing, the current flows one way only. The symbol for a diode shows this direction of

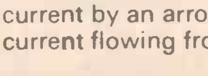


Fig. 4. Diode symbol and terminal names.

current by an arrowhead, using the usual convention of current flowing from battery positive to negative.

ZENER DIODES

One exception is the **zener diode,** though. This type

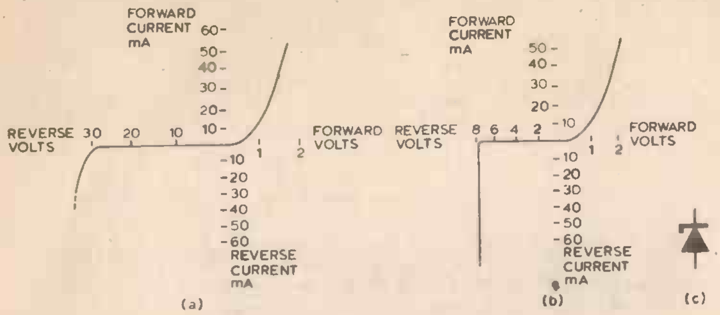


Fig. 5. Diode characteristics. (a) Signal or rectifier diode. Note the difference in the sizes of the voltage and current scales in the reverse direction. (b) Zener diode. The reverse current starts at a definite voltage, and large reverse currents can pass. (c) Zener diode symbol.

of diode (different symbol, too) is always used reverse-biased, but conducting. Reason is that a junction that's heavily doped on each side will break down and start to conduct if enough voltage is put across it on the reverse direction. How much voltage? Well, that's what is so useful. Suitable design and doping will give a range of breakdown voltage from around 3 V to around 200 V. What's more, the voltage is pretty well fixed in any given diode. Whether you pass 1mA or 100mA through the zener diode (reverse direction) the voltage across the diode is the amount written on it — the **zener voltage**. We use them for voltage stabilisation — obtaining a voltage which remains steady despite large changes in current or supply voltage.

DOUBLE YOUR JUNCTIONS

In 1948, Brittain, Bardeen and Shockley made one of the most important discoveries of all time. They managed to make two PN junctions really close together: the first **transistor**. What's so special about two junctions close together? It's like Siamese Twins, that's what, and anything that happens in one affects the other.

Imagine a very thin layer of P-type material as the meat in an N-type sandwich (Fig. 6). By a thin layer we mean just a few hundred atoms thick. Now imagine one N-type layer connected to battery + and the other connected to battery —. From what we know so far there's no way this arrangement could conduct current, its like two diodes connected anode to anode. No matter which way you look at it, one diode is reverse biased and therefore can't conduct. This is where the closeness of the junctions has an effect. Suppose we start one

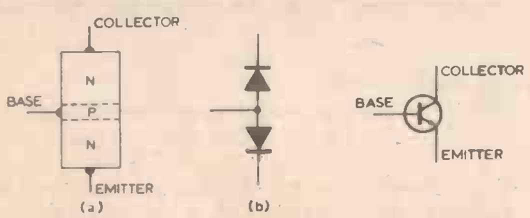


Fig. 6. The transistor. (a) Arrangement of junctions. (b) Two-diode circuit which would give the same readings on an ohmmeter. When two terminals of a transistor are found which do not conduct in either direction, the other terminal must be the base. (c) Symbol of NPN transistor.

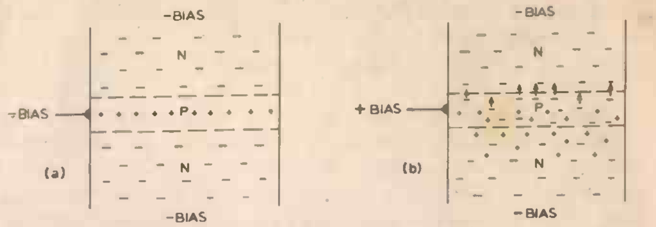


Fig. 7. Transistor effect. (a) With the base-emitter P-N junction unbiased, both junctions are depleted, no current flows. (b) When the base-emitter junction conducts, both junctions are flooded with carriers (electrons in this case) so that both conduct.

junction conducting; the one between the P-type material and the N-type that is connected to battery negative. It won't conduct until the voltage across it is somewhere around 0.55 V (assuming a silicon device), but when it does, the junction is flooded with **carriers**. Because the junctions are so close the other junction also becomes flooded with carriers, though it is reverse biased. This turns the second junction into a conducting junction, despite the reverse bias, so that current flows between the two N-type regions. This current can flow only for so long as carriers are injected from the junction that has been deliberately forward biased.

It's time we put some names to the bits of this device, the bipolar (or junction) transistor. The meat in the sandwich is the part called the **base**, the other two regions are the **collector** and the **emitter**. The reverse biased junction is the junction between collector and base and the forward biased junction is the junction between base and emitter.

Look at it all again. With no bias (or reverse bias) between the base and the emitter, no current flows between the collector and the emitter; reason for that is

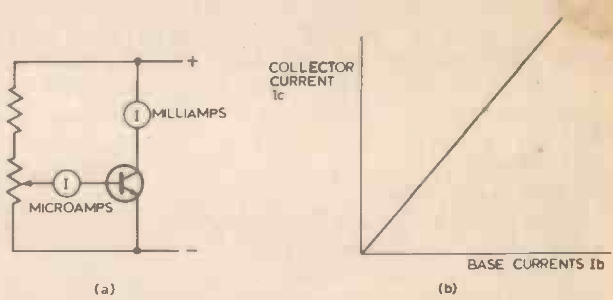


Fig. 8. Current gain. (a) Circuit for measuring base and collector currents. (b) Typical graph of collector current plotted against base current.

the reverse bias between the collector and the base. When the base-to-emitter junction is forward biased, though, the carriers enter the collector junction, so that it conducts. As a result, we can change the collector-emitter circuit from insulating to conducting by altering the base voltage slightly.

We can do even better than this. When we make the base-emitter junction conduct, most of the base carriers are swept across the other junction (base-collector). As a result, much more current flows between the collector and emitter than between base and emitter; a small current between base and emitter controls a large current between collector and emitter. Controls? Yes, controls, because the ratio:

$$\frac{\text{collector—emitter current}}{\text{base—emitter current}}$$ is fairly constant.

A typical value is 100, meaning that the current between collector and emitter, I_c is 100 times the current between base and emitter (I_b). This ratio is called the **forward current transfer ratio**, common emitter, mercifully shortened to h_{fe}. The phrase '**common emitter**' is used because both the base and the collector conduct to the same terminal, the emitter.

NPN AND PNP

Bipolar transistors can be made in two varieties, **NPN** and **PNP**. The NPN operates with its collector positive to its emitter and will conduct when the base (the P-layer) is about 0.55 V positive to the emitter. The PNP transistor

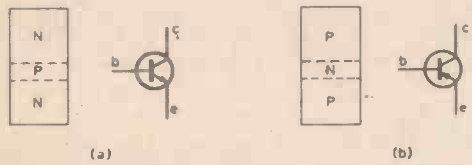


Fig. 9. Junction arrangements and symbols. (a) NPN, (b) PNP.

operates with its collector negative to its emitter and will conduct when the base (the N-layer) is about 0.55 V negative to the emitter. These voltages assume that silicon devices are being used.

GAINING ON THE DEAL

Look at the circuit of Fig. 10a. It has a 6 V, 60 mA bulb in series with a switch and a 6k8 resistor across a 6 V battery. What happens when it's switched on? Nothing noticeable, because 6 V across 6k8 produces less than 1 mA of current, not enough for a 60 mA bulb to glow as bright as a wet fag in the fog. Now try the circuit in Fig. 10b. This time the switch will operate the bulb. The current through the 6k8 resistor is more than enough to make the transistor conduct, passing 60 mA through the bulb. We call this effect **current gain**, and the quantity h_{fe} measures this current again.

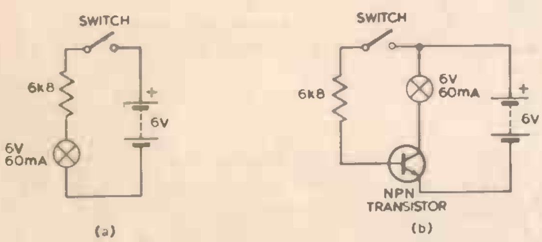


Fig. 10. Current amplification. (a) This circuit cannot pass enough current to light the bulb. (b) The bulb will light when the switch is closed because the base current of the transistor will cause collector current to flow.

Don't get carried away though. The transistor hasn't created this current, just controlled it. If the battery had not been able to supply 60 mA, no cunning tricks with transistors could make the bulb light.

Try the circuit of Fig. 11 for yourself. The bulb will

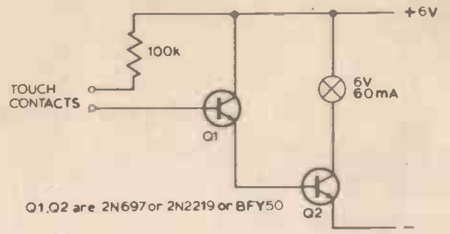


Fig. 11. A touch switch — touching the contacts with your fingers will allow the bulb to light.

light when the two terminals are touched with one finger. The tiny amount of current that flows through you causes a current many times greater to flow in Q1. (We use the abbreviation **Q** for a transistor; an alternative is **Tr**). This greater current flows into the base of Q2, and causes a greater current still, enough to operate the bulb. Suppose we put some sizes to these currents. If the bulb needs 60 mA, then let's suppose, for the sake of simplicity, that Q2 has a current gain (h_{fe}) of 60. Then just 1 mA is needed into the base of Q2 to make the bulb glow. This 1 mA is supplied by Q1. If this transistor also has $h_{fe} = 60$, then only one sixtieth of a milliamp (16 uA) is needed into the base of Q1. You may have seen this type of touch-detector demonstrated in *'Tomorrow's World'* as a way of identifying the end of one selected wire in a bunch of several hundred.

This sort of use of transistors is called **switching**. The bulb, or whatever the transistor is switching on and off, is called the **load**. The load is connected in the collector-emitter circuit, and switched on or off by charges at the base. To switch the lead on:

(a) the voltage between base and emitter must be more than 0.55 V for a Silicon Transistor (0.15 V for a germanium transistor)

(b) the current between base and emitter must be enough to ensure that the correct current will flow through the load.

Just to illustrate these conditions, try to explain why the circuits in Fig. 12 will **NOT** work!

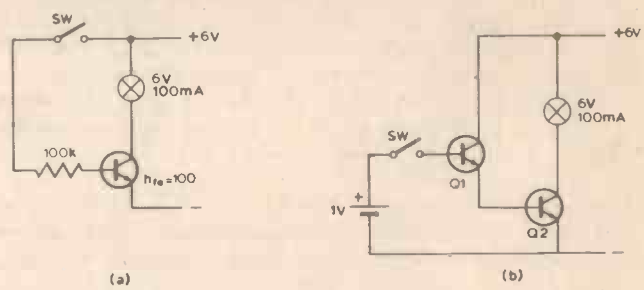


Fig. 12. Two circuits which DON'T work. Can you explaun why?

Variations on the theme

Figure 13 shows another circuit which needs some thought. If the load resistor is in the emitter part of the circuit, then the amount of current needed at the base is the same as it would be if the load were connected in the collector part of the circuit. The voltage needed at the base, however, has to be *more* than the normal voltage across the load. The voltage needed at the base, however, has to be *more* than the normal voltage across the

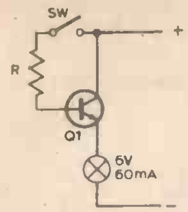


Fig. 13. The emitter-follower.

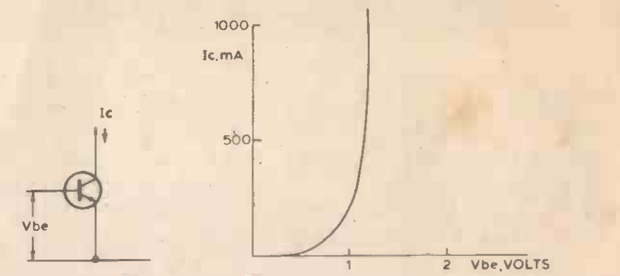


Fig. 14. Mutual characteristic for a medium-current silicon transistor.

load. Think of it this way — for the load to operate it needs the correct voltage across it and the correct current through it. Suppose the load is a 6 V 60 mA bulb. In this circuit, the emitter terminal of the transistor must be at 6 V when the bulb glows. For the transistor to conduct, the base voltage must be 0.6 V or so about the emitter voltage which means around 6.6 V. The shift in the position of the load in the circuit makes a large difference to the voltage that is needed at the base. This is, in fact, a rather different type of circuit, the **common collector circuit.**

The differences between these circuits illustrate rather well differences in the behaviour of transistors. Connect as a common emitter circuit (Fig. 10b) and small *changes* of voltage at the base cause fairly large changes of *base* current. The input circuit of the transistor (base-emitter) behaves like a low resistance. Connect the transistor in a common collector circuit (Fig. 13) and much larger *changes* of voltage at the base are needed to cause the same changes of base current. Now the input circuit behaves like a large resistance. We refer to this as the input resistance of the transistor; it's important because we have to be able to supply the correct voltage to this input resistance to turn on the current.

Transistors have an output resistance too. A transistor connected in a common emitter circuit has a high output resistance. This means that changing the collector voltage has very little effect on the collector current. It's a useful feature, because a high value of output resistance means that the current flowing between collector and emitter is controlled only by the base current, not by the collector voltage. Connecting the transistor up into a common collector circuit has the opposite effect; the output resistance is now low. Any change in the emitter voltage now causes a large change in the emitter current (assuming the base voltage is fixed). These input and output resistance values are shown in Table 2, for the common emitter, common collector and also for the common base connection. The common base connection is seldom used now except in high frequency circuits or as a part of other circuits.

