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VOL 89 NO 1573

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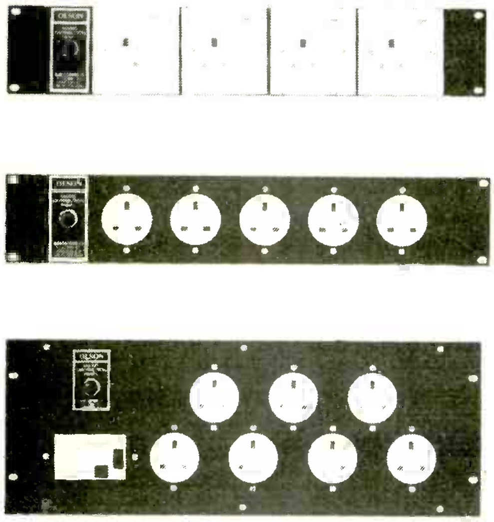

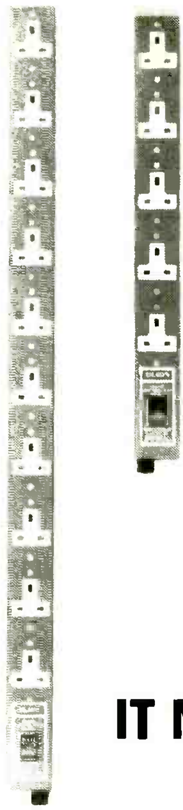

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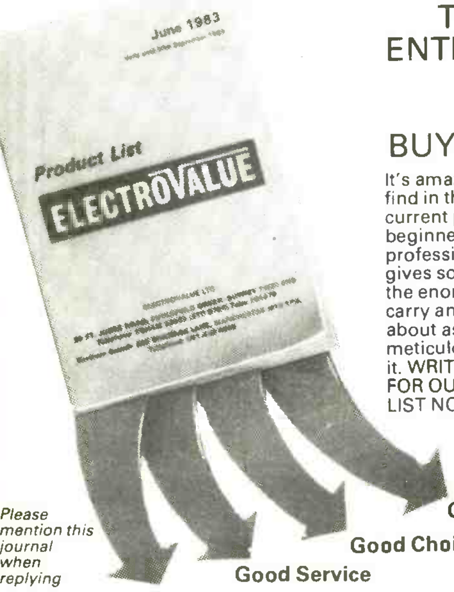

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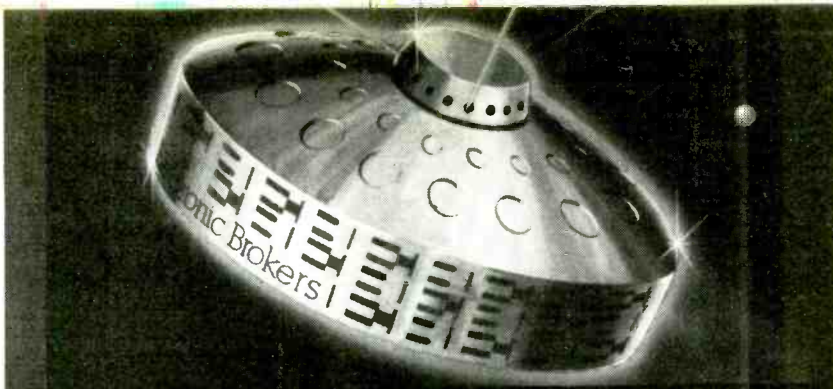

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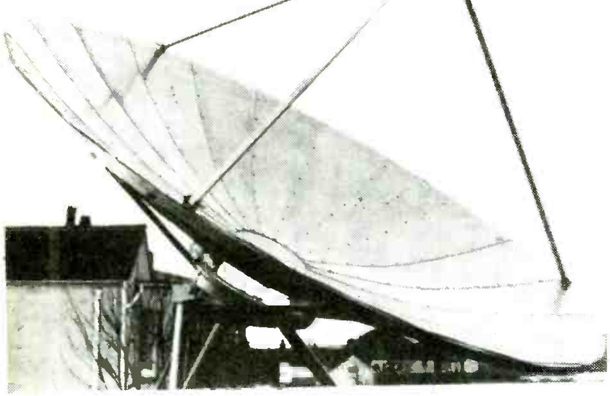

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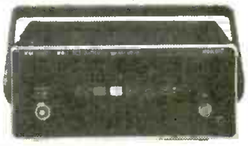

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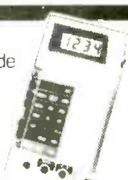

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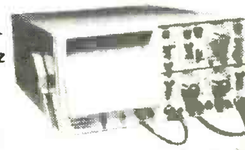

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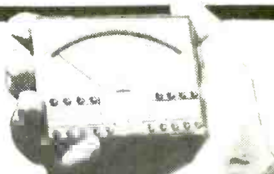

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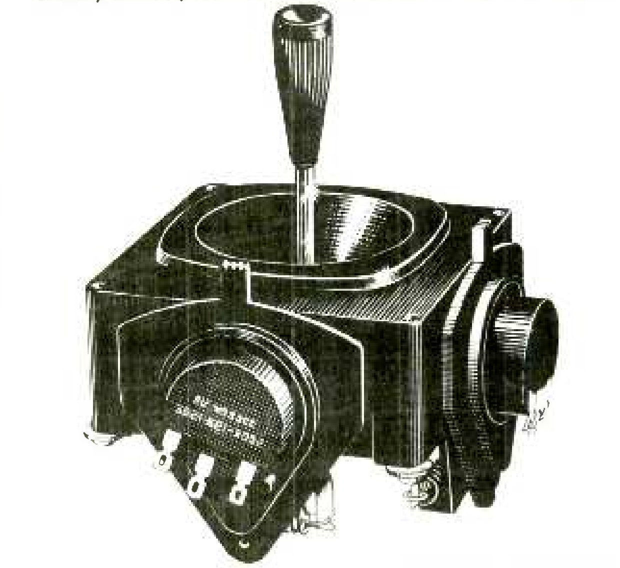

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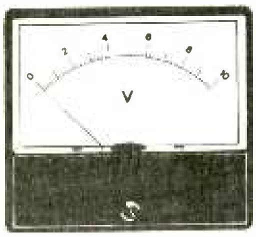

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4116 200NS	D2	0 80
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6800	D7	2 25
6802	D5	2 50
6809	D6	6 30
6810	D1	1 15
6821	D3	1 00
6840	D4	3 75
6845	D5	6 50
6850	D2	1 10
68488	D2	7 30
68B00	D7	5 25
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81AS97	0 80
81LS98	0 80
8T26A	0 90
8T28A	0 90
8T95	0 90
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75107		0 47
75110		0 56
75150		0 64
75154		0 77
75160		2 56
75161		2 80
75162		3 95
75172		1 95
75173		1 44
75174		1 95
75175		1 44
75182		0 50
75183		0 50
75188		0 37
75189		0 37
75451		0.22
75452		0 22
75453		0 22
75454		0 22
75468		0.88
75491		0 31
75492		0 42
AY31015	D2	3 00
AY31270		6 47
AY38910	D6	4 40
AY53600	D2	6 70
DP8304	D1	2 50
MC1488	D1	0 37
MC1489	D1	0 37
NC3242A		6 30
MC3446	D1	2 50
MC3448A	D1	3 75
MC3480	D5	7 30
MC3487	D1	2 00
MC14411	D1	7 65
MC14412		9 45
RO32513L	D1	6 50
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LM301AN	0 24
LM308N	0 48
LM311P	0 50
LM319N	1 99
LM324N	0 30
LM348N	0 60
NE555P	0 16
NE556CP	0 45
TL010	0 39
TL061	0 29
TL062	0 49
TI064	0 98
TL066	0 29
TL071	0 29
TL072	0 47
TL074	1 00
TL081	0 26
TL082	0 46
TL084	1 58
TL091	0 40
TL092	0 58
TL094	1 34
TL487	0 62
TL489	0 62
TL494	1 63
TL496	0 60
TL507	1 33
725	1 60
741	0 14
747	0 48
748	0.27

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78L12	0 30
78L15	0 30
7805	0 40
7812	0 40
7815	0 40
7905	0 45
7912	0 45
7915	0 45
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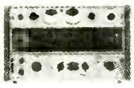

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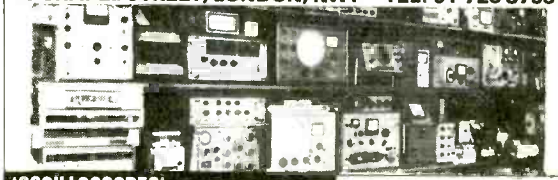

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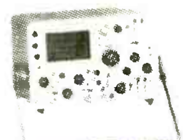

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WW-10

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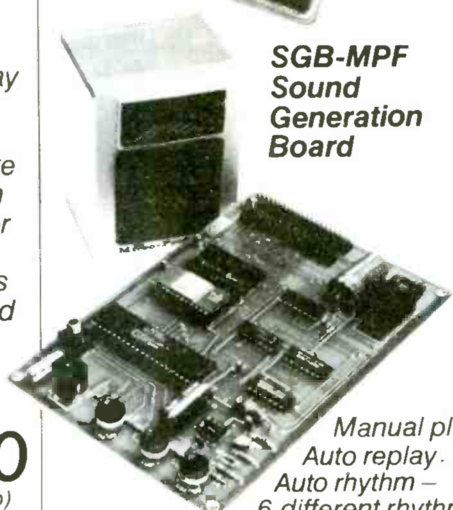

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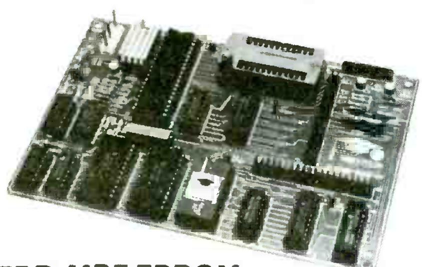
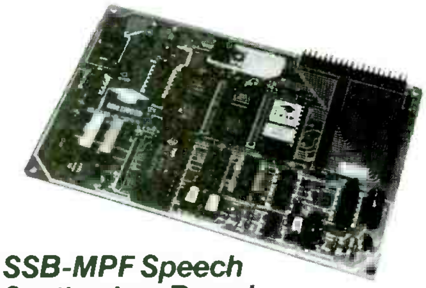


EPB-MPF EPROM Programming Board
For all +5V 1KB/2KB/4KB EPROMS Read/Copy/List/Verify Capability.



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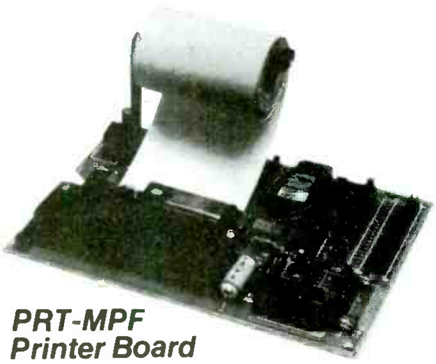

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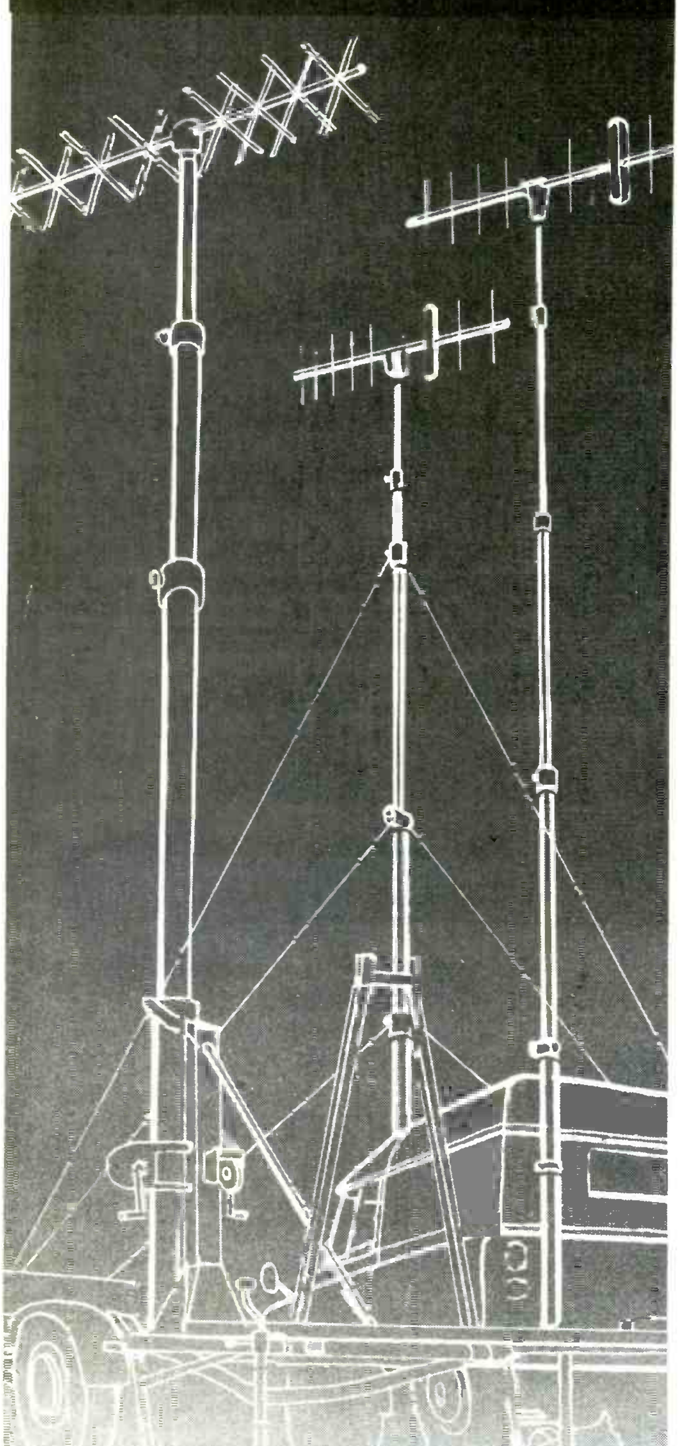

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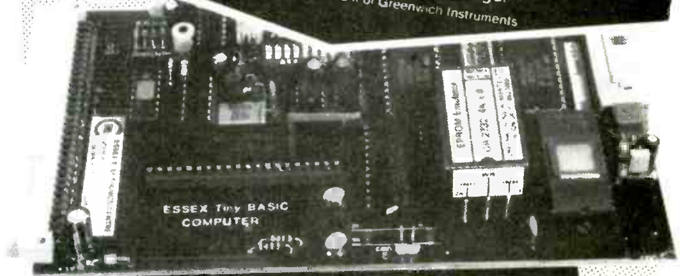
'INSTANT ROM is the trademark of Greenwich Instruments



Essex Buffer Timer

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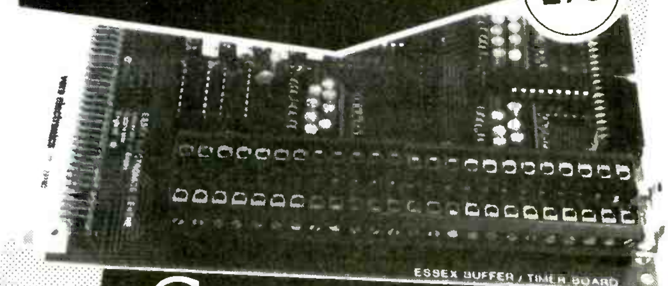

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Connects to the Essex Tiny BASIC System bus to provide an additional 12 opto-isolated inputs and 12 opto-isolated outputs per card for safe connection to external equipment. isolation voltage = 1500 volts

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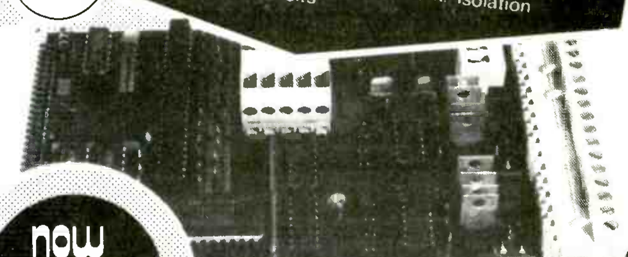

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The new microprocessor controlled EP8000 Emulator Programmer will program and emulate all EPROMs up to 8k x 8 sizes, and can be extended to program other devices such as 16k x 8 EPROMs, Bipolar PROMs, single chip microprocessors with external modules.

Personality cards and hardware changes are not required as the machine configures itself for the different devices.

The EP4000 with 4k x 8 static RAM is still available with EPROM programming and emulation capacity up to 4k x 8 sizes.

FEATURES

- Software personality programming/emulation of all EPROMs up to 8k x 8 bytes including 2704, 2708, 2716(3), 2508, 2758A, 2758B, 2516, 2716, 2532, 2732, 2732A, 68732-0, 68732-1, 68766, 68764, 2564, 2764. Programs 25128, 27128 with adaptors.
- No personality cards/characterisers required.
- Use as stand alone programmer, slave programmer, or EPROM development system.
- Checks for misplaced and reversed insertion, and shorts on data lines.
- Memory mapped video output allows full use of powerful editing facilities.
- Built-in LED display for field use.
- Powerful editing facilities include: Block/Byte move, insert, delete, match, highlight, etc.
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NEW PRODUCT

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2716(3)
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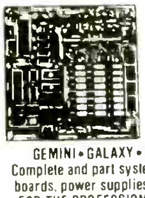

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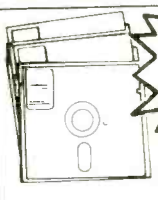

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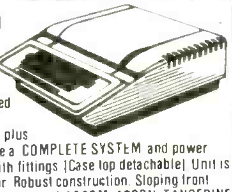

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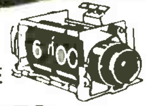

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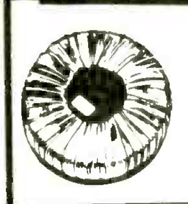

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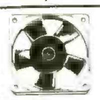

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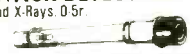

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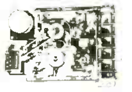

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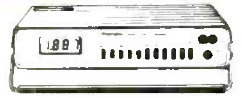

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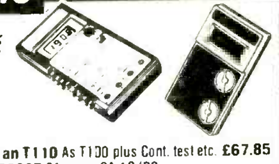

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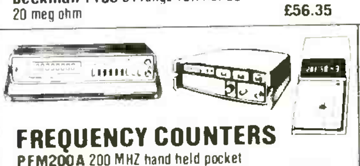

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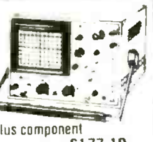

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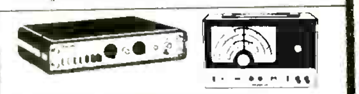

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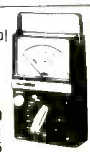

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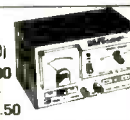

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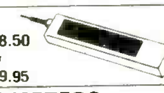

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AMPLIFIERS

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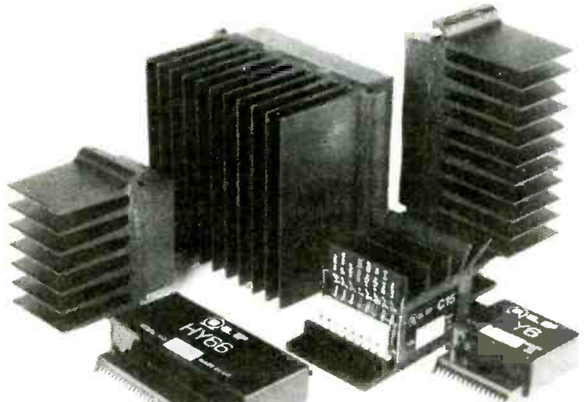
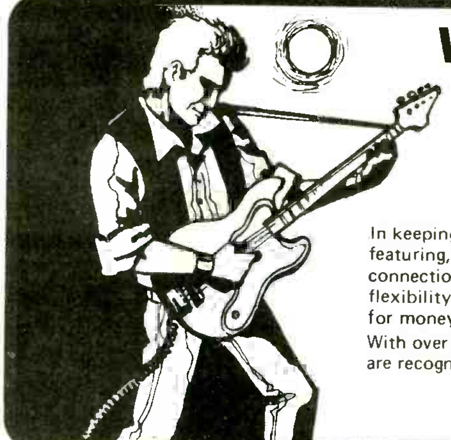


Over the last few years we have received feedback via the general public and industry that our products are from Taiwan, Singapore, Japan, etc... ILP are one of the few 'All British' electronics Companies manufacturing their own products in the United Kingdom. We have proved that we can compete in the world market during the past 12 years and currently export in excess of 60% of our production to over twenty different countries – including USA, Australia and Hong Kong. At the same time we are able to invest in research and development for the future, assuring security for the personnel, directly and indirectly, employed within the UK. We feel very proud of all this and hope you can reap some of our success.

I. L. Potts – Chairman



WE'RE INSTRUMENTAL IN MAKING A LOT OF POWER

In keeping with ILP's tradition of entirely self-contained modules featuring, integral heatsinks, no external components and only 5 connections required, the range has been optimized for efficiency, flexibility, reliability, easy usage, outstanding performance, value for money.

With over 10 years experience in audio amplifier technology ILP are recognised as world leaders.

BIPOLAR MODULES

Module Number	Output Power Watts rms	Load Impedance Ω	DISTORTION T.H.D. Typ at 1KHz	I.M.D. 60Hz/ 7KHz 4:1	Supply Voltage Typ	Size mm	WT gms	Price inc. VAT
HY30	15	4-8	0.015%	<0.006%	± 18	76 x 68 x 40	240	£8.40
HY60	30	4-8	0.015%	<0.006%	± 25	76 x 68 x 40	240	£9.55
HY6060	30 + 30	4-8	0.015%	<0.006%	± 25	120 x 78 x 40	420	£18.69
HY124	60	4	0.01%	<0.006%	± 26	120 x 78 x 40	410	£20.75
HY128	60	8	0.01%	<0.006%	± 35	120 x 78 x 40	410	£20.75
HY244	120	4	0.01%	<0.006%	± 35	120 x 78 x 50	520	£25.47
HY248	120	8	0.01%	<0.006%	± 50	120 x 78 x 50	520	£25.47
HY364	180	4	0.01%	<0.006%	± 45	120 x 78 x 100	1030	£38.41
HY368	180	8	0.01%	<0.006%	± 60	120 x 78 x 100	1030	£38.41

Protection: Full load line. Slew Rate: 15v/µs. Risetime: 5µs. S/N ratio: 100db.
Frequency response (–3dB) 15Hz – 50KHz. Input sensitivity: 500mV rms.
Input Impedance: 100K Ω. Damping factor: 100Hz >400.

PRE-AMP SYSTEMS

Module Number	Module	Functions	Current Required	Price inc. VAT
HY6	Mono pre amp	Mic/Mag. Cartridge/Tuner/Tape/ Aux + Vol/Bass/Treble	10mA	£7.60
HY66	Stereo pre amp	Mic/Mag. Cartridge/Tuner/Tape/ Aux + Vol/Bass/Treble/Balance	20mA	£14.32
HY73	Guitar pre amp	Two Guitar (Bass Lead) and Mic + separate Volume Bass Treble + Mix	20mA	£15.36
HY78	Stereo pre amp	As HY66 less tone controls	20mA	£14.20

Most pre-amp modules can be driven by the PSU driving the main power amp. A separate PSU 30 is available purely for pre amp modules if required for £5.47 (inc. VAT). Pre-amp and mixing modules in 18 different variations. Please send for details.

Mounting Boards

For ease of construction we recommend the **B6** for modules HY6–HY13 £1.05 (inc. VAT) and the **B66** for modules HY66–HY78 £1.29 (inc. VAT).

MOSFET MODULES

Module Number	Output Power Watts rms	Load Impedance Ω	DISTORTION T.H.D. Typ at 1KHz	I.M.D. 60Hz/ 7KHz 4:1	Supply Voltage Typ	Size mm	WT gms	Price inc. VAT
MOS 128	60	4-8	<0.005%	<0.006%	± 45	120 x 78 x 40	420	£30.41
MOS 248	120	4-8	<0.005%	<0.006%	± 55	120 x 78 x 80	850	£39.86
MOS 364	180	4	<0.005%	<0.006%	± 55	120 x 78 x 100	1025	£45.54

Protection: Able to cope with complex loads without the need for very special protection circuitry (fuses will suffice).
Slew rate: 20v/µs. Rise time: 3µs. S/N ratio: 100db
Frequency response (–3dB): 15Hz – 100KHz. Input sensitivity: 500mV rms
Input impedance: 100K Ω. Damping factor: 100Hz > 400.

'NEW to ILP' In Car Entertainments

C15

Mono Power Booster Amplifier to increase the output of your existing car radio or cassette player to a nominal 15 watts rms.

Very easy to use.

Robust construction. **£9.14 (inc. VAT)**

Mounts anywhere in car.

Automatic switch on.

Output power maximum 22w peak into 4Ω.
Frequency response (–3dB) 15Hz to 30KHz, T.H.D. 0.1% at 10w 1KHz
S/N ratio (DIN AUDIO) 80dB, Load Impedance 3Ω.
Input Sensitivity and impedance (selectable) 700mV rms into 15KΩ 3V rms into 8Ω.
Size 95 x 48 x 50mm. Weight 256 gms.