Laying it on the line

Take a look at the graph of Fig. 14. It's a graph of silicon transistor collector current plotted against the base voltage (base-to-emitter voltage, that is). What it shows is that very small changes of base voltage will cause larger changes of collector current. We make use of this when we design voltage amplifiers.

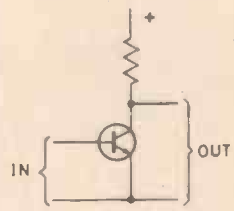
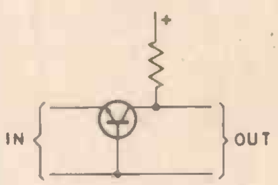
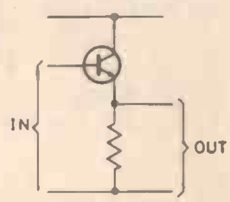
A voltage amplifier has an AC voltage signal at its input and produces a copy of the wave, with greater amplitude at its output. The ratio voltage gain equals

$$\frac{\text{signal amplitude at output}}{\text{signal amplitude at input}}$$

How do we use a transistor as a voltage amplifier? To start with, we have to convert the collector currents into voltages. The simplest method is to use a resistor as a load. Take the example of Fig. 15. The load resistor here is a 1k resistor, and the voltage signal is at the collector of the transistor. When the collector current is zero, the voltage at the collector is 6 V, the supply voltage. When a collector current flows, there is a voltage across the resistor so that the collector voltage drops. The greatest amount of current that could possibly flow in this circuit is 6 mA, because this amount makes the collector voltage zero. We could then get a voltage wave at the output with an amplitude peak-to-peak of 6 V, providing we had enough signal voltage at the input to cause a collector current of 6 mA peak-to-peak. That's where the graph of Fig. 15 comes in, because we can read off the base voltages for the two current limits of zero and 6 mA. Now we have the output voltage (6 V p-p) and the input voltage (0.1 V p-p); so that the voltage gain of this amplifier is 60 times. Easy!

Is the output voltage signal a good copy of the input voltage signal? It can be, but two things can go wrong. One is that the graph of I_c (collector current) against V_{be} may not be a straight line. Any curvature of this line causes a poor copy; we say that there is **distortion**. The other thing is that the base voltage must never drop

TABLE 2
Relative sizes of input and output resistances

	Name	Rin	R
	common emitter	medium	high
	common base	low	high
	common collector	high	low

low: below 100R; medium: several k; high: above 10k.

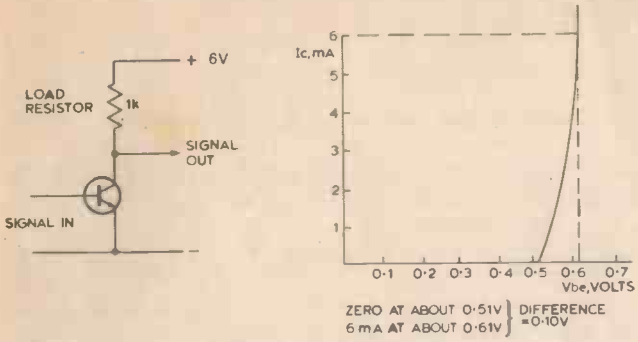


Fig. 15. Voltage amplification using a load resistor.

below the minimum conducting voltage of about 0.55 V. Both problems are tackled by using **bias**. In everyday language, bias is anything that tips things to one side. What we need to tip to one side is the base voltage, to make sure that it can't drop below that figure of about 0.55 V (again assuming a silicon transistor).

A bias circuit does just that. Two common types of bias circuits are drawn in Fig. 16. Fig. 16a shows a circuit using a resistor connected between the base and the collector. We can calculate the value of the resistor so that the collector voltage, with no signal present will be about half supply voltage. This way if we put an AC

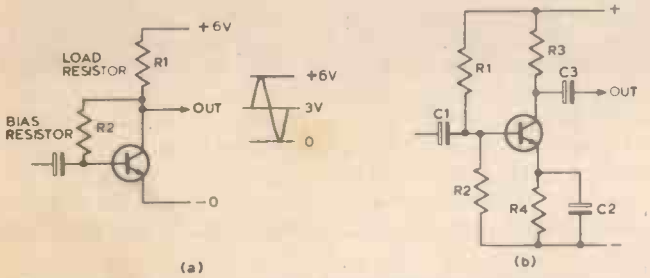


Fig. 16. Two types of bias circuit. (a) Current bias, using a single resistor. (b) Voltage bias, using a potential divider.

signal in at the base, an amplified signal will appear at the collector and its amplitude can be anything up to about half supply voltage without cutting off either peak.

Figure 16b is of another type of bias circuit. In this design, a potential divider sets the voltage at the base. This makes the transistor pass current through the emitter resistor R4 so that the voltage between base and emitter is set to the correct value, around 0.55 V. If we choose the value of the load resistor R3 correctly, the collector voltage can be set to about half supply voltage once again. The capacitor C2 is important. Unless this capacitor is connected, we do not have a true common emitter circuit for signals (because of R4) and the voltage gain will be very low — more of that later.

Both of these methods of bias are self correcting — if we change the base voltage temporarily with a signal, the voltages will afterwards always return to the value that we set. In addition, slight changes in the values of h_{fe} or resistance will not cause noticeable changes in the bias voltages when these circuits are used.

Bias is not necessarily just a method of preventing the peaks of the signal from being chopped (or clipped). Bias can also be used to ensure that the distortion is as low as we can arrange. The graph of I_c against V_{be} is not usually a perfectly straight line, but some parts of the curve may be more nearly straight than others. If we bias the transistor so that a fairly straight portion of line is used, then the distortion is low. The names **'linear amplifier'** and **'linear operation'** come from the idea that the best operating conditions are along a piece of the graph which is a straight line.

We can calculate the gain of a transistor amplifier very easily. The ratio

$$\frac{\text{change of collector current}}{\text{change of base voltage}}$$

called **mutual conductance**, symbol **gm**, is about 40 mA/V for each 1 mA of collector bias current. For a transistor biased to a collector current of 2 mA, for example, the gm value would be 80. This value of gm is also related to the current gain h_{fe} and the input resistance of the transistor h_{ie} by the formula h_{fe}—gmh_{ie}. Now the correct signal out for an input V_{in} must be gmV_{in}, so that the voltage signal is $gmV_{in}RL$ (RL is the value of the load resistance). An even simpler method arises because the DC bias voltage across R_L depends on the bias collector current. The voltage gain of any small signal amplifier using silicon transistors is just 40× (steady voltage across R_L). For example, if there is 5 V across the load resistor with no signal input, the voltage gain of the transistor is 5×40=200 times.

Up and down the scales

We can measure the voltage gain of a voltage amplifier at any frequency of signal we care to use, but we won't get the same results at each frequency. A simple voltage amplifier such as that of Fig. 17 will have its normal value of voltage gain (around 200) at frequencies ranging from about 100 Hz to several hundred kHz. At very low frequencies, of a few Hz, the measured gain will be less. The transistor is still doing its stuff, but the

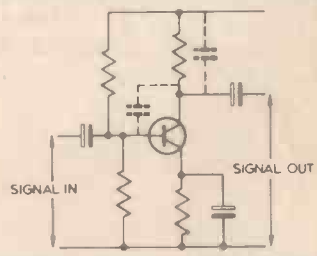


Fig. 17. A complete voltage amplifier stage. The dotted lines indicate important stray capacitances between parts of the circuit.

capacitors that are used in the circuit have such high reactance values at very low frequencies that the signal is potential-divided by each capacitor that is connected to a resistor or the transistor. If we use circuits that eliminate capacitors (direct coupled circuits), the voltage gain remains constant even for DC.

We cannot simply remove the capacitors in a circuit such as that in Fig. 17 because these capacitors are needed to prevent the bias voltages being shorted out or increased by the circuits to which the transistor is connected.

At the high frequencies, it's capacitors again that cause the trouble. This time they're invisible, the type we call **stray capacitance.** Every gap in a circuit is a capacitance, though of small value. In the circuit of Fig. 17 the dotted lines indicate gaps which must have some stray capacitance. The effect of these capacitances is to provide an easier route for high frequency signals than the resistors or even the transistors, so that the voltage gain is, once again, reduced. For audio amplifiers,

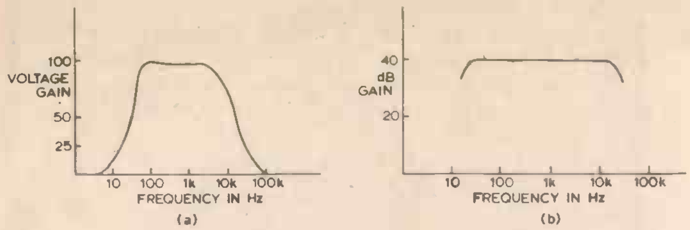


Fig. 18. Frequency response graphs.(a) Using a linear scale for gain. (b) Using a decibel scale for gain.

working with the frequency range 40 Hz-20 kHz, these frequency limits are not usually troublesome. Amplifiers intended for much higher frequencies use tuned (resonant) circuits in place of the load resistor. The stray capacitance then becomes part of the resonant circuit, so that its value does not greatly affect the frequency we can use. At really high frequencies, the transistor itself begins to give up, because the charge does not move fast enough to follow the changes of voltages of high frequency signals. Transistors of rather specialised construction are needed for frequencies of 100MHz or more.

A graph of voltate gain plotted against frequency is called a **frequency response graph.** A typical frequency response graph for an audio amplifier is shown in Fig. 18a. We have to use a logarithmic scale for frequency, with the same distance between 1 kHz and 10 kHz as we have between 100 Hz and 1 kHz. This is because a linear scale would have to be several metres long to show the same frequency points.

The frequency response of an amplifier plotted in this way always looks much worse than we expect from the evidence of our senses. The reason is that the difference between a gain of 100 and a gain of 50 is not so very great when the amplifier drives a loudspeaker or the brightness of a cathode ray tube, it certainly doesn't seem like a 2 : 1 ratio. A better way of showing

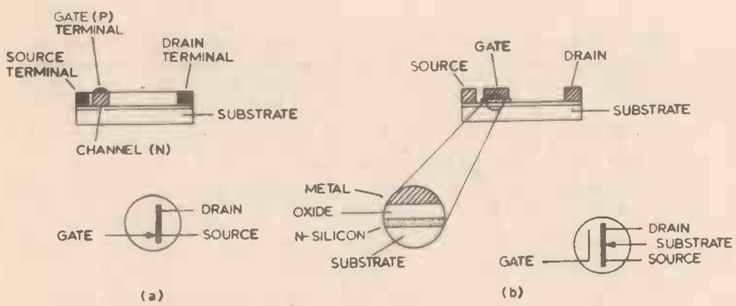


Fig. 19. FETS. (a) Junction type, N channel. (b) MOS type, N channel. The substrate is the silicon layer on which the other layers are deposited.

frequency response is the **decibel** (dB) scale. To convert a voltage gain to decibels, we use dB = 20 log (voltage gain) so that a voltage gain of 20 is 26 dB, a gain of 40 is 32 dB, and a gain of 80 is 38 dB. Note that doubling the gain figure causes the dB figure to *increase* by 6 dB, typical of a logarithmic scale.

A frequency response graph plotted in dBs is shown in Fig. 18b.

FETS

The two-junction, or bipolar, transistor is not the only way of using a semiconductor material for switching or amplification. **Field-effect transistors (FETS)** make use of another way of controlling the movement of electrons or holes in semiconduction without injecting carriers from junctions. The main current path in any FET is called the **channel**, it's a thin narrow strip of silicon, usually N-type. There are no junctions along the length of this channel, so that it behaves like a resistor, allowing current to flow in either direction. The current in the channel is controlled by changing the conductivity of the material, not by injecting carriers into a reverse biased junction.

Two ways of controlling the current are used. One way uses a reverse biased junction, so that the FET is a junction FET. The junction is formed around the strip at one end (Fig. 19a), but the carriers moving through the channel do not pass across the junction. Reverse biasing the junction will deplete it of carriers, so that the conductivity of the silicon around the junction becomes less, and the current in the channel becomes less.

The other type of FET is the MOSFET (Metal-Oxide-Semiconductor FET). A thin layer of silicon oxide (an insulator) is grown on the strip of channel at one end and a layer of metal deposited on top of the insulator. This arrangement forms a capacitor with the silicon of the channel as one plate and the insulated metal as the other. Connecting the metal to a negative voltage causes negative charges to be repelled from the channel, so that the conductivity of the channel becomes less.

In either type of FET, the controlling electrode is called the **gate**; the end of the channel nearest the gate is called the **source**, and the far end of the channel is called the **drain**. A voltage between gate and source controls the current between source and drain, and the ratio

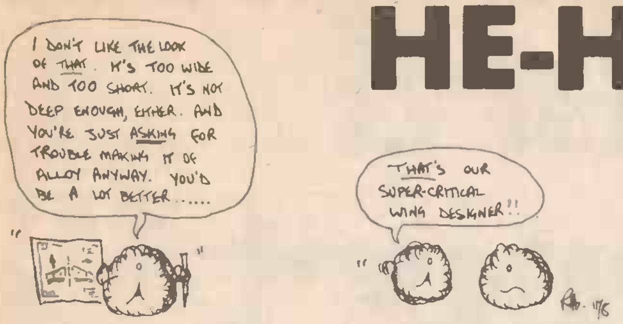
$$\frac{\text{change of channel current}}{\text{change of gate voltage}}$$

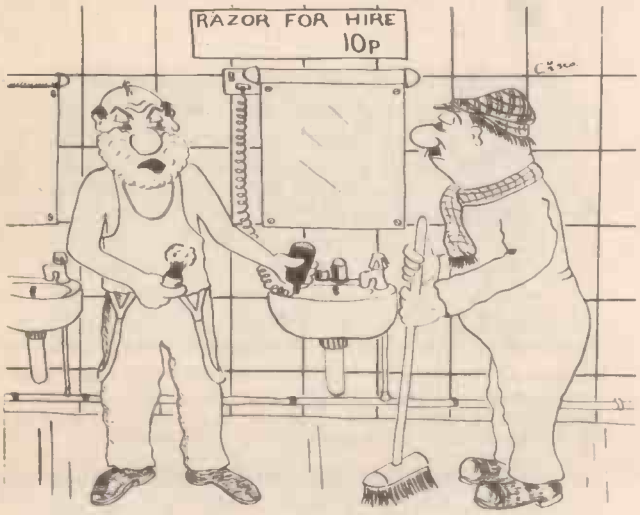
is called **mutual conductance, gm.** The values of gm obtained from FETs are pretty low, 1.2-3.5 mA/V usually, as compared to values of 40 mA/V upwards for bipolar transistors. The big advantage of FETs is their very high input resistance. The MOS types have such a high gate resistance that they can be damaged by the electrostatic voltages produced by rubbing materials together! These types of FET (and the MOS types of integrated circuits) must be handled carefully, keeping the leads shorted together until they can be soldered in place in their circuit. **HE**

In Part 4

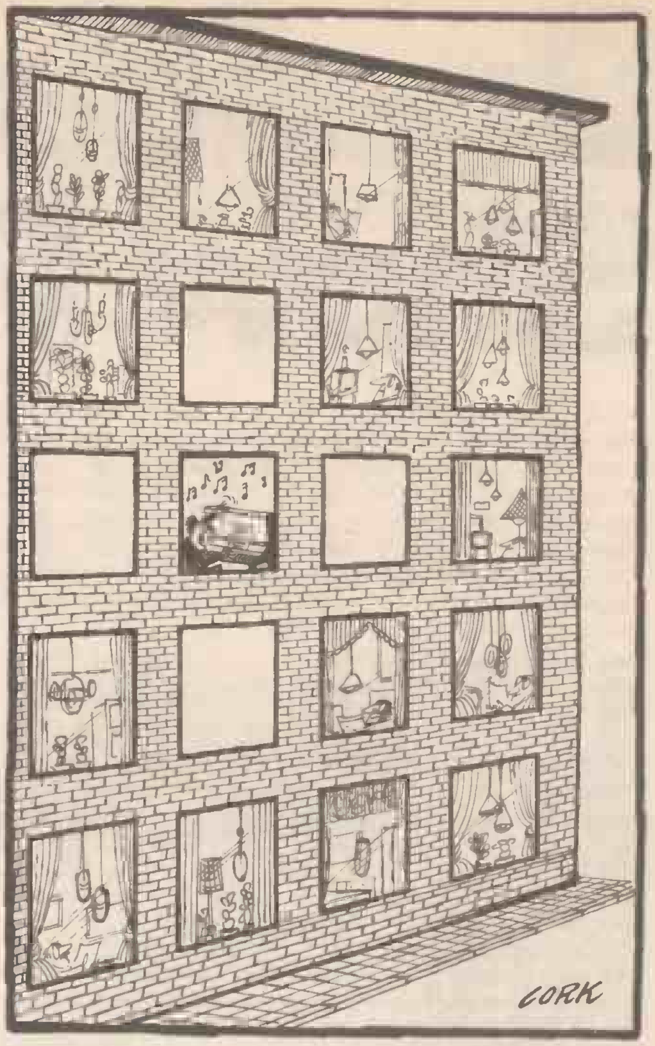
In the next issue we look much deeper into transistor circuitry and show them in real circuits. We deal with coupling stages together, biasing, negative feedback and the rules-of-thumb that are used in design.

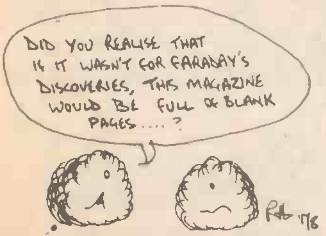
HE-HE!

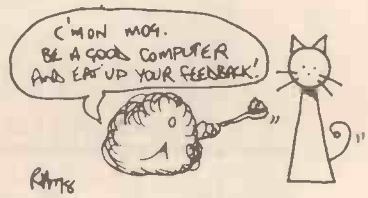


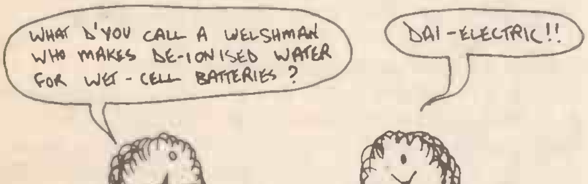


"Hey mate. This razor's dangerous, I've just had a shock."

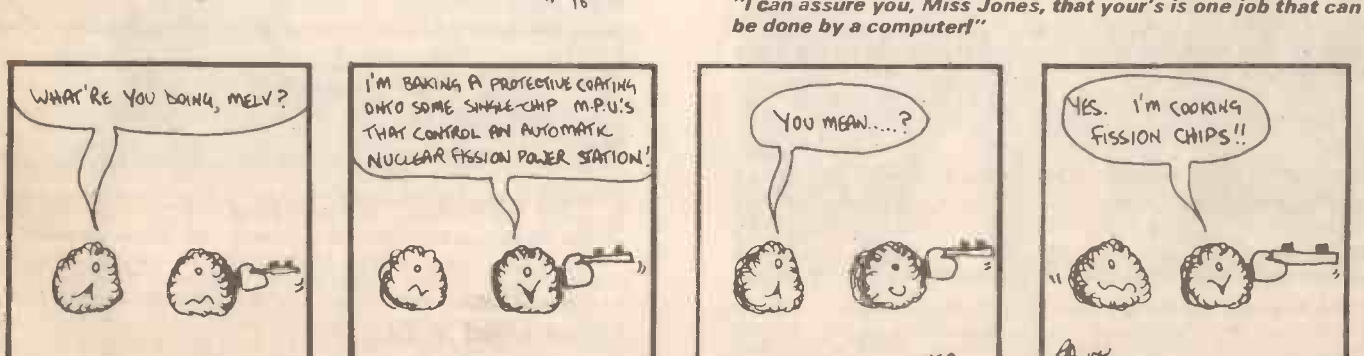








"I can assure you, Miss Jones, that your's is one job that can't be done by a computer!"



Breadboard Show Report

THE BREADBOARD amateur electronics exhibition was held from 21st to the 25th of November in London. It attracted over 10 000 people. HE had a stand there which it shared with its sister magazine, Electromics Today International. While we were there Phil Cohen fought his way through the crowds with his box brownie to bring us these photos of the more interesting bits and pieces on display.

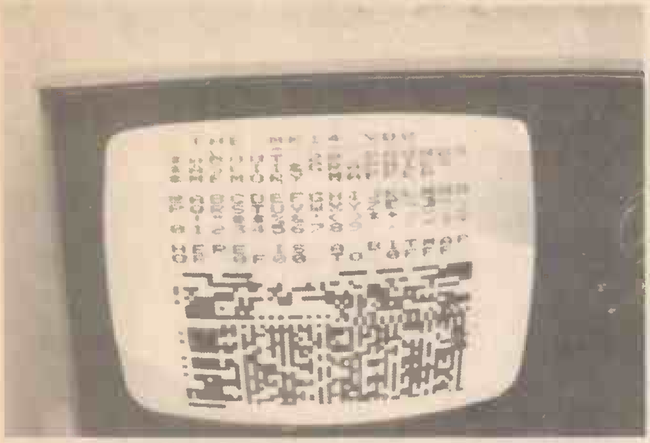
The Electronics Today Triton. This is a home computer costing less than £300, the design for which was published in our sister magazine. The company which market the machine — Transam — brought several of them along so that prospective buyers could get 'hands-on experience'.

Mike Hughes, the designer of ETI's Triton computer project, giving a talk on its attributes. These talks were so popular that the private hall rented for the occasion was seldom less than full.

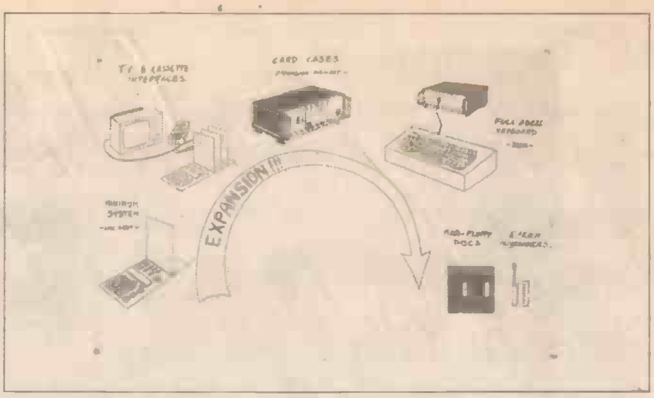
Science of Cambridge's PROM blower kit to go with the MK14 microprocessor evaluation kit. This allows the user to build a 'dedicated' microprocessor system — one which is programmed to begin its task as soon as it is switched on.

The MK14 tape interface kit. This allows programs to be stored onto cassette for future recall.

Another Electronics Today project, the Tcholinka chess recorder. This machine was used by the BBC in their coverage of the Korchnoi/Karpov chess match. The name comes from the Russian — Korchnoi named it (he also uses one). The machine is capable of storing an entire game in its memory and can record it onto a cassette tape for future reference. It also allows the game to be played from cassette with a commentary — thus allowing a professional player to review all the common openings, for instance, the day before a game.



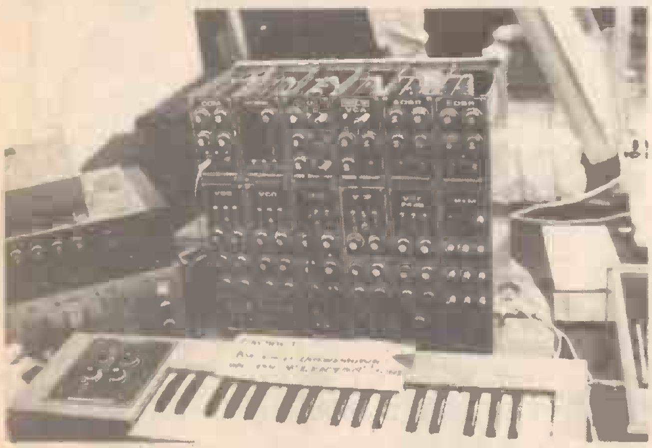
The MK14 now has a VDU kit to go with it. This plugs into the aerial socket of a conventional TV set and allows the display of text and symbols.



The Watford Electronics microprocessor evaluation kit — soon to be marketed (about a month, they tell us). It uses the Z-80 microprocessor, which is more powerful than the SC/MP processor used by the MK14, and is expandable into a full business system (eventually). The price should be around £70 — only £20 more than the Mk.14.

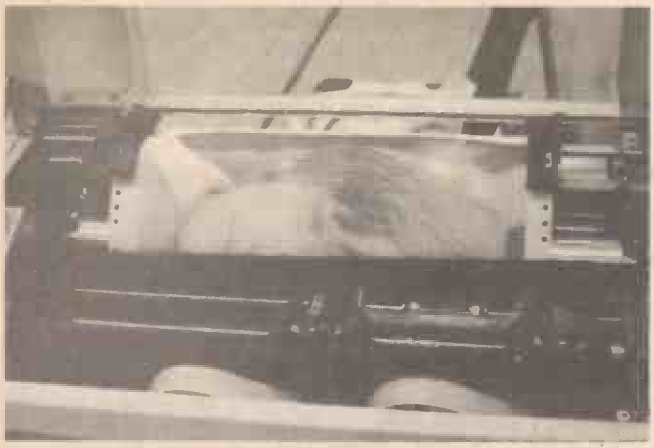
In order that people could gauge the performance of the HE Mixer, Graphic Equaliser and Stereo Amp, we connected them in 'series' and fed in a signal. The combination of all the facilities offered by the three units made this a very versatile setup.

Maplin Electronics had on display a small laser. This was set up as a sort of fairground novelty — the idea being that you had to move the cut-out along the beam to the end without cutting the beam. A small electronic counter with a photo-electric input measured the time the beam was interrupted for. The laser was perfectly safe and wouldn't burn a hole in anything — well, that would spoil the purpose of the game!



The Format synthesiser, the design for which was published in Elector magazine. There were two of these on display — one by de Boer Components (this one) and one by Elector. Those with sharp eyes may be able to read the notice on the keyboard of this machine saying that a demonstration could be had at the Elector stand. We had to make do with a photo of this one, sign and all, because we couldn't get near the Elector one for people looking at it.

The plant in the background is playing a tune (yes, playing a tune) through the 'Bioactivity Translator' unit in the foreground. The unit gives out a series of musical notes which depend on the electrical conductivity of the plant's leaves. The company which was exhibiting them — Jeremy Lord Synthesisers — claim that amongst other things you can tell a plant's state of health from the tune.



The Integrex system uses a small TV camera to feed information into a microprocessor. This displays (with sixteen levels of grey) the scene which is to be printed, so that it can be reviewed by the customer before it is printed.

This is a photo of Margaret, one of the more attractive of the HE staff (excluding the editorial people of course). The characters used are not letters as in some systems, but a special combination of characters made up from a random pattern of dots. This gives a smoother appearance to the final product.