C1515

Stereo version of C15. **£17.19 (inc. VAT)**

Size 95 x 40 x 80. Weight 410 gms.

POWER SUPPLY UNITS (Incorporating our own toroidal transformers)

Model Number	For Use With	Price inc. VAT
PSU 21X	1 or 2 HY30	£11.93
PSU 41X	1 or 2 HY60, 1 x HY6060, 1 x HY124	£13.83
PSU 42X	1 x HY128	£15.90
PSU 43X	1 x MOS128	£16.70
PSU 51X	2 x HY128, 1 x HY244	£17.07

Model Number	For Use With	Price inc. VAT
PSU 52X	2 x HY124	£17.07
PSU 53X	2 x MOS128	£17.86
PSU 54X	1 x HY248	£17.86
PSU 55X	1 x MOS248	£19.52
PSU 71X	2 x HY244	£21.75

Model Number	For Use With	Price inc. VAT
PSU 72X	2 x HY248	£22.54
PSU 73X	1 x HY364	£22.54
PSU 74X	1 x HY368	£24.20
PSU 75X	2 x MOS248, 1 x MOS368	£24.20

Please note: X in part no. indicates primary voltage. Please insert "0" in place of X for 110V, "1" in place of X for 220V, and "2" in place of X for 240V.

FOR EVERYTHING IN ELECTRONICS
Wireless World

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The persuaders

In the long term, it will probably be of benefit to the population as a whole to be aware of and familiar with 'new technology'. In a matter of a few years, people will, perhaps, come to accept the use of computers, interactive services, automatic manufacture and all the other aspects of life in the 'eighties. Maybe it will make for a happier life, given that jobs can be found or that the use of enforced leisure can be made productive. But whether a post-Orwell society is to be acceptable or not, it is disturbing to hear that the Government is to spend many thousands of pounds on persuading us that technology is good for us. And it is even more worrying that the money is to go towards the support of university research into the best ways of convincing the population that next year is only coincidentally 1984 – " . . . to secure greater acceptance of new technologies by developing their positive aspects and minimizing their negative aspects . . ." in the words of a DTI report.

Their new role of advisors on the techniques of public relations may possibly cause some of the researchers furiously to think. While it is generally conceded that the practical application of research is nowadays a praiseworthy object – in additon, of course, to pure research in the accumulation of knowledge with no immediate application – it is a legitimate view that scientists ought to be concerned rather more with defining the truth than with assisting the Government to manipulate it.

The acceptance or otherwise of technology by the public is a matter for the public itself to decide. Teach them the benefits, by all means, but do not try to conceal – "minimize" – the drawbacks. A home computer may well fill the leisure time of a lathe operator with transports of delight, gaining a whole-hearted convert to the concept of information technology. But when he discovers that just such a computer is going to operate his lathe and make him an ex lathe operator, he will not find it easy to listen to anyone wanting to minimize the negative aspect of his experience. He might even express the opinon that someone could, perhaps, have mentioned the possibility of redundancy to him before the event, instead of accentuating the positive and eliminating the negative.

What these social science researchers are being asked to do is suspect and should be examined very carefully before research contracts for the Government are taken on. The very most a scientist should do in these circumstances is to investigate the possible consequences of a comprehensive embrace of technology in all human activities and to lay the options before the public. Once the facts and all the prognoses are present, we need no accentuation or minimization of the truth to help us decide what kind of society we wish to live in. To suggest otherwise is to credit politicians with the possession of greater wisdom than 60 million of the rest of us – a proposition which some may be disposed to question.

COMMUNICATIONS

Pure and applied

Recently the Royal Society organized a valuable one-day colloquium on research that brought together some 70 engineers, scientists and academics whose work contributes to either the commissions of the International Union of Radio Science (URSI) or the more down-to-earth study groups of the International Radio Consultative Committee (CCIR). This could be the forerunner of annual meetings to bring these pure and applied groups into closer touch with each other's work and objectives.

Whether such laudable aims will ever be met fully remains to be seen. The meeting made evident how wide a gap currently exists between research scientists and those concerned with the practical operation of systems for telecommunications, maritime and aeronautical radio, military systems and broadcasting. Neither side seems happy with the way the spectrum is parcelled out and the pecking order of research projects.

It is also clear that the impact of digital techniques is tending to distort the pattern of university and industrial training. Several speakers spoke of a growing shortage of radio-frequency and radio-propagation specialists, resulting from students and teachers preferring the mathematical certainties of digital electronics to the more vague, but often more challenging, analogue systems. Then again, r.f. propagation studies and research projects tend to involve time-scales appreciably more than three years and cannot be easily fitted into university courses.

The academics are also frustrated because the decisions of CCIR, spectrum regulation, etc. are seldom determined by the solutions of pure science, even when available, but more often by political and commercial considerations on the principle of 'the least objectionable to the greatest number'. Several speakers referred to the great gulf that exists between radio physics and practical applications. The academics stressed the difficulty of providing input to CCIR and other international groups. Those who cannot afford to attend the long CCIR meetings find their thoughts are overshadowed by "strong characters with their own pet ideas." Input from non-attenders is often wasted.

Using millimetres

Several of the speakers at the Royal Society meeting concentrated on the renewed interest in utilizing frequencies between 30 and 300 GHz, though paying tribute to the early pioneers such as Bose in India who carried out some surprisingly sophisticated work in the era of spark transmission. There was also renewed interest during the period 1947 to 1978 for the proposed telecommunications trunk waveguide system, involving frequencies between 30 and 110 GHz, finally abandoned in 1978 in favour of optical fibres.

Free propagation is much affected by the absorption bands though, perhaps surprisingly, communications interest is often concentrated on the frequencies with especially high absorption. Such frequencies are ideal for short-range covert communications links that effectively are immune to detection, interception or jamming.

In a review of British and European firms working on millimetric components and systems, Patrick Sargeaunt (Marconi Research Centre) mentioned EMI at Wells, GEC Hurst Laboratories at Wembley, Philips at Redhill, Plessey at Caswell, EEV (magnetrons), etc. Systems work includes 25 GHz satellite systems (GEC-Stanmore), 35 and 95 GHz radar (EMI, Decca, Marconi, British Aerospace), 30 GHz British Telecom links, 40 GHz AEG-Telefunken railway communications, 30-900 GHz modelling techniques (EMI-Wells), 300-500 GHz receivers (ESA) and measurement techniques up to 1THz at NPL.

Aerial puzzles

Almost every m.f. broadcasting station uses some variation of the vertical monopole aerial, with either a single omnidirectional element or a directional phased-array, based on the classic work of Dr George Brown and his RCA colleagues in the 1930s. For h.f./v.h.f. communications, the quarter-wave element is often raised and the ground system of up to about 120 buried earth radials replaced by a few elevated and insulated radials.

One would have imagined that by now both theory and practice of such aerial systems would have been fully and unambiguously developed. Yet recently a surprising number of controversies have arisen.

For example, Archibald Doty, together with two other retired engineers in the USA, has shown the advantages of the once-popular "counterpoise" or elevated ground-screen, noting that the currents flowing in buried radials are not, as conventionally postulated, uniform but depend upon ground conductivity in the immediate vicinity of the individual wires. Les Moxon has similarly shown the value of counterpoise systems and has also drawn attention to the common misconception that the input impedance of a groundplane antenna with horizontal radials is 36 ohms, the same as for grounded monopoles with an extensive earth system; he notes that Brown's original papers showed clearly that the correct figure was nearer 18 ohms, though this was subsequently overlooked in many later standard text books.

In *IEEE Trans. on Broadcasting* (Vol. BC-29, No 1, March, 1983) Wright, Klock and Jubera show that the feed impedances of practical m.f. broadcast monopoles often vary greatly from the theoretical value. They have been able to prove that much of this variation is due to the effect of guy wires, previously not taken into consideration in calculating the impedance.

Helically-wound loops

For many years there have been determined efforts to improve the radiation efficiency of miniature h.f. transmitting aerial elements. Loading coils, top-hat capacitances, folded elements, ferrite-loaded elements, single-turn and multi-turn small loops, the normal-mode helix: all these and other techniques have been used with some degree of success, but all imposing compromises.

In theory any element, no matter how small in terms of wavelength, can radiate all the power fed to it; in practice severe difficulties are experienced in feeding energy into a short element without losing most of the energy in the coupling networks, incurring significant power losses due to the very low radiation resistance relative to ohmic losses, and the narrow bandwidth of high-Q elements.

Alec Clelland, DJOFL/G3UUQ, has drawn my attention to a recently published European Patent Application (EP 0 043 591 A1) by James F. Corum of West Virginia. This covers a large family of aerials based on the reduction in size of a full-wave loop element by winding it helically in the form of a torus. The conductor is configured to establish a closed standing wave path to inhibit the velocity of propagation and support a standing electromagnetic wave. The inventor claims that although such elements can have a much smaller physical size than existing aerials they possess greater radiation resistance and hence greater efficiency than conventional loop aerials of similar size, and can radiate controllable mixtures of vertically, horizontally and elliptically polarized waves. He describes practical examples of such aerials for use from l.f. to v.h.f., using circular and square loops for broadcast, communications, amateur radio and c.b. frequencies. Bandwidth, however, would appear to remain restricted.

Hazards

The American Center for Disease Control, Atlanta, has recently warned that many r.f. dummy loads manufactured as recently as the late 1970s used cooling oil containing polychlorinated biphenyls (PCBs), a man-made chemical that has been linked with liver cancer. Even fumes from a hot-running load are stated to be dangerous in poorly ventilated situations.

COMMENTARY

PCBs were used in the UK for about 40 years until 1977 in oil-cooled transformers, high-voltage and fluorescent-lamp capacitors, dummy loads, etc.

A legal battle in New Jersey is centred on the question of possible health hazards from hand-held transceivers. General Electric (US) is being sued by the father of a 14-year-old boy, who alleges negligence in not providing the warning recommended by the US federal government in 1973. If the claim succeeds, American amateurs fear the case could be used as a basis for local authority legislation that might severely restrict the use of hand-held amateur radio. It is generally believed that hand-portables with an output of less than about 5 watts can be used without risk, even with short normal-mode helix aerials not far from the eyes.

Aerial tower restrictions in Burbank, Illinois are being legally contested by radio amateurs on the grounds that they represent a violation of constitutional rights of free speech and civil rights.

Here and there

An American study by International Research Development foresees the development of combined power and fibre optics cables which would carry into homes not only tv programmes and all interactive telecommunications but also electric power. The power cable would provide the necessary supportive package for the fragile glass fibres.

An investigation by NHK of Japan into the feasibility of introducing s.s.b. into h.f. broadcasting suggests that in a transitional period the carrier could be reduced by 6dB to permit continued use of envelope detection. Later 12dB suppression would be used with synchronous detection. Tests over various paths have underlined the advantages of s.s.b. including lower susceptibility to selective fading distortion. Carrier suppression of more than 12dB, however, would lead to degradation of quality due to the difficulty of achieving proper carrier extraction for synchronous demodulation.

Recently I reported the use by 50 American stations of the Harris linear a.m.-stereo system: by early summer the number had risen to 67, but the more interesting development is that this includes 10 m.f. stations in Australia and New Zealand, and also Radio Mundo Brazil.

RCA chairman, Thornton F. Bradshaw, has established a $100,000 grant for the electrical engineering department of Purdue University in memory of television pioneer Dr Vladimir Zworykin who died last year at the age of 92. Zworykin received more than 120 U.S. patents ranging from television to medical electronics.

AMATEUR RADIO

Return to Post Office

On the day following the publication of the Merriman Report, the Department of Trade and Industry announced the transfer, from September 19, of amateur radio licensing to the Post Office from the Radio Regulatory Division, now part of DoTI. This is expected to lead quickly to computerization of the records and to reduce the time in dealing with applications to a maximum of ten days at peak times and five days normally. Applications will be processed by post when sent to: Radio Amateur Licensing Unit, Chetwynd House, Chesterfield, Derbyshire S49 1PF (telephone Chesterfield (0246) 207555) who will also issue the application forms. Amateur radio was administered by the Post Office for many years until the setting up of the short-lived Ministry of Posts and Telecommunications.

While most amateurs, particularly those who have recently passed their RAE, will welcome the promised speed up in licensing process, there is some fear that this change is a further step towards making amateur radio 'up-market c.b.' as a form of revenue-collecting, leisure-time hobby rather than at least to some degree a self-training and experimental service of technical investigations in support of radio science and technology. The vast increase in licences over the past decade to 48,000 reflects the introduction of the Class B v.h.f.-only licence and the multi-choice form of RAE, combined with the complete absence in the UK of any form of incentive licensing.