Pinball Wizards

Long before video games were even a twinkle in any designer's eye, the world had pinball machines. A lot of people (the author included) still think that pinball is more fun to play than even the most advanced video games. How do they work — and what goes wrong? Jim Perry investigates.

THREE NAMES THAT ANY CONNOISSEUR of the finer points of life will recognize are Bally, Williams and Gottleib. They all make pinball machines, and have brought many a strong man close to tears of both joy and anger — depending on whether the bonus or tilt lit up! The developments that have taken place in the last few years have meant that even pinballs are now succumbing to the onslaught of the microprocessor.

Part of the reason for my 'nostalgia' is that I received my grounding in electronics via repairing pinball machines (working in my uncle's arcade during holidays!), but the main reason is the gradual reduction in mechanical thumps, clangs and dings which were the hallmark of old-fashioned models!

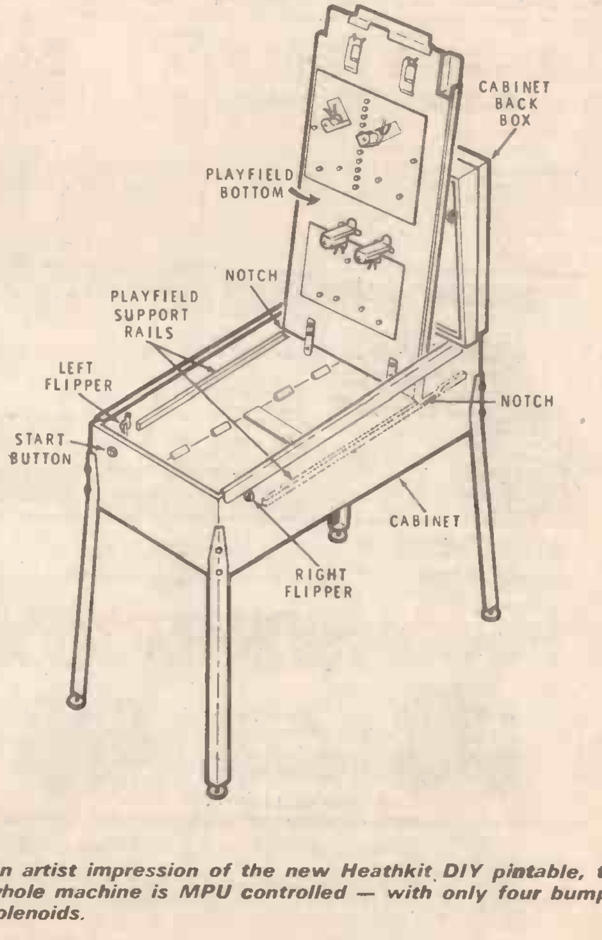
If you look inside an ultra-modern machine you will see very little, apart from a few solenoids and a black box containing a dedicated computer — not a very enlightening experience. So to understand the principles behind the machines let's take a step back in time and see how the older models developed into their modern cousins.

TIME MACHINE. . .

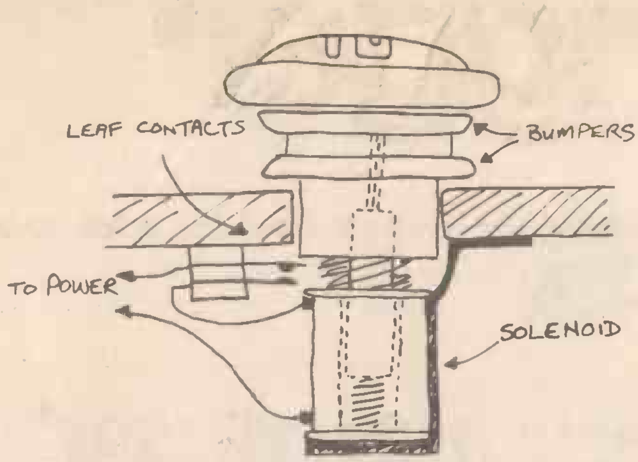
Originally pintables were little more than extensions of Bagatelle games — with movable flippers to keep the ball in play; the scoring systems were mostly mental! Then some budding genius had the idea of using electrically operated flippers and bumpers; so that the flippers could be positioned anywhere on the playing area, and the bumpers would give more 'action' by physically repelling the ball harder than unassisted rubber could manage.

By positioning switches behind the bumper rubbers, solenoids were activated when the ball hit the rubber — and the solenoid operated a lever to push the rubber towards the ball. From this system it was but a small step to operating electric counters for score-keeping. The next major innovation was the mid-field 'mushroom' which was formed from two bumpers and a solenoid. When the ball hits the mushroom it forces the bottom bumper down; this operates a switch to power the solenoid. When energised the solenoid pulls the upper bumper down sharply — thus forcing the ball away from the bumpers. Naturally the solenoid circuit is then broken as the lower bumper springs back into place, and the upper bumper also returns to its normal position.

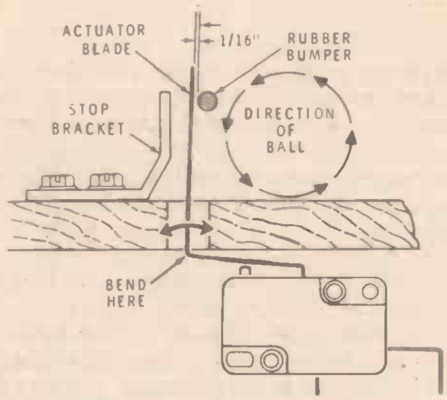
The electrical circuits were connected and disconnected by relays, operated by the bumper switches and 'roll-over' contacts scattered over the playing area. Advantages of using relays included less contact wear on the switches operated by bumpers (as relays con-



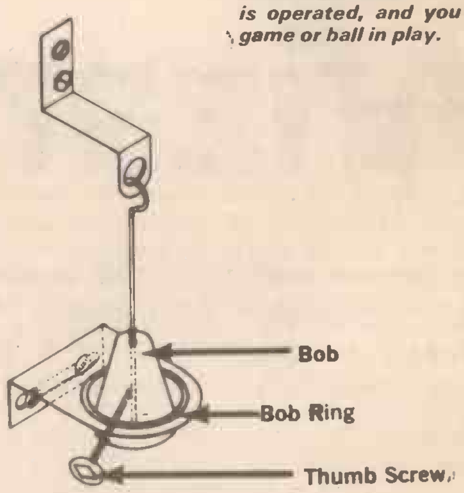
An artist impression of the new Heathkit DIY pintable, the whole machine is MPU controlled — with only four bumper solenoids.



Above is a rough sketch of the midfield 'mushroom' mechanism, found on all pinball machines. Bumper switch mechanism can be seen below, the switch operates a solenoid to force the ball away.



TILT! The device used to prevent you totally abusing any pintable is elegant but simple in operation. When the hanging bob touches the bob ring a relay is operated, and you lose the game or ball in play.



A modern machine from a Spanish company Recel, this one is called 'Mr Evil' and is electronic rather than electromechanical.

sume relatively little current compared to solenoids), and possibilities of more sophisticated switching with the aid of complex interlinking of the multiple contacts available on each relay. In fact the relay systems in pinball machines were the equivalent of dedicated computers (which explains why MPUs have been used to replace them).

. . BREAKS DOWN . .

A headache with Pinball machines is when they work — but not quite correctly. Mechanics have been known to spend days on a single machine, trying to trace an elusive intermittent fault. It can be the equivalent of a proverbial needle in a haystack, with upwards of 3000 contacts in an average machine — each one critical to the functioning of the complex logic needed for scoring and bonus awarding, etc. But the big benefit of relay and solenoid control was the ease of fault finding. In most cases it is easy to spot a burning coil, buzzing relay or other similar symptom of catastrophic failure.

If a machine appeared to be in order physically the logic had to be checked through systematically, with checks on all the possible interactions from other parts of the circuit — a very good way of learning about logic control and methodical fault finding!

. . . NOW AND THEN

So because of the close similarity between what the electromechanical circuitry did, and MPUs are designed to do, the older types of Pinball machine are rapidly being replaced by modern equivalents. The other main factor is that of reliability and ease of repair — MPU systems are inherently more reliable and a single module can be used for several similar but different models.

As a result it is possible to buy second (well, probably fifth or sixth) hand Pinball machines for as little as £20 — well worth it if you fancy learning about complex (yet simple?!) electromechanical devices, and even just to have a good time.

HE

Flash Trigger

Trigger your photo-flash with light, sound, or switch contact with this simple unit.

IT'S NOT TOO HARD for even the amateur photographer to take quite spectacular photographs, freezing motion at a critical stage. To operate the shutter on camera manually, even if this could be done at the critical moment, simply won't work in freezing most fast motion as even the fastest shutter speeds will cause the image to blur.

However, by darkening the subject, opening up the shutter and operating a flash gun we can obtain very, very short effective exposure times because of the high light level for a brief period. In addition we can use an electronic circuit to fire the flash gun which in turn can be triggered by light or sound.

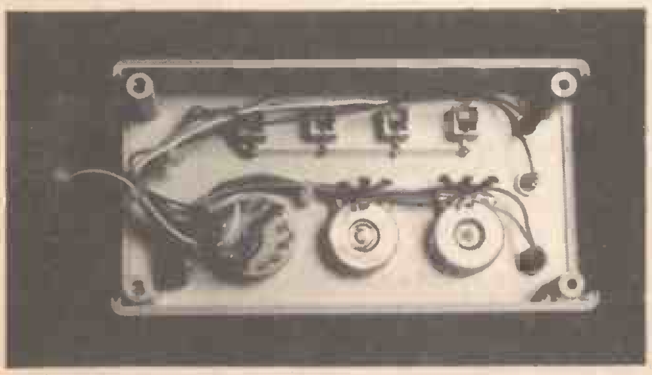
Our project here will operate with any of these triggers and in addition enables you to delay the flash for a small but variable time after the triggering impulse; this will be found very useful for some effects.

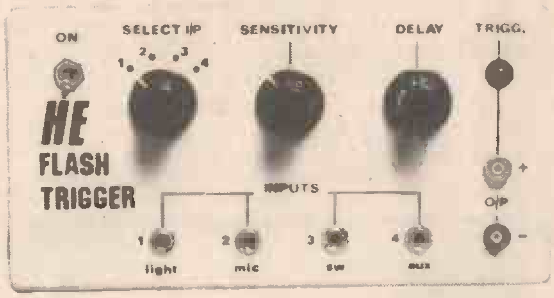
Although the circuit will enable spectacular shots to be taken, it is quite simple and makes use of the NE555 Timer IC (often abbreviated to just 555) which is advertised usually for under 40p.

This IC has a very sensitive input and the ability to provide the required variable time delay as well as sufficient output to trigger the SCR (thyristor) which is fitted across the normal contacts for firing the flash.

CONSTRUCTION

Using the PCB pattern shown makes constructiion very easy, only one thing needs to be watched. The triggering current needed is only 0.5 microamps (this goes into pin 2 of the IC) and with the adjacent pins being the negative supply and the output, leakage across the board can be a problem. Normally excess solder flux, dirty thumb-prints etc. on a PCB don't make much difference to the operation of a circuit but here we have to be careful. Once the PCB is built up, clean it up with methylated spirits. A dirty board will show itself up by continuous triggering; dampness around pin 2 will affect the circuit in a similar way.





Since flash tubes do not have an unlimited life, it's not a good idea continually to use the flash itself as an indicator that the unit is set up properly; instead the LED serves this function.

It will be necessary to carry out a couple of 'dummy' runs in order to get the sensitivity control (RV1) set correctly.

Connect either a crystal microphone or a loudspeaker across Input 2; due to the sensitivity of the circuit either will give an output of sufficient level to operate.

Start by setting the sensitivity to maximum (this is with RV1 at a minimum); in this state the circuit will probably be triggering continuously. Then back off the control until the LED goes out but comes on again when the required sound is made. There is no advantage in using maximum sensitivity all the time as you will find that the unavoidable noises in resetting the equipment after the first tests have been made will fire the equipment.

LIGHT TRIGGER

Although a light dependent resistor (such as the ORP12) can be used, these are fairly slow to react and you will have a built-in minimum time delay. It is better to use a light sensitive transistor; although this costs more, it will introduce little, if any, time delay.

Light triggering can take one of two forms. With the delay set at minimum, the unit can be used as a slave flash, triggering by the principal flash unit. It is not difficult to set up a light beam which is broken just before the photo is needed. The circuit can be arranged to trigger for both an increase and a decrease in light level.

For an increase in light the phototransistor should be fitted across Input 1 with the resistor across Input 2; for a decrease the two should be reversed.

The unit can also be operated with either a switch closing, or opening. As with the phototransistor, a resistor must be fitted across the other input.

OPERATIONAL TIPS

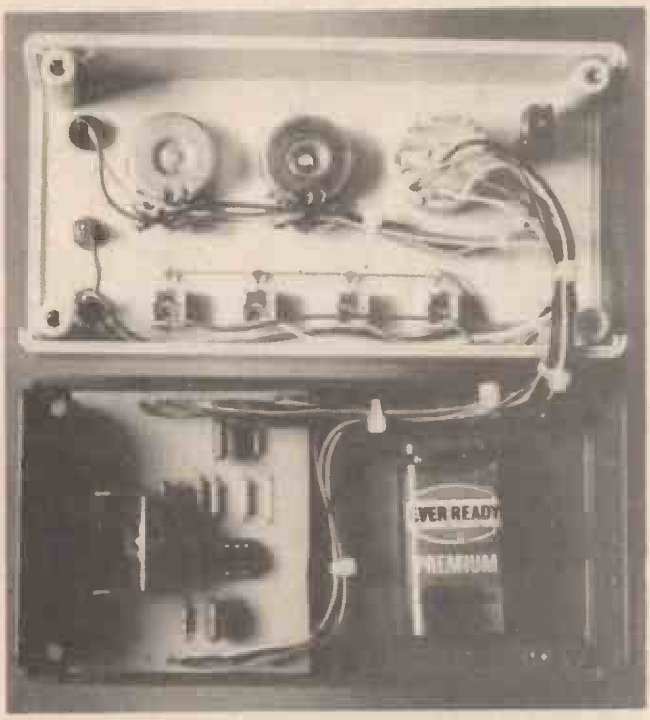
If you're an experienced photographer the following will be like teaching granny to suck eggs, in that case ignore this section.