With the majority of its licensed members now holding the Class B licence, RSGB policy appears to be changing. The 1983 president Don Baptiste, CBE, is on record as stating "the Class B permit is in no way to be regarded as inferior to the Class A version but simply reflects an interest in v.h.f./u.h.f. technique rather than in h.f.-bands communications". The Society claims there is "little or no demand" for a novice licence intended to encourage training in Morse. A number of Class B members are lobbying for the society to support code-free licences for h.f. operation.

85% of "optimum"

In the August "Letters to the Editor", Paul Thompson suggested that I was mistaken in believing that the Woodpecker roughly follows the m.u.f., and thought it more likely that the troublesome over-the-horizon radar follows the "optimum traffic frequency" (f.o.t.). While I am not privy to the Russian procedures, I believe this suggestion arises from a common misconception of the definition of f.o.t. Far from being a true "optimum frequency" it is a purely notional frequency, usually taken as 85 per cent of the m.u.f., in order that h.f. communications links are not disrupted by the considerable daily and hourly variations and errors in the predicted values of the m.u.f. A frequency-agile system such as the Woodpecker, that disregards IFRB frequency assignments and Radio Regulations, would clearly be made more effective by keeping as near to the m.u.f. as possible. It is indeed a typical piece of misplaced engineering jargon that defines f.o.t. as the *optimum* frequency!

There is, however, an important exception to the idea that one should always use the highest possible frequency for a specified path. This is for around-the-world "long-path" transmissions where using the daylight m.u.f. may result in much less favourable propagation than using a "darkness" or grey-line chordal-hop path at much lower frequencies. A good example is to be found in using 10 or 14MHz bands to contact Australia in the European mornings even when the daylight m.u.f. may well be above 21MHz.

In brief

Headquarters station of the RSGB at Potters Bar, normally GB3RS, is additionally using the call GB3WCY (World Communication Year) on Friday afternoons until the end of 1983, mostly on the 7MHz band . . . American amateurs are no longer legally required to keep a detailed station log, one result of F.C.C. "deregulations" . . . Ray Cracknell, Z22JV, beacon operator and transequatorial propagation pioneer, whose efforts to renew his British amateur licence were noted in the July issue is, after all, being granted his old G2AHU licence without having to take the RAE and Morse test . . . The next Radio Amateurs Examinations will be on December 5, 1983; March 19 and May 14, 1984 . . . RAE courses and/or Morse classes are starting this September in a number of further education centres, etc. RAE classes at Basildon, Birmingham, Colwyn Bay, Crawley, Derby, Dudley, Durham, Heckmondwyke, London (Acton and Brixton), Manchester, Melton Mowbray, Newcastle-upon-Tyne, Newquay, Nottingham, Orpington, Morley, Portsmouth, St Austell, Stamford, Turnford, Walsall, Wakefield and Witney; Morse classes at Bromsgrove, Cheshunt, Grantham, Heckmondwyke, London (Acton, Beckenham) and Manchester . . . The Midlands VHF Convention will be held at the British Telecom Training School, Stone, Staffs on Saturday, October 15 . . .

PAT HAWKER, G3VA

Strain-gauge weighing scale

A range of 0.1g to 1kg, with a high degree of linearity and low drift, is obtained from a novel, simply made load cell and an improved d.c. amplifier. The instrument will also measure temperature, using a thermocouple.

by John L. Linsley Hood

The old familiar swinging arm balance has now almost entirely disappeared from our shops and laboratories, to be replaced by electronic weigh scales with fixed-position pans and digital displays, a change which will be regretted by very few of those who have to use them in the course of their work. Such a scale is a very convenient thing to have around the house – though at the moment, rather expensive.

Since one of my hobby interests is photographic chemistry, in which the weighing out of chemicals for various processing solutions is a frequent activity, my thoughts have turned from time to time towards the construction of such an instrument. In the consideration of this, my view has been coloured by the relatively limited facilities and skills which are at my disposal in the mechanical field, and the solution which I have adopted has therefore tended to favour electronic rather than mechanical complexity. Manufacturers would choose a different compromise – but then they are not contemplating a one-off exercise.

The basic elements of an electronic balance, to give it its more usual name, are a load cell, some form of electronic amplifier having zero and gain adjustment facilities, and a digital display system. Since digital display elements are now readily available commercially, at a sensible price, this part of the task presents no problem. The load cell is a different matter, alas, and my own searches through manufacturers lists did not disclose any suitable cell at less than several hundred pounds in cost, which would defeat the purpose in mind.

The methods available for determining the weight of a body placed on a weighing pan fall into three broad categories; a simple strain gauge load cell; a pan suspended on a spring mount with a linear displacement transducer attached to the suspension so that the displacement under load produces a suitable signal output; and a force balance of some kind, such as an electrically energised solenoid in which a magnetic plunger is held against the applied load by electromagnetic force, its position being held substantially constant by some closed-loop servo-system based on a position sensing element, which increases the current through the solenoid, as the load increases, to maintain the status quo.

Other systems have been employed for this purpose, such as those based on a resonant element whose period of artificially sustained low-level oscillation changes as the mass on the weighing pan is altered, but the three listed above represent the main stream of electrical weighing systems.

Of the methods listed, undoubtedly the spring system with a displacement transducer would have the greatest ability to withstand overloads and misuse, but of the non-contacting displacement transducers, the linear differential transformer is the most suitable, and this is an element which would be difficult to construct for oneself while preserving adequate linearity. The idea of using a differential grating, with a photocell, and simply counting the alternating cycles of light and dark was a beguiling one, but the finest grating easily available (old Dufaycolor reseau) offered only 40 l/mm, and if a range of 10,000:1 or even 1000:1 was sought, the displacement would need to be substantial, with consequent problems of linearity.

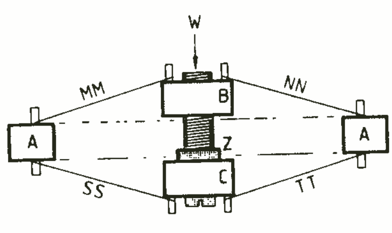


Fig. 1. Wire load-cell principle. Anchor ring A is fixed, B and C move and vary tension on wires.

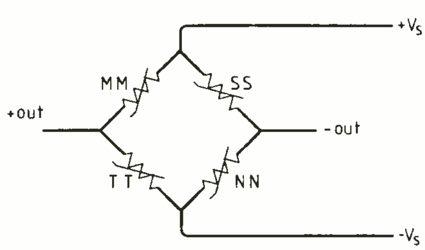


Fig. 2. Connexion of wire elements to form Wheatstone bridge.

Similarity, with a desired maximum load of 1kg, a suitable solenoid for a force balance would need to be a massive one. I therefore returned to the consideration of possible strain-gauge systems which might possibly meet the basic specification of a measuring system which would operate over the range 0-1kg, with a possible resolution of 0.1g. To avoid the need for any sophisticated engineering in the suspension system, it was desired that there should be no moving or pivoted elements, and that the total suspension should be of the taut wire form.

These considerations led to the evolution of the structure shown in Fig. 1. In this a pair of fixed members A-A served as anchor points for resistance wire elements MM, NN, SS, TT, connected to the central movable bushes B and C urged outwards to tauten the wire elements by the tensioning screw Z. Under a

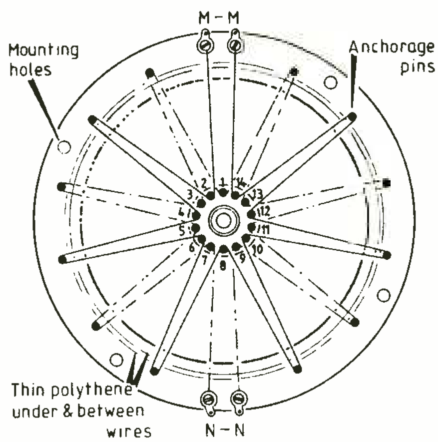


Fig. 3. One side of load cell. Where wires MM and NN cross, plastic film used for insulation.

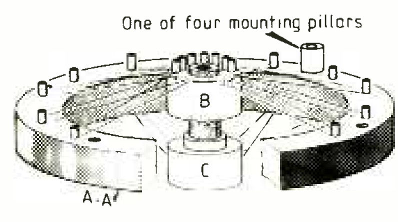


Fig. 4. Completed cell.

downward load W, the elements MM and NN become less taut, and the elements SS and TT become tighter. If then, the four elements are connected in the Wheatstone bridge form shown in Fig. 2, there is a resultant electrical unbalance, and a measurable output voltage if a load is applied to B-C.

In a practical form, the member A-A is an annular ring and B and C are smaller discs mounted in the centre of this, as shown in the plan view of Fig. 3. In the prototype, the strain gauge element was made from a 4×4in square of ⅜in 'Perspex' sheet, from which the outer ring, 4in o.d., and 3in i.d., and the two inner bushes each ¾in o.d. were cut. A series of 14 1.3mm holes was then drilled, uniformly around the periphery of the inner bushes, and a corresponding series of 12 similar holes, plus two pairs of tapped holes to hold solder tags, was then made in the outer ring, so that the whole could be strung with resistance wire, as also shown in Fig. 3. The wire starts and finishes at the solder tags and is looped around standard Vero type solder pins inserted into the holes, and anchored there by applying a hot soldering iron to the head of the pins so that they move inwards under the influence of the applied heat and pressure, and cause the softened Perspex to grip them firmly, when it cools.

The mechanical structure of this load cell is shown in Fig. 4, and the central bushes, in 'exploded view', in Fig. 5. The tensioning screw 'Z' was made from an 0BA cheese-head screw, on to the head of which a piece of ¼in brass spindle was soldered, with a screw slot on the lower end to allow it to be rotated to tension the wire elements.

After some inward debate, supported by experiments, it was decided to make the wire elements from 44s.w.g. Nichrome, obtainable (if one is patient) from the Scientific Wire Co, of London E4. Strain gauges are usually made from one of the zero temperature-coefficient Cu-Ni alloys, such as 'Eureka' or 'Constantan.' However, Nichrome has a higher specific resistance, which is helpful, and is very much stronger, which avoids the aggravation of the wire breaking during the threading up.

A relatively crude test suggested that the breaking strain of the 44s.w.g. Nichrome is in excess of 1kg, so that if the angle of the wire elements to the horizontal is 20°, and there are 28 of these bearing the downward load, the cell should carry 28.sin 20° kg (less the pretensioning force, say 1.2kg) before rupture. Since this is some 8.3kg, it would appear that the structure would be adequately strong for its purpose. As even finer wire, such as 46s.w.g., would undoubtedly be usable, with a higher gauge output, if the awkwardness of handling such a fine wire could be tolerated. Some form of jig such as shown in Fig. 7, to hold the central bushes in position is essential during threading up, and some care must be exercised both to ensure that the loops of wire sit against the Perspex at the base of the pins, and that the threading tension is

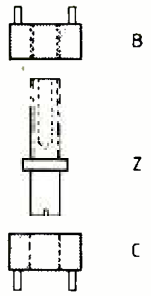


Fig. 5. Load-cell tensioning screw. centre bushes and

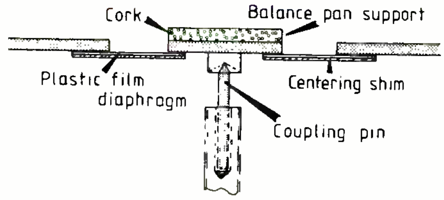


Fig. 6. Pan mounting. Coupling pin is pointed to ensure load is applied vertically when object in pan off-centre.

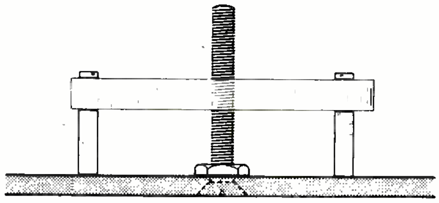


Fig. 7. Wiring jig for load cell.

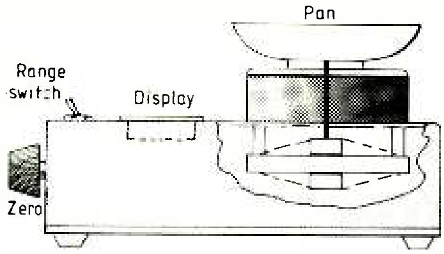


Fig. 8. Layout of instrument.

the same on both sides of the annulus. Otherwise, when the tensioning screw is tightened up, the screw will tilt over at an angle to the vertical, which will impair the performance of the bridge. It is well to be reconciled to the probability that one will have to go through this exercise several times before achieving a reasonably satisfactory result, and it is prudent to refrain from cutting off the stray ends of the wire until the result has been passed as satisfactory.