As the shutter will have to be open for several seconds awaiting the trigger flash, clearly background light is not desirable but you don't need pitch black (which makes setting up almost impossible).

If you get movement in the developed pictures, try a different flash unit, we have come across at least one cheap flash that doesn't give the highly intense, very short duration flash needed.

You will also find that with a flash you will be operating frequently much more closely to the subject than that allowed for on the tables which you have to consult for aperture settings — in this case move the flash away from the camera.

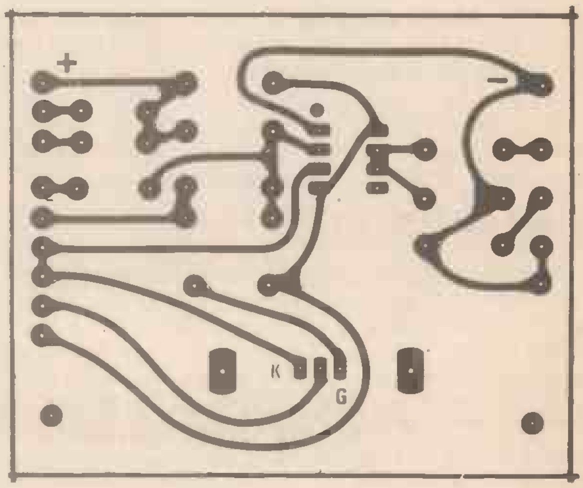
Oh — and if you want to try breaking light bulbs (which can give beautiful results) don't underestimate the mess created; form a complete 'cup' of paper or material to catch the bits before you start!



How it Works

A negative pulse at the input is fed via capacitor C1 to the input pin (2) of the IC. Pin 2 is held slightly above its triggering voltage of 1/3 V_{cc} by the voltage divider comprising R1, R2, and RV1. The negative pulse triggers the IC and output (pin 3) goes high for a time period controlled by RV2, R3 and C2. When the output goes low again at the end of the time interval capacitor C3 charges through the gate cathode circuit of the SCR switching it on and firing the flash.

Capacitor C1 isolates the input from the voltage divider so that the unit isn't sensitive to the DC level at the input. RV1 acts as a sensitivity control by allowing the voltage to be adjusted to a suitable level so that the input signal will trigger the IC. Resistor R4 limits the discharge current from C2 at the end of the timing cycle so protecting the IC. The LED and its protective resistor R5 act as an indicator to show that the unit has triggered, so simplifying the setting up process and minimising the number of times the flash has to be fired. This means that the flashgun needn't be fired until a photo is to be taken.



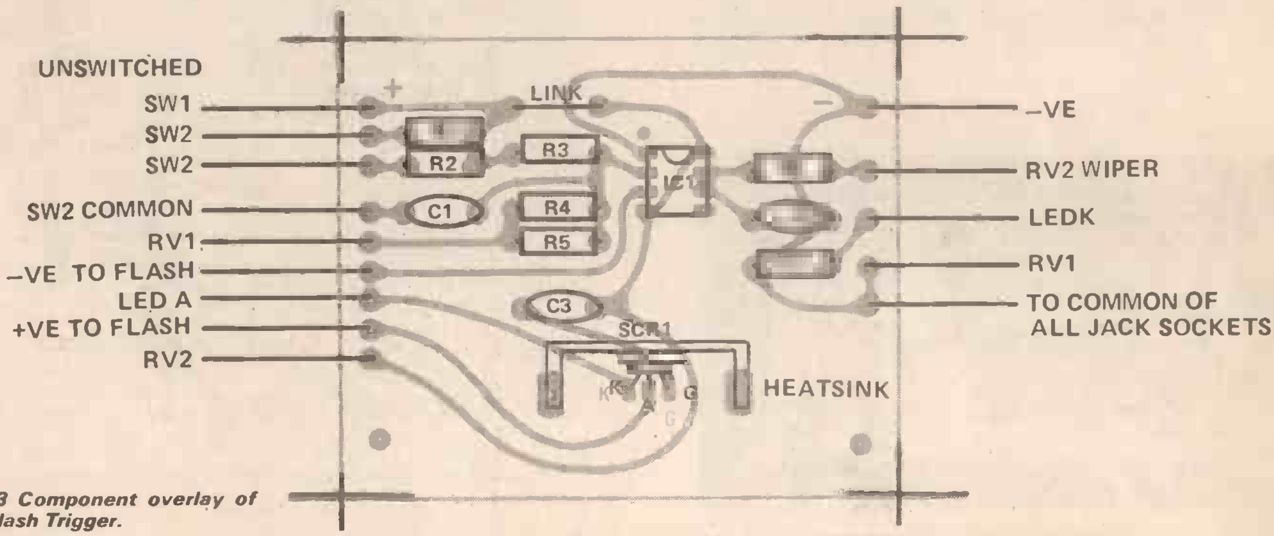
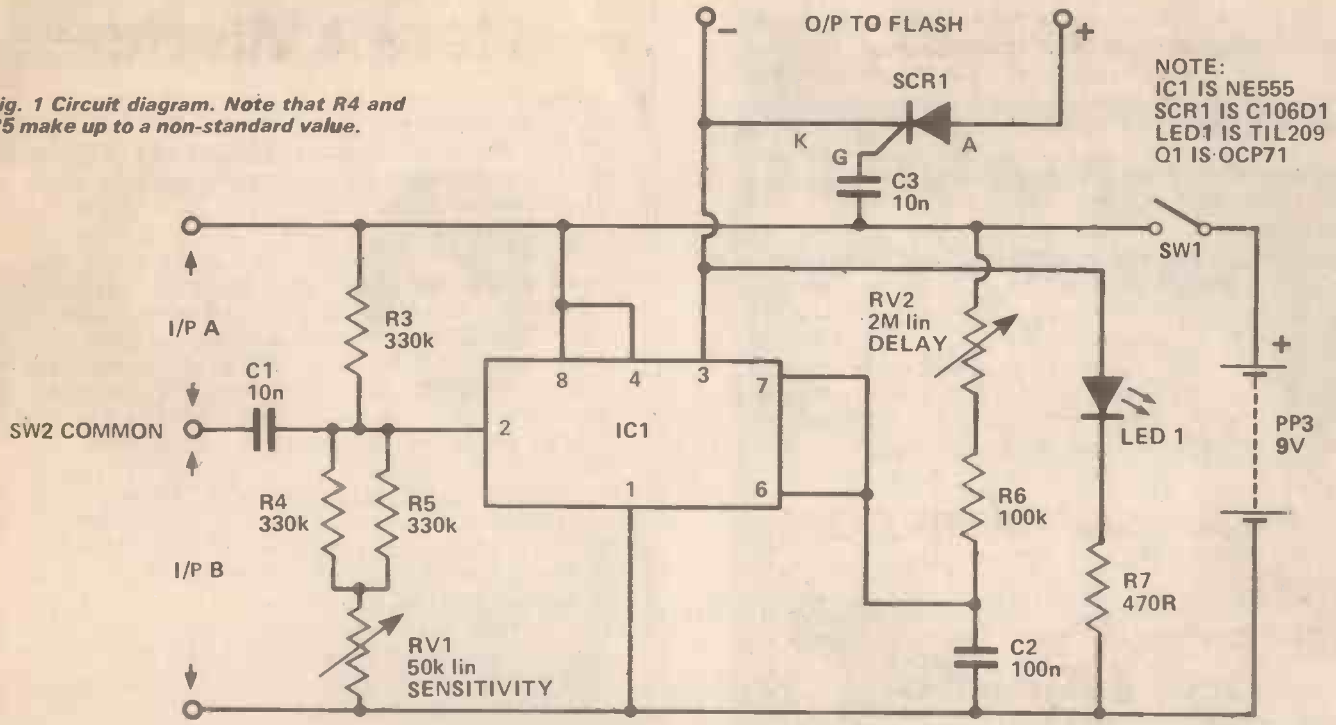


Fig. 3 Component overlay of the Flash Trigger.

Fig. 1 Circuit diagram. Note that R4 and R5 make up to a non-standard value.



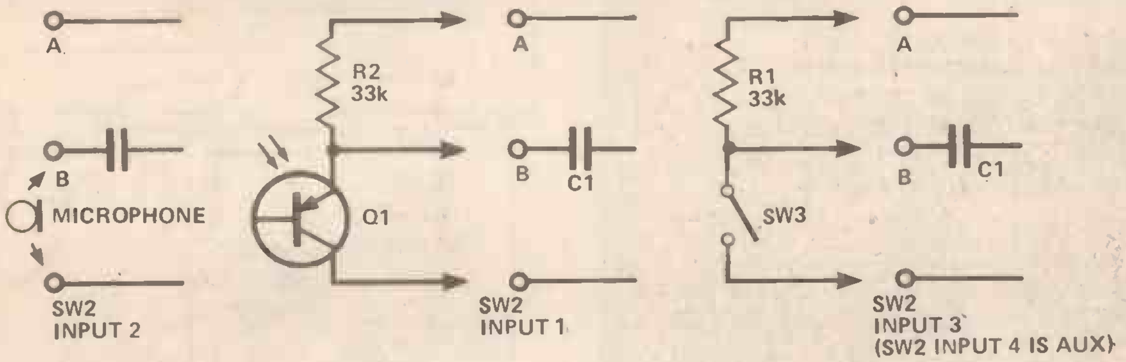


Fig. 2 Alternative input connections.

Parts List

RESISTORS (all 5%, ¼W)

R1	330k
R2	165k (2x330 k in parallel)
R3	100 k
R4	10 k
R5	560 ohm
R6	33 k (optional depending on input)

CAPACITORS

C1	10nF ceramic
C2	100nF ceramic
C3	10nF ceramic

SWITCH
Any SPST switch suitable

POTENTIOMETERS

RV2	2 Meg linear
RV1	50 linear

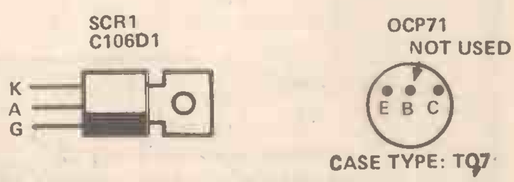
SEMICONDUCTORS
IC NE 555
SCR C106 D1 or similar with a 400 volt rating
LED Miniature red

INPUT DEVICE
OCP71 transistor
Crystal mike insert etc

OUTPUT DEVICE

Electronic flashgun, preferably computer type as these give a much shorter flash duration at close range

MISCELLANEOUS
Input sockets
Output to suit flash unit being used
Knobs 2 for pots
Battery Connector
PCB



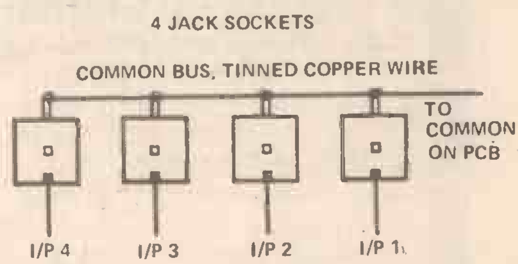


Fig. 4 Jack socket connections.

Solder

Solder is solder is solder . . . or is it? K. T. Wilson takes a closer look.

SIMPLE ENOUGH, isn't it? You just buy a reel of cored solder and that's it. Or is it? In fact there is no single material called solder, and there's a very wide range of behaviour that you can expect from solder, depending on their composition. Add to that dozens of materials that can be used for a flux core, and it doesn't look so simple.

Basically, solder is a mixture of lead and tin. Pure lead melts at about 327 C, tin at 232 C, but mixtures of tin and lead melt at temperatures which depend on the composition. Fig. 1 is a diagram which shows the melting points of various alloys — the important solders are the alloys which contain up to 60% tin. This type of diagram shows an important point — that there are mixtures of tin and lead which have melting points lower than either tin or lead. This lowest melting point is for a 63% tin mixture, called the eutectic — a name given to any mixture of materials whose melting point is the minimum.

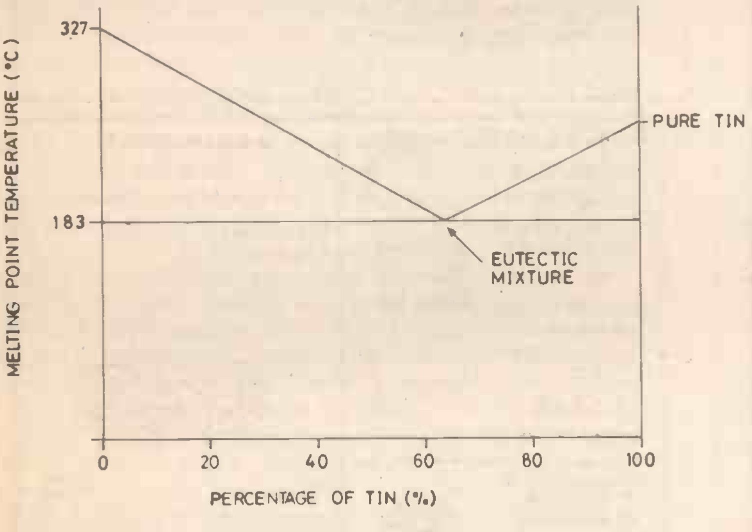


Fig. 1. Graph of melting point plotted against composition for tin/lead mixtures.