As constructed, the bridge elements each have a resistance of about 100 ohms, and with a bridge supply of approx. ±3.4 volts d.c., the d.c. output is of the order of 2mV/100g. With a display having a sensitivity of 199mV, so that 100mV would be equivalent to 100g on the 0-199g range, an amplifier gain of about 50× is required. Although something a bit better than the standard '741' is needed as the amplifier element, there are some very good i.c. op-amps available which have negligible noise or drift under these conditions. The extra complexity of an a.c. energized bridge and synchronous demodulator was not therefore thought to be worthwhile. In fact, the major source of long- and short-term drift is in the thermal sensitivity of the strain-gauge element due to the physical separation of the four component arms of the bridge. To combat the adverse effects of random movements of air within the strain gauge, two thin polythene diaphragms are placed under the position of the wires before the strain guage is threaded up, and in the final model, the whole gauge was enveloped in a single layer of cling film on top of the wire elements. This was helpful.

The choice of 46s.w.g. for the elements would increase the bridge sensitivity by some 1.76×, and would give an element resistance of about 175 ohms, which would reudce the gauge dissipation from 460mW to 240mW and help lessen thermal effects.

To lessen the extent of the sensitivity of the strain gauge to lateral components of the downward force, due to unsymmetrical loading of the pan, the top of the gauge is coupled to the pan support by a steel pin, sharpened to a point at both ends, held between a conical hole in the centre of the top plate and the bottom of the hole drilled in the tensioning screw, as shown in Fig. 6. The top plate itself is then held against lateral movement by a 'spider' made from three webs cut from 0.002in brass shim, anchored at the edge of the plate in which a suitable aperture has been cut to allow the upper scale plate to be accessible.

In my own instrument, the circular strain gauge, the electronics, power supply and display unit were mounted in a 8.5×5.5×2in diecast box, with the top balance plate and coupling linkage housed on top of it, as shown in Fig. 8. Although I feel that the choice of the positions within the box in which the separate components are to be mounted can well be left to the judgment of the constructor, the layout which I adopted was to have the display element mounted at the front of the upper face, with the main zero-adjust knob below this. The other controls were grouped on the right-hand side of the box, for the convenience of a right-handed user, and some space was left at the rear for a small, internally screened, compartment to house the power supply transformer, rectifiers and reservoir capacitors. This then left an unoccupied left-hand wall on which the small electronic amplifier panel, assembled, on a piece of 0.1in perforated 'Vero' strip. board, could be mounted on short, threaded stand-off pillars.

The unit was then finished, mechanically, by four stick-on rubber feet on the detachable lid which forms the base of the lower box, and a disc of cork was then stuck on to the upper pan plate to provide a small degree of mechanical shock isolation to the strain gauge element from items dropped upon the pan.

Electronics

As mentioned above, my deliberate choice in this design was to use the simplest practicable mechanical load measuring element and to accept the extra complexity which this would impose upon the electronic circuitry used with this. Inevitably, the problems in d.c. amplification, from such low-output signal levels as those from a strain gauge bridge,

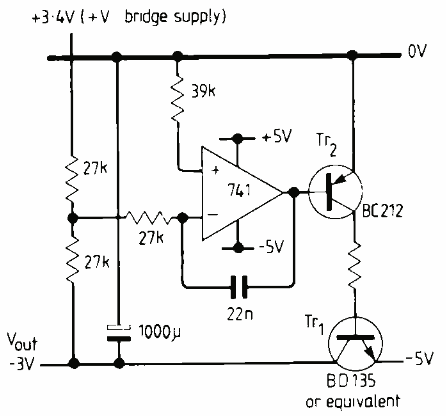


Fig. 9. *Negative supply mirrors fluctuations in positive line.*

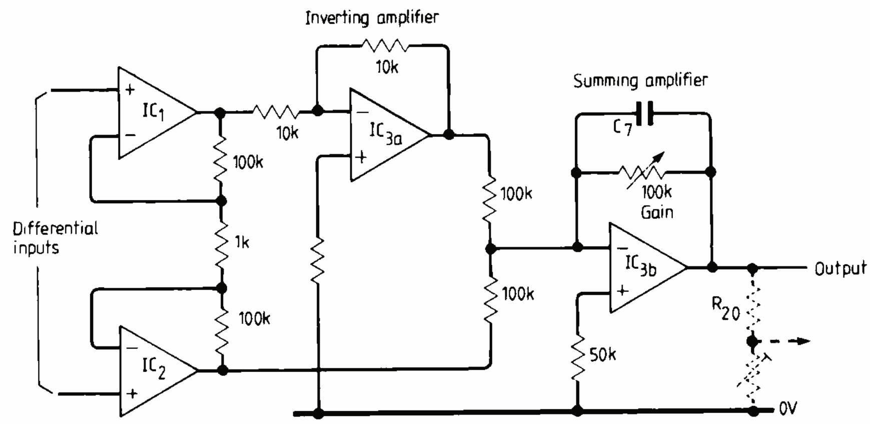


Fig. 10. *Improved d.c. differential amplifier.*

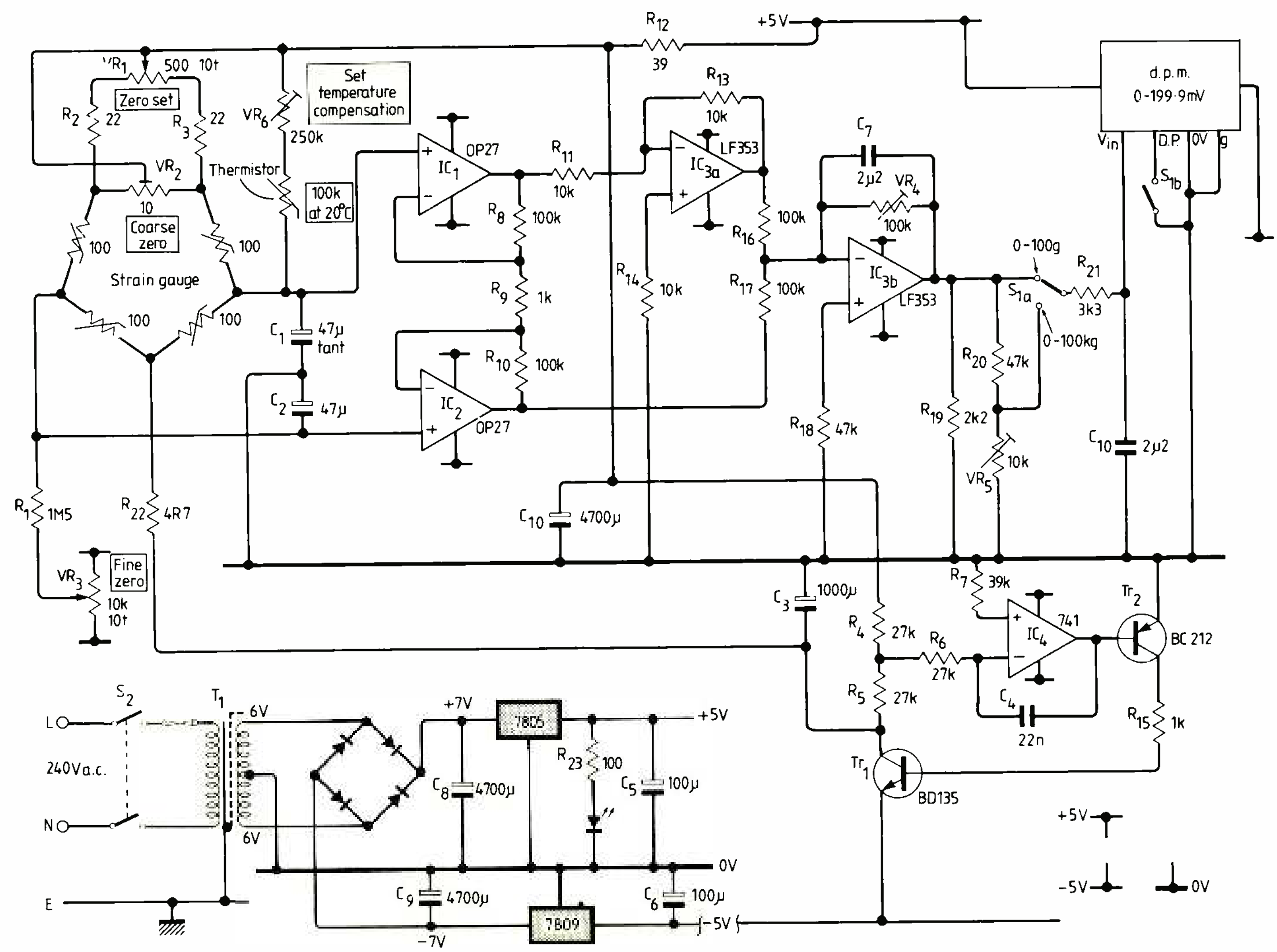
centre around the presence of zero drift. With modern i.c.s, this need not be due to inadequacies in the d.c. amplifier itself, but will arise in respect of the input signal.

The inevitable difficulty due to differential thermal effects upon the resistance wires of the load cell has already been mentioned. This can only be minimized by restricting air movement within the weigh scale housing, by using a well-sealed container box, and within the strain-gauge element by the use of thin polythene diaphragms interleaving the windings to diminish internal air cooling effects. Fortunately, in my experience using the prototype, this only affects the long-term zero setting, which is adequately stable during any one weighing for the beginning and end zero readings to be the same within the ±0.1g basic uncertainty of the reading.

However, there is a more insidious difficulty, due to random excursions of the voltage of the + and -5V supply lines. With a 2mV/100g bridge sensitivity, the required 0.1g zero stability represents 2μV. Using the standard ±5V i.c. regulators as the basic bridge supply brought home to me that random fluctuations of a few mV in their output potential, could represent common-mode voltage swings of a few mV at the output terminals of the bridge. To achieve the required input voltage stability of better than 2μV demanded a common-mode rejection capability from the d.c. amplifier of some 70-80dB. This was much greater than attainable from a low-drift op-amp used in the conventional differential amplifier mode. The first improvement in the performance of the system was therefore made by the use of a separate d.c. supply system for the negative line, shown in Fig. 9, in which the operation of the circuit is such that a negative supply is generated which closely matches, in opposite polarity, any random excursions of the positive supply line, as seen at the strain gauge bridge pick-off point at the junction of R_{12} and C_{10}.

The second circuit improvement relates to the design of the d.c. differential amplifier itself, shown in Fig. 10. The

Fig. 11. *Complete circuit diagram.*



normal 'instrumentation amplifier' layout employs two i.cs (as IC_1 and IC_2) arranged to have a high gain to signals applied differentially to their inputs, but only unity gain in respect of signals applied equally to both. A third i.c. op-amp is then used as a differential amplifier to reject the residual common mode output.

Unfortunately, it is impracticable to employ negative feed-back around such an op-amp differential amplifier without making the two inputs unsymmetrical, so that there is a higher gain from the non-inverting input than from the inverting one. Conventionally, this shortcoming is remedied by inserting an attenuator network in the non-inverting input limb, but this would only work for a fixed-gain stage as the differential amplifier, and would preclude the use of this stage as an active integrator to slug the response of the circuit to unwanted l.f. noise.

In the improved arrangement shown, an additional inverting stage $IC_{3(a)}$, (½LF353) is inserted in one of the output limbs from the input differential amplifier pair, so that $IC_{3(b)}$ can be used as a summing amplifier, in which common-mode signals, now presented in opposition, will cancel at the 'virtual earth' input point, while differentual signals will be added at this point. There is then no difficulty in making the gain of $IC_{3(b)}$ adjustable to provide for a full scale calibration adjustment on the 0-100g scale, and in putting a suitable value integration capacitor (C_7) across this i.c. to give a suitably 'dead-beat' response to the weigh scale reading. (This is advantageous when weighing up chemicals by pouring them into the pan, since they are likely to be lumpy, which would give an apparently jerky character to the meter reading.)

The 0-100g and 0-1kg scales are switched by an output attenuator on the output of $IC_{3(b)}$, rather than by switching VR_4, to avoid shifts in the d.c. zero from one range to the other. If suitable facilities are available for determining resistor values, R_{20} and VR_5 could be replaced by a fixed 1/10 resistive attenuator. With the 0-0.1999V digital panel meter unit employed, it was possible to switch the decimal point so that the 100g range read 100.0g and the 1kg range read 1000g, as the scale was switched.

A small 6VA 6-0-6V mains transformer powers the unit, feeding a pair of 5V i.c. voltage regulators to provide a stable voltage line for the i.cs and the bridge, unaffected by mains voltage fluctuations, and a l.e.d. is fed from the positive 5V line to warn that the unit is on.

Any convenient and suitable transistors can be used for Tr_1 and Tr_2, IC_1 and IC_2 should be a low-drift, low-noise i.c. type. In the prototype I have used the excellent OP-27 types, available from Precision Monolithics Inc., (Bourns in UK) because I had a pair of these to hand, though there is little doubt that other, less expensive, instrumentation type low-drift operational amplifiers, such as the LM725, would serve equally well. With these i.cs, the zero stability, with both inputs taken to 0V, is well within the 0.1mV output requirement over a period of 24hr, which vindicates the original decision to use a d.c. energized bridge, in that the residual problems due to differential thermal effects in the strain gauge would be present equally in an a.c. energized system. The d.c. systems avoids difficulties due to inadvertent signal coupling through wiring stray capacitances. The circuit of the complete weigh-scale amplifier is shown in Fig. 11.

Temperature compensation

Although the bridge system is very nearly fully symmetrical, inadvertent asymmetries in the mechanical construction, coupled with the physical changes, due to thermal effects, of the structure of the load cell, lead to a negative temperature coefficient in the prototype of some 5g/°C. A first-order compensation for these is provided by the thermistor/resistor network across the limb of the bridge feeding the non-inverting input.

Use and setting up

As indicated earlier, it is probable that one's first attempt(s) at wiring up the strain gauge element will be less good than those made when one has gained a little more familiarity with the problems involved in getting the wires to sit in the required positions, and with uniform tension when the tensioning screw is tightened. Fortunately, with a suitable jig to hold the separate parts of the strain gauge while the wire is applied, it doesn't take too long to pull it apart and try again. So, it is sensible to build the electronic amplifier and power supply unit before one makes the load cell so that this can be tested after it has been assembled.

A slightly disconcerting effect, initially, is the way in which the output signal will vary up and down, in a random manner, after the tensioning screw is adjusted, or readjusted, as the tensions in the individual wires in the strain gauge rosette accommodate to one another by slipping round the anchoring pins. The process can be speeded up a bit by gently tapping the tensioning screw, but ultimately one must just be patient and wait a few hours for the load cell to settle down again. This accommodation of the individual wires to a state of uniform tension is also responsible for the hysteresis (failure of the gauge to return to zero after a load has been applied and removed) which is an annoying feature commonly found in freshly constructed load cells. Normally this effect will progressively lessen as weights are applied and removed during the calibration process of setting VR_4 and VR_5, for appropriate f.s.d. readings.

If hysteresis persists, one must conclude, with regret, that the strain gauge cell has not been built adequately well, and have another go. In the prototype, the hysteresis is now, after some time in use, of the order of 0.2g following an applied load of 200g. I have, I think, in the course of developing the prototype, rebuilt the load cell five times, though some of these were in the pursuit of hoped-for design improvements. I still have the feeling that I could make it a bit better, to equal the performance given by one of the earlier versions, where I had got the wire tension particularly uniform.

The static tension applied to the wires by the tensioning screw should be adequate to make the gauge linear over the range of loads which it is desired to apply: further tightening is of no benefit.

In use, the zero adjust pot. VR_1 and the fine zero adjust pot. VR_3, both of which are 10-turn types, should be set to a position near to their mid point. The 10R coarse zero-adjust pot. (VR_2) should be adjusted, slowly, until the reading is somewhere within ±100gms on the 1kgm scale range. The zero set pot. VR_1, in parallel with VR_2 can then be adjusted to set the meter reading within the ±2gms range covered by the fine zero control,

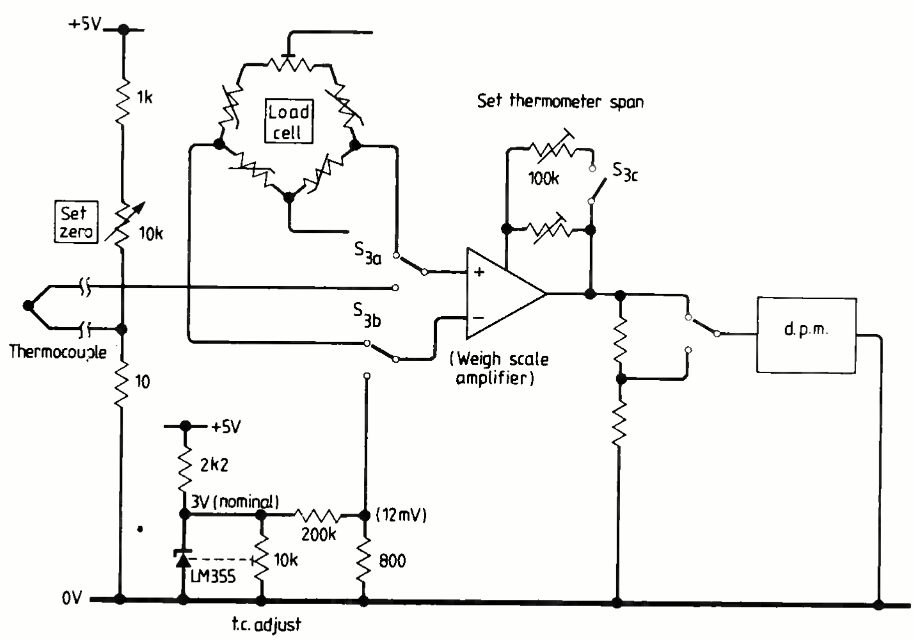


Fig. 12. Stability is such that temperature measurement can be carried out. Circuit shows offset voltage source and input switching.

which is the normal operating zero control of the instrument.

The linearity of the prototype, when checked against a set of good-quality chemical balance weights, was within 0.2% over the range 0-250gms, with the major contribution to this being the small remaining hysteresis. It is probable, therefore, that the scales could be set up adequately by pouring a measured quantity of water into a suitable vessel mounted on the weighing pan, in the absence of appropriate calibrated weights, without incurring unacceptable errors in intermediate readings.

Adjusting temperature compensation

As mentioned above, because the final strain-gauge load cell, in the prototype, was not completely symmetrical, there is a residual long-term sensitivity to changes in ambient temperature, which require the zero to be reset more often, in day to day use, than is desirable. A simple thermistor compensation circuit is therefore connected across the +3.4V supply and an input to the amplifier. (Which input is required will depend on the final strain-gauge temperature characteristics, which will depend on its construction.) The easiest way to adjust the trimmer resistor VR_6 is to put the whole instrument in a refrigerator, and then, after removal, as it warms up to room temperature, adjust VR_6 so that the scale reading drifts neither up nor down.

The total power consumption of the instrument is less than 2 watts, and there is no detectable change in the temperature of the housing, compared with the ambient, over a 12 hour period. To prevent errors due to air currents entering the instrument through the exit hole surrounding the load cell shaft, a thin polythene diaphragm is fixed under the top load plate to seal the unit. If it is desired to turn the instrument over, for access to the electronics, the lid of the upper box, carrying the load plate and its coupling pin should be removed to obviate possibly heavy loads being applied to the load cell, which might affect its calibration.

The gain and stability of the amplifier unit is sufficiently good for the instrument also to be usable, with a copper/constantan or chromel/alumel thermocouple input, (40μV/°C) as an accurate digital thermometer, provided that a suitable switching input socket is employed, and an appropriate temperature-dependent offset voltage source to act as a 'cold junction' reference is provided. A suitable circuit is shown in Fig. 12.

WW

Wheelchair word-processor

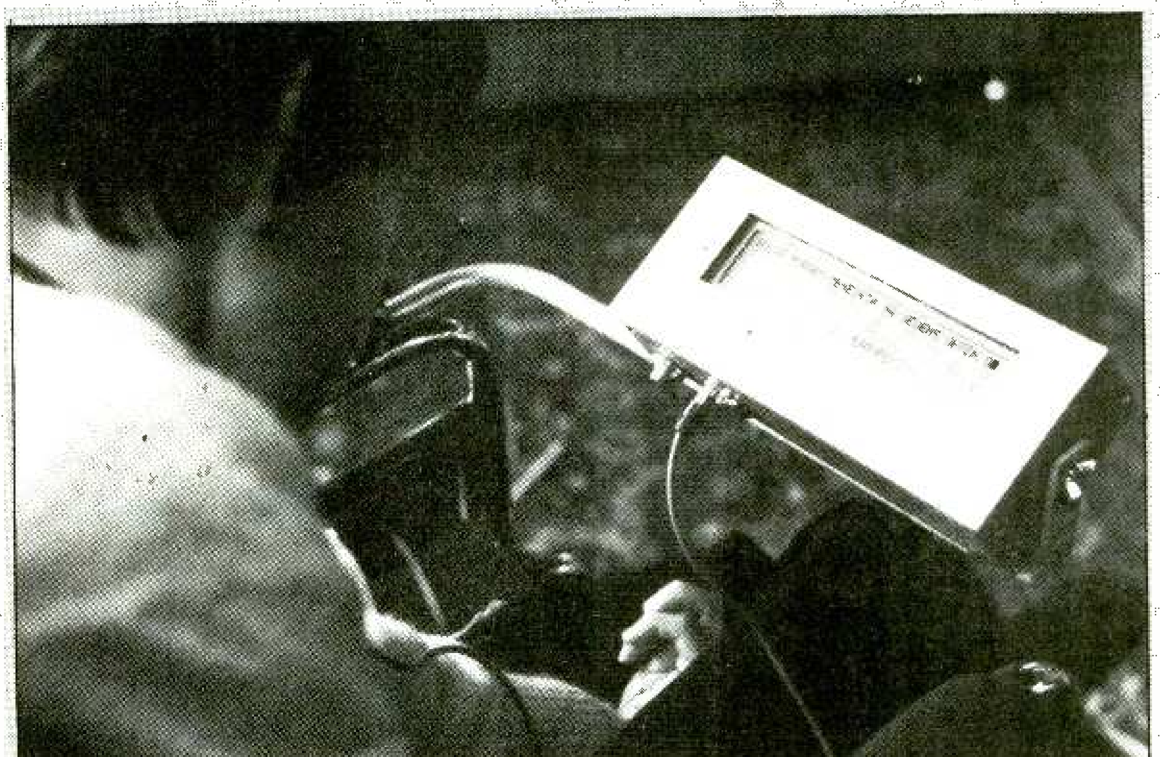
This communication aid for the disabled is not an entry for our competition, but it does show the sort of results that can be achieved by volunteers working to a restricted budget. Designed for those whose faculty of speech is impaired or perhaps lacking altogether, the Writing Box can be produced in a variety of configurations to match the needs of the individual user. The device is the work of a non-profit-making group in Belgium and cost around £300.

The liquid-crystal display shows four lines of 40 characters, while for longer texts there is memory capacity for up to 6500 characters. Writing and editing is possible using a keyboard, although users with a lesser degree of dexterity can choose from a range of unusual input devices including foot switches, eye-movement detectors, blow pipes and sound-operated switches.

The fourth line of the display can act as a menu to help in obtaining the right characters; and a subtle feature of the unit is the capability for storing and displaying messages defined by the user. For example, three switch-pushes might produce "lift me up a bit, please". In addition to this, there is a word memory holding up to 500 longer words which can be adapted to the requirements of the individual: words which would normally call for 14 or more pushes can thus be produced with four or five.

For more elderly patients there is another mode of operation, simpler to use but slower; and for children who have not yet learned to read there is even a sort of video game designed to familiarise them with the box and its method of operation.

The output of the box is available in RS232 serial code for connection to a printer. Power comes from a built-in rechargeable battery giving 11 hours of continuous operation and the unit has an energy-conserving standby mode to which it reverts when not in use.



Precision preamplifier

Many designers have not, until recently, considered op-amps a suitable choice for preamplifier designs of the very highest quality. Newer types now obtainable have changed this and Doug Self's new design exploits the 5534 op-amp

Until relatively recently, any audio preamplifier with pretensions to above-average quality had to be built from discrete transistors rather than integrated circuits. The 741 series of op-amps was out of the question for serious audio design, due to slew-rate and other problems, and the TL071/72 types, though in many ways excellent, were still significantly noisier than discrete circuitry. In an article some years ago[1] I attempted to show that it was still feasible to better the performance of such devices by using simple two or three-transistor configurations.

The appearance of the 5534 low-noise op-amp at a reasonable price, has changed this. It is now difficult or impossible to design a discrete stage that has the performance of the 5534 without quite unacceptable complexity. The major exception to this statement is the design of low-impedance low-noise stages such as electronically-balanced microphone inputs or moving-coil head amplifiers, where special devices are used at the input end.

5534 op-amps are now available from several sources, in a conventional 8-pin d.i.l. format. This version is internally compensated for gains of three or more, but requires a small external capacitor (5-15pF) for unity-gain stability. The 5532 is a very convenient package of two 5534s in one 8-pin device with internal unity-gain compensation, as there are no spare pins.

The 5534/2 is a low-distortion, low-noise device, and a typical audio stage could be expected to generate less than 0.005% t.h.d. over the range 1kHz-20kHz, leaving the residual distortion lost in the noise of all but the most expensive analysers. Noise performance obviously depends partly on external factors, such as source resistance and measurement bandwidth, but as an example consider the moving-magnet disc input stage shown in Fig. 3. When prototyped with a TL071, the noise (with a 1k resistor input load) was -69dB with reference to a 5mV r.m.s. 1kHz input. Substituting a 5534 improved this to -84dB, a clear superiority of 15dB.