The graph of Fig. 1 shows only melting points — but there's more to it than that. Pure materials, such as pure tin or lead, have sharp melting points — meaning that they go from liquid to solid for only a tiny fraction of a degree change in temperature. The eutectic mixture (63% tin) does this also, but all other mixtures of tin and lead which contain more than about 15% tin have a 'pasty' stage (Fig. 2), neither liquid nor solid. This pasty stage is important in soldering, because slight vibration during the setting of solder can cause fractures if there is no pasty range of temperatures. Fig. 2 shows the temperature range of the pasty stages for the various mixtures — not that these are always completely solid at 183 C, so that this is the final setting temperature of any tin/lead solder.

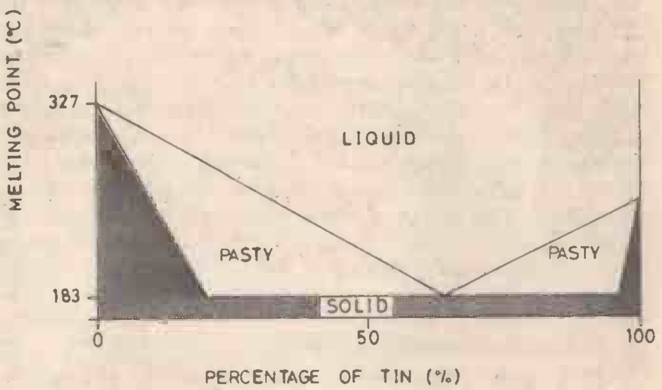


Fig. 2. The pasty part of the temperature/composition graph.

SOLDER ON

The reason for the popularity of the 60/40 alloy (60% tin) is fairly clear. It has a low melting point and a small pasty range; a good combination of qualities for hand-soldering. The low melting point lets us use low-power irons, and also avoids damage caused by the quick burn-off of flux which would occur at higher temperatures. The small pasty range (flux 180 C to 188 C) means that the alloy will set fairly quickly — blow on it once or twice and it's then strong enough to forget about. There are some merits which do not appear in the graph, though. One is that the 60/40 mix is one of the strongest, another is that it is the best electrical conductor of all the tin/lead alloys (about 11.5% of the conductivity of pure copper).

The 60/40 alloy, along with the 50/50, 45/55 and 40/60 alloys are the solders most commonly used for soldering small electrical equipment. Solders with lower tin contents are used for purposes where higher running temperatures are encountered, such as in lamp bases, electric motors, dynamos and fuses.

The lead/tin alloy isn't the only type of solder mixture, though, particularly for the industrial user. A straight lead/tin mixture dissolves copper, and copper is the material that we use for the business end of the soldering iron. The result is that bits of irons wear away very rapidly as the copper of the 'iron' bit dissolves, and the tracks of PCB's can also be dissolved in the same way, causing thinning of the copper layer. This problem is serious for large-scale production soldering work in particular, and can be overcome by making solder which already has a content of about 1.5% of copper. This is about as much copper as a tin-lead solder would normally dissolve, so that the inclusion of copper into the solder virtually puts an end to the dissolving of copper by the alloy from the bit or the PCB. Copper-alloy solder, invented by Multicore, and sold under the trade name of

SAVBIT, is used extensively for large-scale work, and is sufficiently well proven to be approved for soldering work on military equipment.

GOLD SOLDERS NEVER DIE

Not all soldering makes use of 60/40 alloys. For high-temperature soldering, alloys with only 5% tin are available (melting at 301 C); at the other end of the composition scale there is non-toxic solder which has 96.3% tin and the remainder silver. Such lead-free solder can be used when soldering has to be in contact with foodstuffs (as in tin-cans for example, or water pipes). Just for a bit of variety, there is also a low melting point solder, melting at 145 C, which contains 50% tin and 18% cadmium. This is of particular use in soldering onto gold, and the very low soldering temperature is an advantage for IC internal soldering. Another low melting point alloy is 62% tin, 2% silver, 36% lead, which solders particularly well to silver-coated sutaces. It finds particular use in soldering ceramics to metals. Table 1 shows some alloy compositions.

The metal, of course, is only half of the solder process. When we solder metals together, the temperature that has to be used is high enough to enable the oxygen in the air to attack the metals and the solder as well. In addition, we want the solder to spread over the surface of the metals. Now the spreading of a liquid over a solid is greatly affected by the presence of other materials — for example, water will not spread on glass if there is a trace of silicone grease on the glass. Liquid solder is equally fussy, and traces of dirt on metal surfaces will simply prevent solder from spreading.

A flux is a material which is used to avoid both of these problems. A good flux should help to clean up the metal surfaces (though it can't be expected to perform miracles) and should form a protective coating around the solder and the metals being joined so as to avoid oxidation.

For non-electrical soldering, acid fluxes like the traditional 'killed spirit' can be used. These materials are acid enough to dissolve away impurities; the sort of work that is soldered in this way is usually 'pickled' in acid anyway, so that the acidity of the flux is unimportant. For electrical work, however, strongly acid flux of this type has to be avoided like the plague. It's not very often that we can boil our printed circuit boards in water for several hours to get rid of acid, and if we don't remove it then the life of the conductors will be pretty short.

SOLDER GLUE

Electrical fluxes are therefore based on resin, the gummy material which is extracted from wood. Molten resin flows evenly over metals, giving protection for the joint for some time. Any resin which remains on a joint is hard and non-corrosive; a useful protective coating in fact.

Unfortunately, resin by itself does not dissolve a film of oxide from a metal surface, so that it doesn't have the cleaning effect of an acid flux. Fortunately, we can make use here of the fact that soldering is a high temperature operation. Some chemicals, such as the range of salts called halides, will dissociate when heated, meaning that they will release acid vapours which will be neutralised again when the material cools. Chemicals such

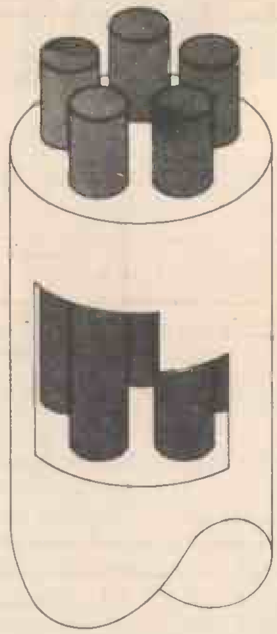


Fig. 3. Cross-section of 5-core solder.

as tin or lead chlorides can be used for the purpose. The addition of such materials, called activators, to a resin has a very noticeable effect on the fluxing ability of the resin. The release of chlorine from a chloride, for example, cleans metal oxides very effectively, but has less adverse effects than acid on the life of the joint because the chlorine is reabsorbed wherever the material cools. Less strongly active materials can be used when there is any risk of contaminating the area around the joint. In general, fluxes for electronics use have a fairly low halide content. A few types of halid-free fluxes have also been developed, and are used for such applications as circuits which are to be encapsulated. For circuits which must have very long corrosion-free life in hot climates, pure resin-flux is available.

In the early days of soldering, the flux was always applied separately from the solder. Since Multicore pioneered the idea of flux-cored solders, the separate-flux system has died out almost completely. Though several manufacturers now make flux-cored solders, Multicore are still unique in offering five cores (Fig. 3), ensuring quick and even dispersion of the flux. In case you were in any doubt, by the way, the resin cored solder is made in the same way as Blackpool rock — a thick rod of solder is cast with five holes running through it, these holes are filled with flux, and the whole thing is drawn out into the fine solder which we use. It's a fascinating process to watch too!

KEEP IT CLEAN

And after all that, let's hope we are soldering correctly. Boards such as Veroboard which have copper tracks should be scrubbed clean — don't let the flux have to do all the job of cleaning the board. Similarly, tarnished leadout wires of components should be cleaned by pulling them through loops of emery-paper. For really good joints, it pays to use leads and tracks that are tinned in advance (like the Blob-board tracks); gold plated leadout wires on transistors will also solder very easily.

Make sure the iron is hot enough. Some irons always seem to run a bit cool and if a very small bit is used, the heat sinking action of a circuit board can be enough to

ALLOY	GRADE	Melting Temp. Solidus °C	Liquidus °C	USES
2/2/96 Sn/Sb/Pb	"DOUBLE TWO"	305	315	High temperature High creep strength
5/93.5/1.5 Sn/Pb/Ag	HMP	296	301	High melting point
95/5 Sn/Sb	95A	236	243	High melting point Lead free
Pure Tin Sn	PT	232	232	Lead free
15/85 Sn/Pb	W	225	290	Lamps
96/4 Sn/Ag	96S	221	221	Stainless steel Bright, strong, non-toxic
20/80 Sn/Pb	V	183	275	Lamps
30/70 Sn/Pb	J	183	255	Lamps, motors
31.2/67/1.8 Sn/Pb/Sb	L	185	243	Radiators, general purpose Non-electrical
40/60 Sn/Pb	G	183	234	General purpose
45/55 Sn/Pb	R	183	224	General purpose
50/48.5/1.5 Sn/Pb/Cu	SAVBIT 1	183	215	Saves copper erosion
50/49.7/0.3 Sn/Pb/Sb	Sn 50	183	212	General purpose
50/50 Sn/Pb	F	183	212	General purpose
60/39.7/0.3 Sn/Pb/Sb	Sn 60	183	188	Electrical
60/40 Sn/Pb	KP	183	188	Electrical
63/36.7/0.3 Sn/Pb/Sb	Sn 63	183	183	Electrical
62/35.7/2/0.3 Sn/Pb/Sb/Ag	Sn 62	179	179	Silver-plated surfaces
62/36/2 Sn/Pb/Ag	LMP	179	179	Silver-plated surfaces
18/180.1/1.9 Sn/Pb/Ag	ALU-SOL 45	178	270	Aluminium
50/32/18 Sn/Pb/Cd	TLC	145	145	Low melting point, soldering on gold
70/30 Sn/Zn*	—	196	307	Spray wire for metal
80/20 Sn/Zn*	—	196	268	film capacitors
30/70 Sn/Cd*	TC 30	176	240	Low thermal EMF solder

* These alloys are only available as solid wire. For those purposes where solid wire is still used on automatic appliances precision made solid wire can be made in any alloy to special order.

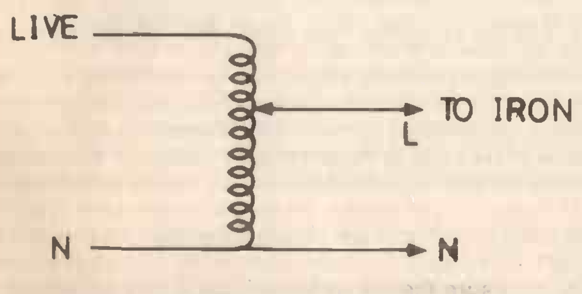


Fig. 4. Using an autotransformer, such as a Variac, to control iron temperature.

keep the bit too cool to melt the solder properly. A very hot iron, on the other hand, will cause oxidation and burning if it's left on too long. The power output of soldering irons for electronics use is so low that a simple thyristor controller can cope, and excellent heat regulation can be obtained if an auto-transformer is also used (Fig. 4). Incidentally, a lot of awkward problems can be overcome by using ready-formed solder shapes, such as rings and spheres, or by the use of solder and flux mixed in the form of a cream or paint.

May the flux be with you!

HE

The author gratefully wishes to acknowledge the help of Multicore Solders Ltd in providing information for this article.

Kit Review — WEIN BRIDGE OSCILLATOR

A WEIN BRIDGE oscillator is a circuit which produces a sine wave output. This kit makes a test-bench unit which gives a variable frequency sine wave for a variety of purposes.

A sine wave source is very useful in many applications. It is the only waveform which contains only a single frequency. By 'sweeping' it — varying the frequency a little at a time — and finding the response of a particular circuit (how much it reduces the level of the input waveform), the overall frequency response can be found by drawing a graph of response against input frequency.

This procedure requires a sine wave source of a known, but variable, frequency.

This unit will produce a sinewave at frequencies between 15 Hz and 20 kHz, accurate to about 10%. This should prove sufficient for most test applications.

FIRST IMPRESSIONS

The kit cost £7.99 and for this price we expected a small, cheap case. Nothing could be further from the truth. The case is *heavy*. It's made (we think) from steel plate — or at least, that's what it feels like!

The front panel is printed in red and white and looks very impressive, with the top painted with grey hammer finish enamel. It wouldn't look out of place on board a battleship.

The components came in two plastic bags, one holding all the board and panel mounting components as well as PCB pins and wire. The other bag contained *more* PCB pins and *more* wire! Very strange. Later we discovered that the pins in the first bag (which was stapled shut) were the wrong size for the holes — the second bag had obviously been added after the first had been sealed — fair enough. Why the extra wire, though? We never did find the answer to that one.

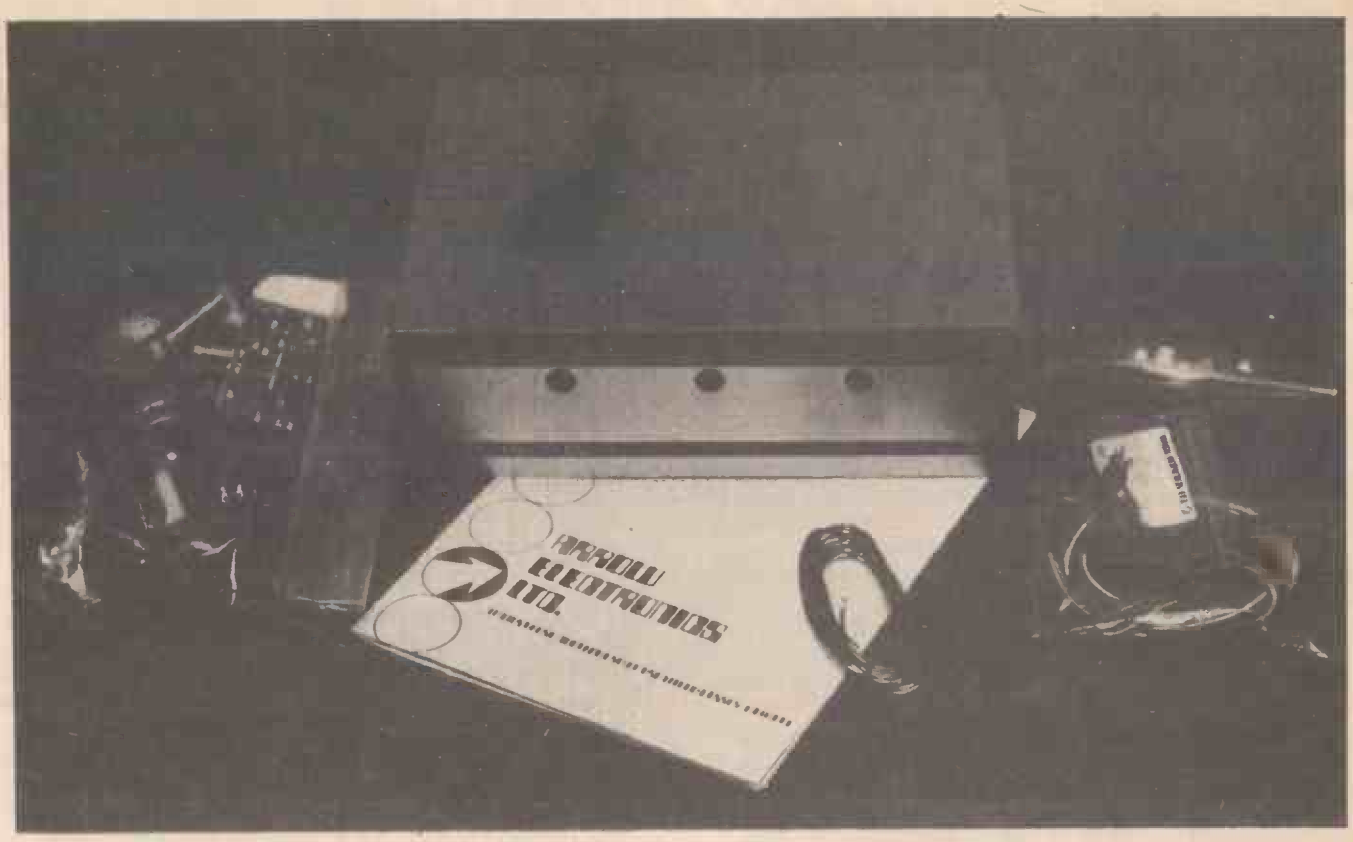
There was also a huge length of solder included — much more than was required.

BUILDING IT

Let me say right at the start that if you can't follow a circuit diagram, you can't build this kit. It's excellent value in terms of the hardware and components provided but it's not easy to build.

The main problem is the book of instructions — it's badly written and produced and, in places, positively

The completed unit — very smart, except for the frequency scale (which goes from 15 to 150). White on aluminium is a mistake.



What you get. The case makes up most of the weight.

cryptic. Anyone who could build a project from the circuit diagram could find their way round it easily enough but if you want step-by-step instructions then it will give you problems.

COMPONENT CHECK

The first thing we did was to check to components supplied against the parts list in the manual. Surprisingly enough, the instructions gave the resistor and capacitor colour codes where necessary. This is very much at variance with the level of knowledge assumed in the rest of the book.

A couple of components were not as marked in the list — a close value to that required was supplied instead.

The list itself was full of ambiguities:

C6-C10

didn't mean C6 *to* C10; it meant C6 *and* C10.

TR1-TR2 BC177-178-179

meant that TR1 and TR2 are both either a BC177, a BC178 or a BC179!

Having came to terms with this sort of thing (and having referred to the circuit diagram once or twice), we discovered that all of the required components *were* there and so we could proceed with the construction.

PUTTING IT TOGETHER

The board has the component positions printed onto it. While on the one hand this is a good idea, it's also a good idea to print the component positions somewhere in the paperwork also. This means that when you've soldered everything down (covering the component position markings as you go, of course) and the manual tells you to solder a PCB pin to a position "alongside C3", you don't have to refer to the circuit diagram and the PCB foil pattern to find out where C3 *is!*

We had no trouble following the component positioning, however, and managed to get everything in the right place.

The resistors were a bit fiddley — they were of the 'pre-formed' type, with the leads bent ready for insertion into a PCB. The only trouble was, they weren't bent in the right places to fit the board! As the instructions put it, "Resistors are pre-formed. Straighten and re-bend before use". Easier said than done.

The manual is also worth quoting when it comes to D1 and D2. These are wired in parallel, facing in opposite directions or, as the book puts it, "D1-2. 1N4011 Diode. These are fixed in an alternate manner"!

THE FRONT PANEL

The multi-way range switch (a 2-pole, 6-way rotary) has no less than four wires and eight capacitors mounted directly onto it. This is not easy and must make it fault-prone during extended operation. It could have been avoided by making the PCB a little bigger. There was more than enough wire, solder and PCB pins to connect the switch to the capacitors mounted on the PCB.

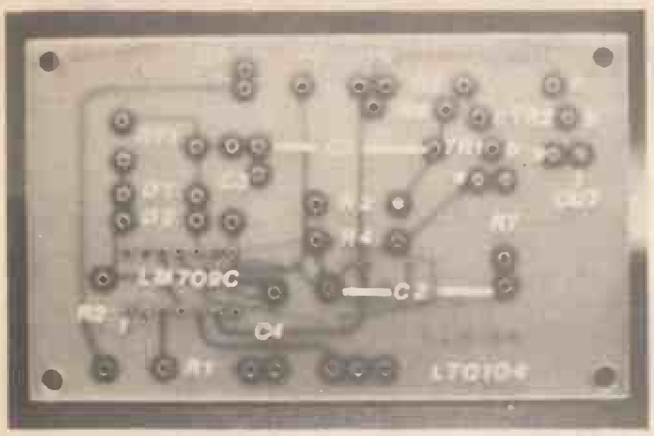
All three of the front panel components had mounting tags on them. These are designed to poke through a small hole beside the spindle of the device to stop it from rotating. As there were no such holes in the front panel, the tags had to be clipped off. This was not mentioned in the instructions.

WIRING IT UP

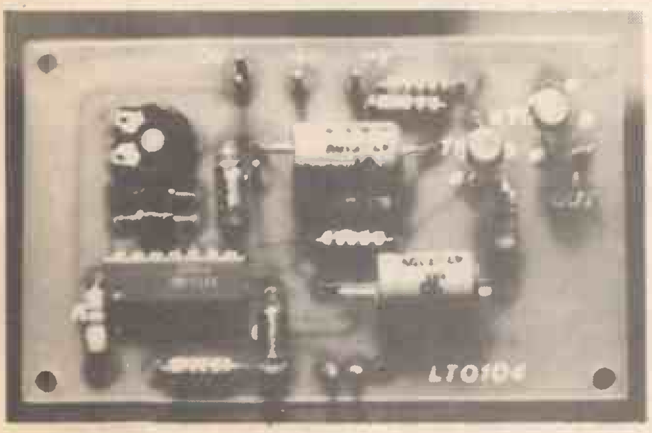
The rest of the construction went off without a hitch. Sleeving was provided for 'flying' connections. A few components mounted directly onto the front panel components. While this is not elegant, it shouldn't cause any problems in building or operation.

The PCB was mounted on plastic pillars which push-fitted into holes in the chassis and the PCB, providing a stable and strong construction.

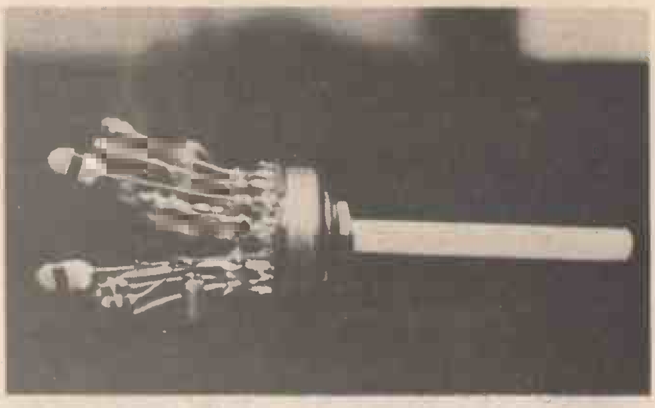
A piece of paxolin (the stuff PCBs are made of) and another couple of PCB mounting pillars held the batteries (two PP3s) in place fairly securely. The last connection was made and a 'scope plugged into the coax socket on the front panel. The unit was then switched on.



The completed board. Can you follow the component positions through the components? We can't!



The board before construction. The component position markings are fairly easy to follow.



This is what the multi-way switch looks like after everything has been soldered onto it.

OPERATION

It worked first time, the only problem being that the output level control operated in the wrong direction — clockwise rotation *reduced* the signal level. Again the ambiguous instructions had let the product down. Easily enough fixed, though.

The unit produced a range of frequencies from about 30 Hz to over 150 kHz — no doubt the 'nearly correct value' components contributed to the lack of low frequencies.

Another problem was the DC shift on the output. The average value of the signal voltage was not zero volts, even though the output was decoupled by a capacitor!

Replacing the decoupling capacitor revealed the source of the trouble — it was an electrolytic type. These are 'polarised' and have slightly different characteristics to current flowing in one direction, compared to current flowing in the opposite direction.

This means that there is effectively a diode in series with the output. Anyway, replacing the capacitor with a polyester type cured it.

SUMMARY

This is not a kit for the complete beginner. To anyone who is *not* a complete beginner, however, I would recommend this kit highly. When completed it is very rugged, reliable and would prove very useful to anyone interested in (particularly) audio work. It's the best value for money I've seen in a kit for some time. If what you're after in a kit is for someone to do your component buying for you in bulk, then this is for you. If you're looking for something easy to build, buy something else.

HE

This kit is available from:
Arrow Electronics,
Leader House,
Coptfold Road,
Brentwood,
Essex,
CM14 4BN
For £7.99p all inclusive. Order as LTO 104.

Short Circuits

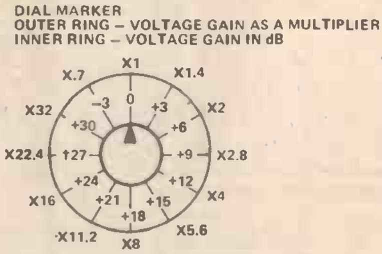
A PREAMP WITH DB STEPPED GAIN CONTROL

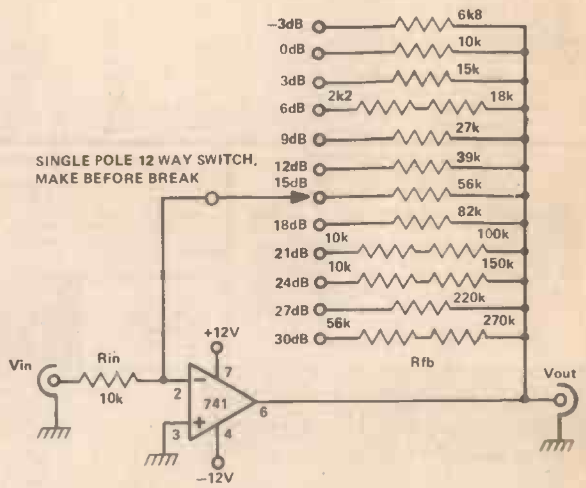
A handy little piece of test equipment is a preamplifier with stepped gain control selected by a rotary switch. The circuit here uses a single IC, a 741, 14 resistors and a single-pole, 12-way rotary switch.

The voltage gain of an op-amp (and that is what the 741 is) is determined by the ratio of R_{FB}/R_{in}; thus by having R_{fb} switched, the voltage gain can be varied.

The input impedance of the preamplifier is set by R_{in} to 10k. Having the gain set in decibel (dB) intervals is most useful in audio applications because our hearing, like dBs, is logarithmic. The gain in dB is defined as being equal to $20 \times \log_{10}$ (Voltage Gain) which equals $20 \times \log_{10} (R_{FB}/R_{in})$. Therefore a voltage gain of 1 is $20 \times \log_{10} 1 = 0$dB but a voltage gain of 2 is $20 \times \log_{10} 2 = 6$dB.

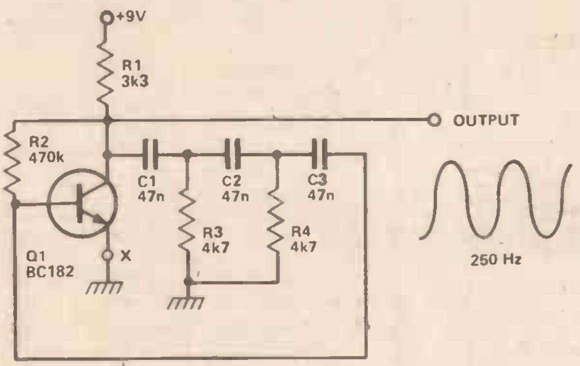
Although this may at first seem like a complex approach, the decibel is an easy to use method for describing gain and attenuation since all you have to do is add and subtract them. For instance, say a signal passes through four devices with gains of 9dB, 15dB, −3dB and −3dB, the overall signal gain is 9+15−3−3 which is 18dB (this is a voltage gain of times 8). Note that negative dB means attentuation (reduction in strength). Now consider the same situation without using dB; a signal passes through four devices with gains of 2.8, 5.6, 0.7 and 0.7. The overall signal path is 2.8×5.6×0.7×0.7 which comes to the same result but a lot more difficult to calculate than adding and subtracting.