Another advantage of this device to the audio designer is its ability to drive low-impedance loads (down to 500 ohms in practice) to a full voltage swing, while maintaining low distortion. This property is much appreciated by studio mixer designers, whose output amplifiers are still expected to drive largely fictitious 600 ohm loads. As a comparison, the TL071 is only good for loads down to about 2kΩ.

Architecture

As explained in a previous article[1], the most difficult compromise in preamp. design is the distribution of the required gain (usually at least 40dB) before and after the volume control. The more gain before the volume control, the lower the headroom available to handle unexpectedly large signals. The more gain after, the more the

by D. Self

noise performance deteriorates at low volume settings. Another constraint is that it is desirable to get the signal level up to about 100mV r.m.s. before reaching the volume control, as tape inputs and outputs must be placed before this. The only really practical way to get the best of both worlds is to use an active gain-control stage – an amplifier that can be smoothly varied in gain from effectively zero up to the required maximum.

If the input to the disc stage is a nominal 5mV r.m.s. (assumed to be at 1kHz throughout the avoid confusion due to RIAA equalization) from either moving-magnet cartridge or moving-coil head amp, then 26dB of gain will be needed to give the 100mV which is the minimum it is desirable to offer as a tape output. This can easily be got from a single 5534 stage, and taken together with the supply rails (±15V) this immediately fixes the disc input overload at about 320mV r.m.s. A figure such as this is quite adequate, and surpasses most commercial equipment.

One must next decide how large an output is needed at maximum volume for the 5mV nominal input. 1V r.m.s. is usually ample, but to be certain of being able to drive exotic units to their limits, 2V r.m.s. is safer. This decision is made easier because using an active gain-control frees us from the fear of having excessive gain permanently amplifying its own noise after the volume control. Raising the 100mV to this level requires the active gain stage to have another 26dB of gain available; see the block diagram in Fig. 1.

The final step in fixing the preamp. architecture is to place the tone-control in the optimum position in the chain. Like most Baxandall stages, this requires a low-impedance drive if the response curves are to be predictable, and so placing it after the active gain-control block (which has the usual very low output impedance) looks superficially attractive. However, further examination shows that (a) the active-gain stage also requires a low-impedance drive, so we are not saving a buffer stage after all, and (b) since it uses shunt feedback the tone-control stage is rather noisier than the others[2], and should therefore be placed before the gain control so that its noise can be attenuated along with the signal at normal volume settings. The tone-control is preceded by a unity-gain buffer stage with low output impedance and a very high input impedance, so that the load placed on line input devices does not vary significantly when the tape-monitor switch is operated. This brings us to the block diagram in Fig. 1. Figure 3 shows the circuit diagram of the complete preamplifier. The components

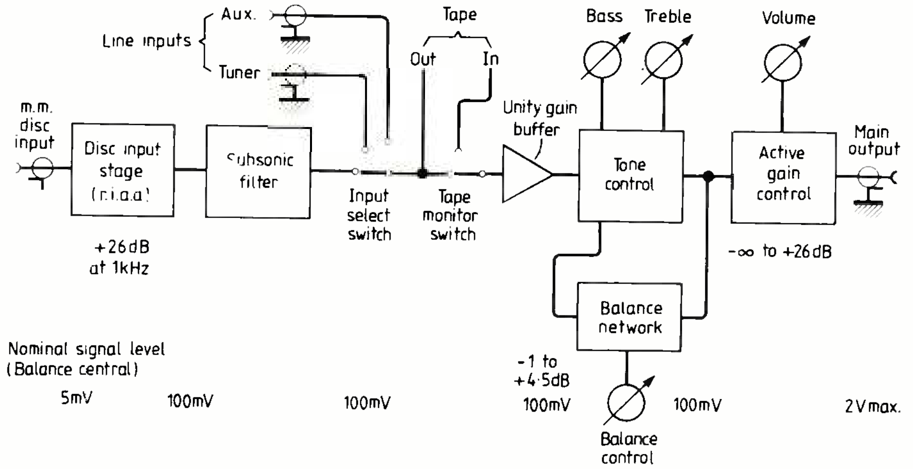


Fig. 1. Block diagram. Tone-control placed before gain-control block to reduce noise from tone-control.

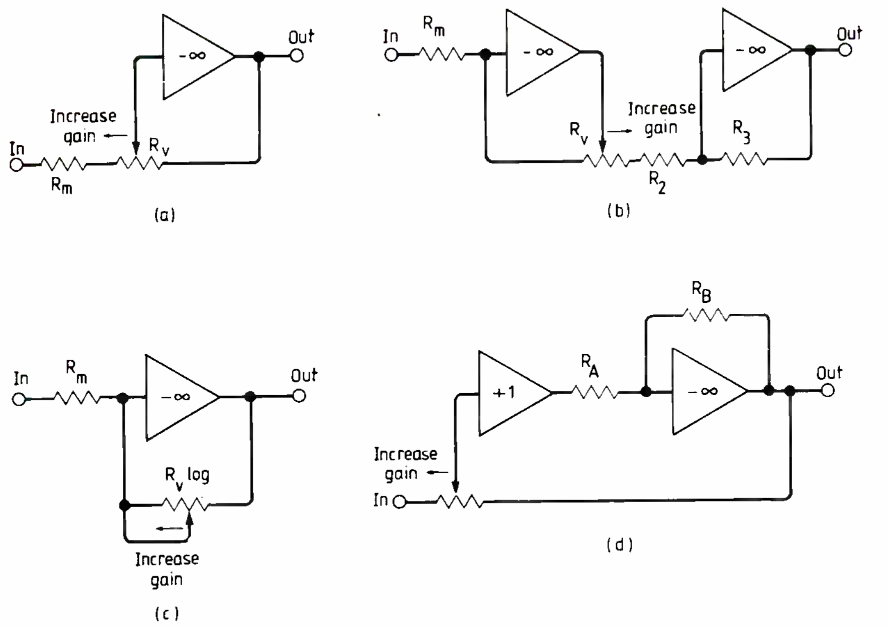
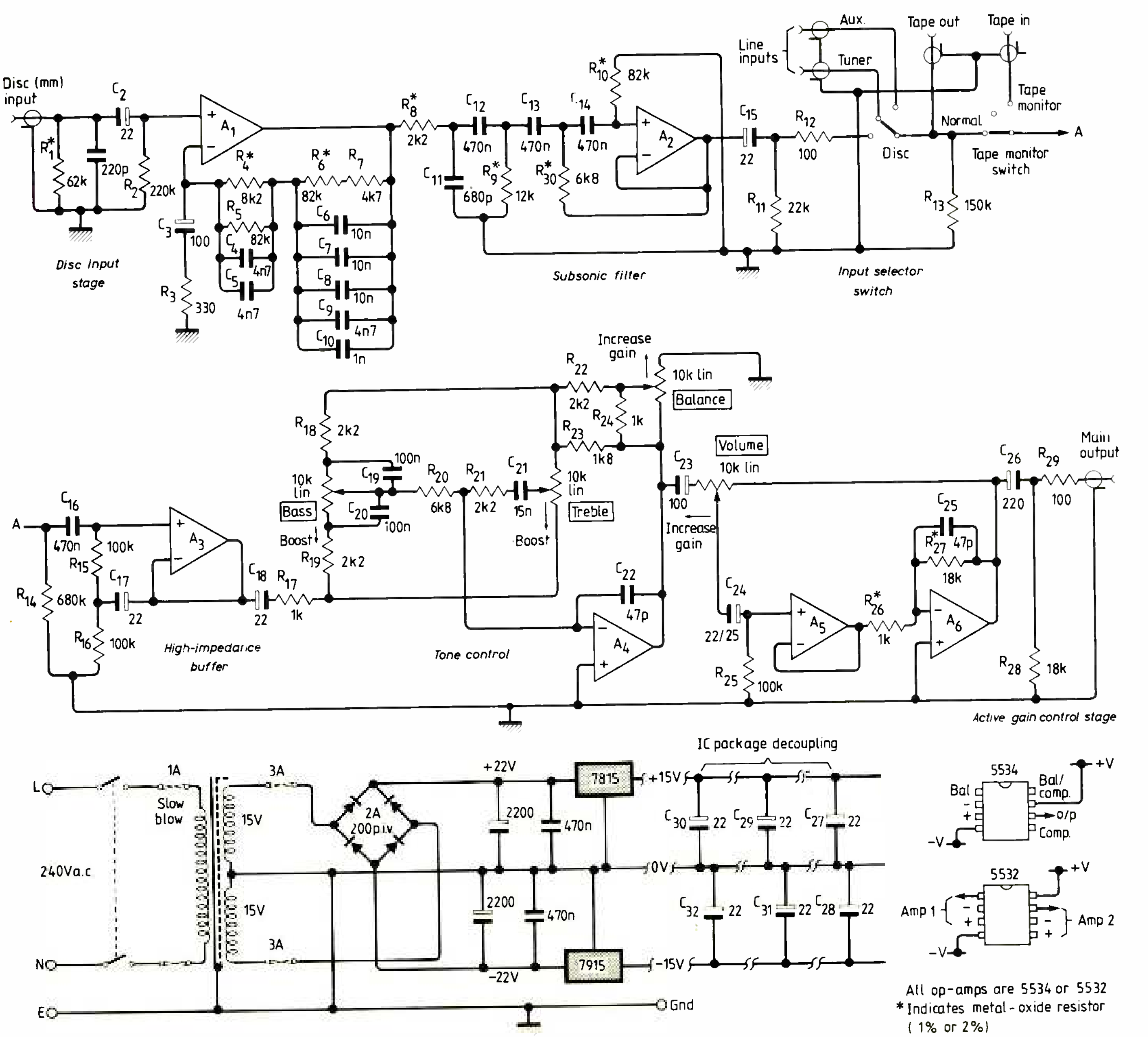


Fig. 2. Evolution of active gain-control stage. That due to Baxandall, chosen for this design, is at (d).

around A_1 and A_2 make up the moving-magnet disc stage and its associated subsonic filter. Disc preamp. stage A_1 uses a quite conventional series feedback arrangement to define the gain and provide RIAA equalisation. This provides a clear noise-performance advantage of 13dB over the shunt feedback equivalent[2], which is sometimes advocated on the rather dubious grounds of "improved transient response". The reality behind this rather woolly phrase is that the series configuration cannot give the continuously descending frequency response in the ultrasonic region that the RIAA specification seems to imply, because its minimum gain is unity. Hence sooner or later, as the frequency increases, the gain levels out at unity instead of dropping down towards zero at 6dB per octave. As described in refs. 1 and 2, when a low-gain input stage is used to obtain a high overload margin, "sooner" means within the audio band,

Fig. 3. Complete circuit diagram. Decoupling capacitors for i.cs must be close to packages.



and so an additional low-pass time-constant is required to cancel out the unwanted h.f. breakpoint; once more it is necessary to point out that if the low-pass time-constant is correctly chosen, no extra phase or amplitude errors are introduced. This function is performed in Fig. 3 by R_8 and C_{11}, which also filter out unwanted ultrasonic rubbish from the cartridge.

It was intended from the outset to make the RIAA network as accurate as possible, but since the measuring system used (Sound Technology 170 A) has a nominal accuracy of 0.1dB, 0.2dB is probably the best that could be hoped for. Designing RIAA networks to this order of accuracy is not a trivial task with this configuration, due to interaction between the time-constants, and attempting it empirically proved most unrewarding. However, Lipshitz, in an exhaustive analysis of the problem, using heroic algebra in quantities not often seen, gives exact but complicated design equations[4]. These should not be confused with the rule-of-thumb time-constants often quoted. The Lipshitz equations were manipulated on an Acorn Atom microcomputer until the desired values emerged. These proved on measurement to be within the 0.2dB criterion, with such errors as existed being ascribable to component tolerances.

Design aims were that the gain at 1kHz should be 26dB, and that the value of R_3 should be as small as feasible to minimize its noise contribution. These two factors mean that the RIAA network has a lower impedance than usual, and here the load-driving ability of the 5534 is helpful in allowing a full output voltage swing, and hence a good overload margin.

There is a good reason why the RIAA capacitors are made up of several in parallel, when it appears that two larger ones would allow a close approach to the correct value. It is pointless to design an accurate RIAA network if the close-tolerance capacitors cannot be easily obtained, and in general they cannot. The exception to this is the well-known Suflex range, usually sold at 2.5% tolerance. These are cheap and easy to get, the only snag being that 10nF seems to be the largest value widely available, and so some paralleling is required. This is however a good deal cheaper and easier than any other way of obtaining the desired close-tolerance capacitance.

Metal-oxide resistors are used in the RIAA network and in some other critical places. This is purely to make use of their tight tolerance (1% or 2%), as tests proved, rather unexpectedly, that there was no detectable noise advantage in using them.