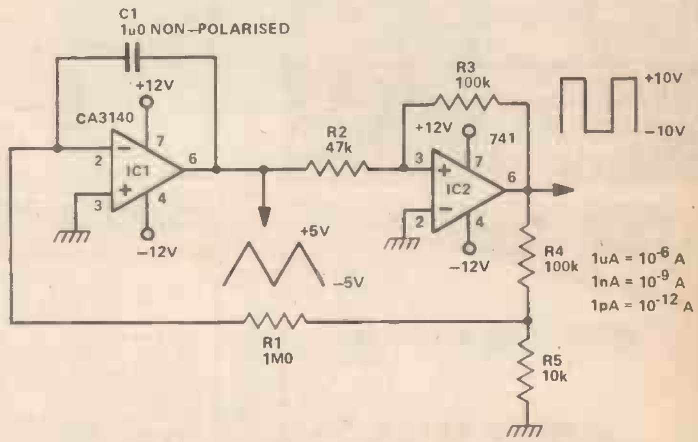
VOLTAGE GAIN = Rfb/Rin
NOTE: AMPLIFIER INVERTS SIGNAL

PHASE SHIFT OSCILLATOR



A single transistor can be used to make a simple phase shift oscillator. The output is a sinewave with a 'lump' in it, which means that the distortion content is rather high, about 10%. This is not always a problem, quite often when generating audio tones a high harmonic content will make a more interesting sound. The sine wave purity can be increased by putting a variable resistor (25 ohms) in the emitter lead of Q1 (x). The resistor is adjusted so that the circuit is only just oscillating, then the sinewave is relatively pure. However, if the power supply level varies, the oscillation may cease altogether. The operating frequency may be varied by putting frequency may be varied by putting a 10k variable resistor in series with R3, or by changing C1, 2, 3. Making C1, 2, 3 equal to 100nF will halve the operating frequency. Also, the operating frequency can be voltage controlled by a FET in series with R3, or optically controlled by an LDR in series with R3.

A LOW FREQUENCY OSCILLATOR



IC1 is a MOSFET OP amp. Thus its input bias current is very low indeed, typically 10 pA as compared with 100 nA for a 741 (10 000 times larger!). This allows very low current designs to be produced. The circuit above shows an integrator (IC1) and a Schmitt trigger (IC2). Imagine that the output of the Schmitt is high (+10 V). The voltage at the junction of R4, R5 is approximately +1 V. This pushes a current of 1 uA through R1 which then charges C1. Thus C1 (the output of IC1) ramps down at a rate of I/C which is in this case 1 V/Sec. When this voltage reaches −5 V, the Schmitt trigger flips over into its low state (−10 v). Now the current through R1 flows the other way, and so the output of IC1 ramps up at 1 V/sec. This continues until it reaches +5 V (the upper hysteresis level of the Schmitt). The Schmitt trigger then jumps to its high output and so the process repeats itself. The circuit produces a square wave (±10 V) and a triangle (±5 V) output. Using the components shown the period is 20 seconds. To get 200 seconds make R1 = 10M. To get 2 000 seconds make R1 = 10M, R5 = 1R.

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Good Evans

Amaze your friends! It's not necessary to know anything at all about electronics to hold your head up high in the most august circles — simply remember our Gary Evans' jargon generator.

THE BAUD RATE on the CUTS serial I/O connecting my CPU to my background storage medium needs adjusting because at present I am getting a large quantity of read errors.

My Hi-Fi Amp is suffering from HF instability and the LF component of the S/N figure has increased due, I think, to a corresponding increase in the ripple on the LT rails of the system.

Lost in the Jargon Jungle? — well I can help. I may not be able to teach you about all the ins and outs of the technical shorthand that permeates the world of electronics in a few words but at least I'll be able to help you reply in kind when exposed to the talents (sic) of a jargon juggler. The point is you don't have to understand what you're saying, in fact it helps if you don't, you just have to sound convincing in your performance.

Study the ready-made jargon generator below — some of the phrases are more applicable to electronics than others but all should baffle your friends and influence people.

The jargon generator will produce up to 40 000 discrete, well balanced "State of the Art" sentences quickly and simply with very little propagation delay.

To put the generator to work, arrange the modules in W, X, Y, Z order. Next generate a four digit random number, this may be the most difficult phase but if a pseudo-random number generator is not available, you could, at a pinch, use your grey cells to generate said number. The first digit of the number will select a phrase from module W, the second from X etc. The result is a jargon filled sentence. Add more sentences for a paragraph and if you carry on you could soon have a book in print.

After you have mastered the basic technique you can try the advanced version of the generator by altering the order of the modules — be warned though, in these advanced configurations some additional comas may be required.

Jargon Generator Module W

1. in particular
2. on the other hand,
3. however,
4. similarly,
5. in a real time environment,
6. in this connection,
7. as of now,
8. for example,
9. thus,
10. the "State of the Art" implies,

Jargon Generator Module X

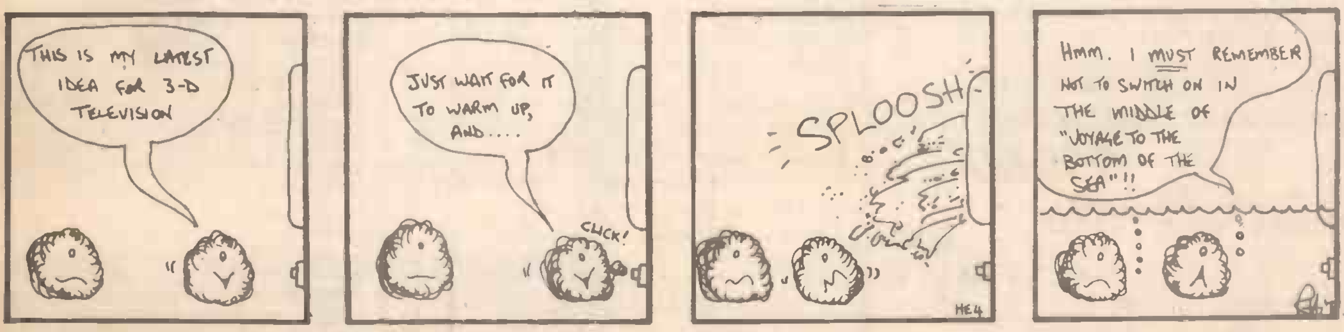
1. a large portion of interface coordination communication
2. the concept of electron mobility
3. the characterization of specific criteria
4. the worst case load situation
5. the fully integrated test program
6. the incorporation of DIN requirements
7. any associated supported component
8. a constant data path
9. in independent functional principle
10. a primary interrelationship between system and/or sub system technologies

Jargon Generator Module Y

1. must utilise and be functionally interwoven with
2. maximises the probability of project success and
3. adds explicit performance limits to
4. necessitates that urgent consideration be applied to
5. requires considerable systems analysis to arrive at
6. is further complicated when taking into account
7. presents extremely interesting challenges to
8. recognises the importance of
9. effects a significant improvement in the performance factor of
10. adds over-riding performance constraints to

Jargon Generator Module Z

1. the sophisticated hardware
2. the anticipated fourth generation equipment
3. the sub system compatibility testing
4. the structural design concepts
5. the preliminary qualification limit
6. the evolution of specifications over a given period of time
7. the philosophy of commonality and standardisation
8. the greater fight-worthiness concept
9. any discrete configuration mode
10. the total system rationale.



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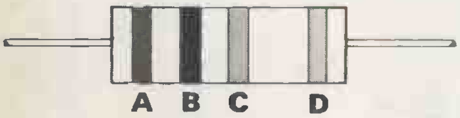
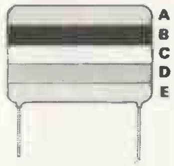
RESISTOR COLOUR CODE



	A and B	C
BLACK	0	- - ohms
BROWN	1	- - 0 ohms
RED	2	- k -
ORANGE	3	- - k
YELLOW	4	- - 0 k
GREEN	5	- M -
BLUE	6	- - M
VIOLET	7	
GREY	8	
WHITE	9	

	D (tolerance)
NONE	20%
SILVER	10%
GOLD	5%
RED	2%
BROWN	1%

CAPACITOR COLOUR CODE



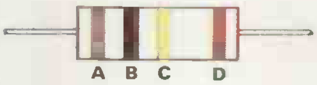
	C
BLACK	- - p
BROWN	- - 0 p
RED	- n -
ORANGE	- - n
YELLOW	- - 0 n
GREEN	

D (tolerance)	
BLACK	20%
WHITE	10%
GREEN	5%

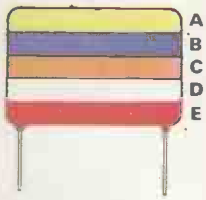
E (voltage)	
RED	250 V

A and B: As for resistors.

EXAMPLES:



A = 1, B = 0, C = - - 0 k, so value is 100 k; D = accuracy = 2%



A = 4, B = 7, C = - - n, so value is 47 n; D = accuracy = 10%; E = voltage = 250 V

BRITISH STANDARD COMPONENT MARKINGS

M (pronounced mega) means multiply by 1 000 000,
k (pronounced kilo) means multiply by 1 000,
m (pronounced milli) means divide by 1 000,
u (pronounced micro) means divide by 1 000 000,
n (pronounced nano) means divide by 1 000 000 000 and
p (pronounced pico) means divide by 1 000 000 000 000.

So when we write 10 mV, we mean (10 / 1000) V, or 0.01 V. Note: it is usual to leave the "F" and "ohm" out altogether when writing, but as we rarely talk about resistances less than one ohm or capacitances greater than one farad, this does not cause *too* much confusion.

Examples: 10 uV = (10 / 1 000 000) V = 0.000 001 V; 330 R = 330 ohms (R is used for ohms when no multiplier is needed); 10 k = 10 000 ohms; 3.9 mV = 0.003 9 volts; 3.9 u = 0.000 003 9 farads.

Now, at some stage, someone decided to jazz up the system by putting the suffix in place of the decimal point, so that: 4k3 is 4 300 ohms and 4u9 is 0.000 004 9 farads.

Also, in case one of the digits got lost, it was decided that there should always be at least three numbers or letters in the value, so: 5k is written 5k0, et cetera.

Examples: 3M0 = 3 M ohms = 3 000 000 ohms; 4n5 = 4.5 nF = 0.000 000 004 5 farads.

INTEGRATED CIRCUIT NUMBERS

TTL: (SN)7(490) — SN = manufacturer; 90 = device function (2 or 3 digits). Example: DM 74121

CMOS: (CD)40(42)(A) — CD = manufacturer; 42 = device function (2 digits); A = electrical fragility (A = do not handle — static charges will destroy device; B or C = protected against static). Example: CA 4015 B

OTHER TYPES: (uA)(741) — uA = manufacturer; 741 = device function (3 or more digits). Examples: LM 309, CA 3011, NE 555

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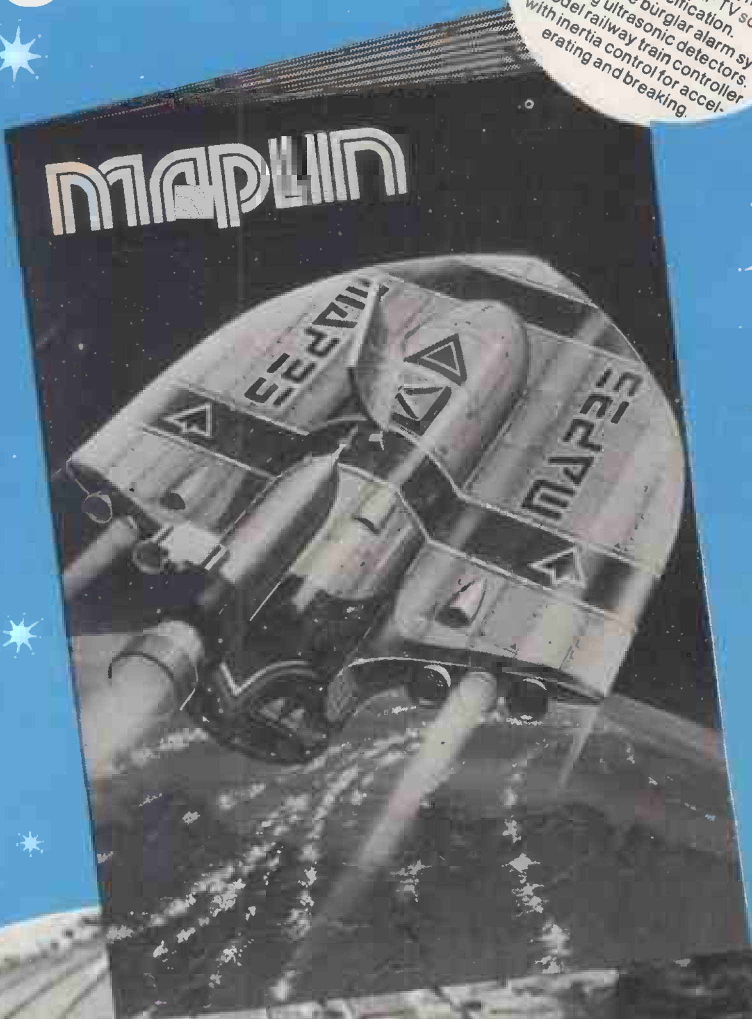

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