The recently updated RIAA specification includes what is known as the "IEC amendment". This adds a further 6dB/octave low-cut time-constant that is -3dB at 20.02Hz. It is intended to provide some discrimination against subsonic rumbles originating from record warps, etc, and in a design such as this, with a proper subsonic filter, it is rather redundant. Nonetheless the time-constant has been included, in order to keep the bottom octave of the RIAA accurate. The time-constant is *not* provided by R_3, C_3 which is no doubt what the IEC intended) but by the subsonic filter itself, a rather over-damped third-order Butterworth type designed so that its slow initial roll-off simulates the 20.02Hz time-constant, while below 16Hz the reponse drops very rapidly. Implementing the IEC roll-off by reducing C_3 is not good enough for an accurate design due to the large tolerances of electrolytic capacitors. However, the R_3, C_3 combination is arranged to roll-off lower down (-3dB at about 5Hz) to give additional subsonic attenuation.

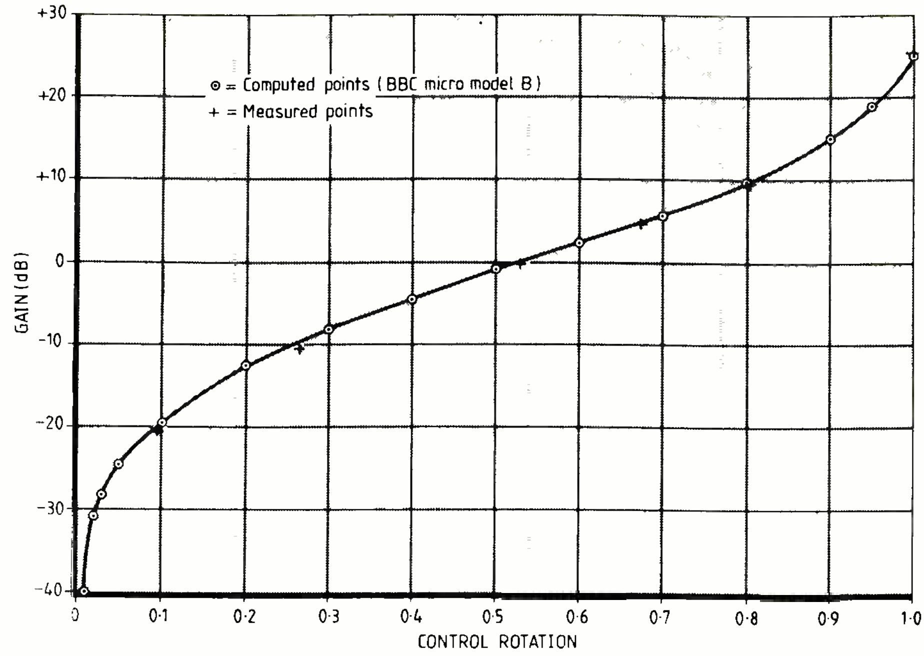


Fig. 4. Law of gain-control pot., approximately linear over main part of range.

Capacitor C_1 defines the input capacitance and provides some r.f. rejection. A compromise value was chosen, and this may be freely modified to suit particular cartridges.

The noise produced by the disc input stage alone, with its input terminated with a 1k resistor to simulate roughly a moving-magnet cartridge, is -84.5dB with reference to a 5mV r.m.s. 1kHz input (i.e. 100mV r.m.s. out) for a typical 5534A sample. The suffix A denotes selection for low noise by the manufacturer. When the 1k termination is replaced by a short circuit, the level drops to -86dB, indicating that in real life the Johnson noise generated by the cartridge resistance is significant, and so the stage is really as quiet as it is sensible to make it.

Subsonic filter

As described above, this stage not only rejects the subsonic garbage that is produced in copious amounts by even the flattest disc, but also implements the IEC roll-off. Below 16Hz the slope increases rapidly, the attenuation typically increasing by 10dB before 10Hz is reached. The filter therefore gives good protection against subsonic rumbles, that tend to peak in the 4-5Hz region.

This filter obviously affects the RIAA accuracy of the lowest octave, and so C_{12}, C_{13}, C_{14} should be good-quality components. A 10% tolerance should in practice give a deviation at 20Hz that does not exceed 0.7dB, rapidly reducing to an insignificant level at higher frequencies. The tape output is taken from the subsonic filter, with R_{12} ensuring that long capacitative cables do not cause h.f. instability. If it really is desirable to drive a 600 ohm load, then C_{15} must be increased to 220 µF to maintain the base response.

High-impedance buffer

This buffer stage is required because the following tone-control stage demands a low-impedance drive, to ensure that operating the tape monitor switch S_2 does not affect the tape-output level. If the input selector switch S_1 was set to accept an input from a medium impedance source (say 5k), and the buffer had a relatively low input impedance (say 15k), then every time the tape-monitor switch was operated there would be a step change in level due to the change of loading on the source. This is avoided in this design by making the buffer input impedance very high by conventional bootstrapping of R_{15}, R_{16} via C_{17}. This is so effective that the input impedance is defined only by R_{14}. Unlike discrete-transistor equivalents, this stage retains its good distortion performance even when fed from a high source resistance, e.g. 100k.

Tone-control stage

Purists may throw up their hands in horror at the inclusion of this, but it remains a very useful facility to have. The range of action is restricted to ±8dB at 10kHz and ±9dB at 50Hz, anything greater being out of the realm of hi-fi. The stage is based on the conventional Baxandall network with two slight differences. Firstly the network operates at a lower impedance level than is usual, to keep the noise as low as possible. The common values of 100k for the bass control and 22k for the treble control give a noise figure about 2.5dB worse. Even with the values shown, the tone stage is about 6dB noisier than the buffer that precedes it. Both potentiometers are 10k linear, which allows all the preamp. controls to be the same value, making getting them a little easier. The low network impedance also reduces the likelihood of capacitative interchannel crosstalk. Once again, implementing it is only possible because of the 5534's ability to drive low-value loads.

Secondly, the tone-control stage incorporates a vernier balance facility. This is also designed as an active gain-control, with the same benefit of avoiding even small compromises on noise and headroom. The balance control works by varying the amount of negative feedback to the Baxandall network, and therefore some careful design is needed to ensure that the source resistance of the balance section remains substantially constant as the control is altered, or the frequency response may become uneven. Resistors R_{22}, R_{23}, R_{24} define this source resistance as 1k, which is cancelled out by R_{17} on the input side. The balance control has a range of +4.5 to -1.0dB on each channel, which is more than enough to swing the stereo image completely from side to side. If you need a greater range than this, perhaps you should consider siting your speakers properly.

Active gain-control stage

An active gain-control stage must fulfil several requirements. Firstly, the gain must be smoothly variable from maximum down to effectively zero. Secondly, the law relating control rotation and gain should be a reasonable approximation to logarithmic, for ease of use. Finally, the use of an active stage allows various methods to be used to obtain a better stereo channel balance than the usual log. pot. offers.

All the configurations shown in Fig. 2 meet the first condition, and to a large extent, the second. Figures 2(a) and 2(b) use linear controls and generate a quasi-logarithmic law by varying both the input and feedback arms of a shunt-feedback stage. The arrangement of Fig. 2(c), as used in the previous article, offers simplicity but relies entirely on the accuracy of a log. pot. While 2(a) and 2(b) avoid the tolerances inherent in the fabrication of a log. track, they also have imperfect tracking of gain, as the maximum gain in each case is fixed by the ratio of a fixed resistor R_m to the control track resistance, which is not usually tightly controlled. This leads to imbalance at high gain settings.

Peter Baxandall solved the problem very elegantly[1], by the configuration in 2(d). Here the maximum gain of the stage is set not by a fixed-resistor/track-resistance ratio, but by the ratio of the two fixed resistors R_a, R_b. A buffer is required to drive R_a from the pot. wiper, because in a practical circuit this tends to have a low value. It can be readily shown by simple algebra that the control track resistance now has no effect on the gain law, and hence the channel balance of such a system depends only on the mechanical alignment of the two halves of a dual linear pot. The resulting gain law is shown in Fig. 4, where it can be seen that a good approximation to the ideal log (i.e. linear in dB) law exists over the central and most used part of the control range.

A practical version of this is shown in Fig. 3. A_5 is a unity-gain buffer biased via R_{25}, and R_{26}, R_{27} set the maximum gain to the desired +26dB. Capacitor C_{25} ensures h.f. stability, and the output capacitor C_{26} is chosen to allow 600 ohm loads to be driven. A number of outwardly identical Radiohm 20mm dual-gang linear pots were tested in the volume control position, and it was found that channel balance was almost always within ±0.3dB over the gain range -20 to +26dB, with occasional excursions to 0.6dB. In short, this is a good way of wringing the maximum performance from inexpensive controls, and all credit must go to Mr Baxandall for the concept.

At the time of writing there is no consensus as to whether the absolute polarity of the audio signal is subjectively important. In case it is, all the preamp. inputs and outputs are in phase, as the inversion in the tone stage is reversed again by the active-gain stage.

Power supply

The power supply is completely conventional, using complementary i.c. regulators to provide ±15V. Since the total current drain (both channels) is less than 50mA, they only require small heatsinks. A toriodal mains transformer is recommended for its low external field, but it should still be placed as far as possible from the disc input end of the preamplifier. Distance is cheaper (and usually more effective) than Mu-Metal. Since the 5534 is rated up to ±20V supplies, it would be feasible to use ±18V to get the last drop of extra headroom. In my view, however, the headroom already available is ample.

Construction

The preamplifier may be built using either 5534 op-amps or the 5532 dual type. The latter are more convenient (requiring no external compensation) and usually cheaper per op-amp, but can be difficult to obtain. To compensate each 5534 for unit gain, necessary for each one, connect 15pF between pins 5 and 8. Note that the rail decoupling capacitors should be placed as close as possible to the op-amp packages – this is one case in which it really does matter, as otherwise this i.c. type is prone to h.f. oscillation that is not visible on a scope, but which results in a very poor distortion performance. It must also be borne in mind that both the 5534 and 5532 have their inputs tied together with back-to-back parallel diodes, presumably for voltage protection, and this can make fault-finding with a voltmeter very confusing.

Only 2.5% capacitors should be used in the RIAA networks if the specified accuracy is to be obtained. Resistors in Fig. 3 marked * should be metal oxide 1% or 2%, for reasons of tolerance only. Each of these resistors sets a critical parameter, such as RIAA equalization or channel balance, and no improvement, audible or otherwise, will result from using metal oxide in other positions.

Several preamp. prototypes were built on Veroboard, the two channels in separate but parallel sections. The ground was run through in a straight line from input to output. Initially the controls were connected with unscreened wire, and even this gave acceptable crosstalk figures of about -80dB at 10kHz, due to the low circuit impedances. Screening the balance and volume connections improved this to -90dB at 10kHz, which was considered adequate. It must be appreciated that the crosstalk performance depends almost entirely on keeping the two channels physically separated.

Some enthusiasts will be anxious to (a) use gold-plated connectors; (b) by-pass all electrolytics with non-polarized types; or (c) remove all coupling capacitors altogether, in the pursuit of an undefinable musicality. Options (a) and (b) are pointless and expensive, and (c) while cheap, may be dangerous to the health of your loudspeakers. Anyone wishing to dispute these points should arm themselves with objective evidence and a stamped, addressed envelope.

Specification

(Based on measurements made on three prototypes, with Sound Technology 1710A).

Moving-magnet

noise ref. 5mV r.m.s., 1kHz input	-81dB
RIAA accuracy	±0.2dB
input overload point (1kHz)	300 mV r.m.s.

Line inputs

noise ref. 100mV r.m.s. i/p	-85dB
maximum input	9V r.m.s.
maximum gain	+26dB
treble control range	±8dB
bass control range	±9dB
vernier balance control	-1dB to +4.5dB
volume control channel balance	±0.3dB
distortion (1kHz-20kHz)	0.005%
maximum output	9.5V r.m.s.

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Current dumping review – 2

Current dumping is a circuit technique which claims to abolish all crossover and other distortion caused by a class B output stage. This analysis shows that in precisely this respect the performance of current dumping is notably inferior to that of a traditional amplifier of similar design.

by Michael McLoughlin

Discussion so far can be summarized by reference to Fig. 8, where V represents the distorting dumper V_{be} and its quasi-rectangular behaviour. Signal input has been ignored as it is the influence of V on E which is to be studied.

The aim is to ensure that variation of V does not affect E. If A is taken as finite this cannot be done by balancing the bridge in the usual fashion. For no change at E then implies no change at C or at B, implying change at E contrary to hypothesis. What is required is for the bridge to be a little off balance, so that when E remains constant a small amount of V is fed back to the amplifier: enough to shift B appropriately. Clearly then the small bridge unbalance required is inversely proportional to the gain A. Algebra will handle the details, and dumper distortion will totally cancel, however V behaves.

As mentioned, taking A as infinite leads to destruction of the system. The bridge would require to be balanced as normal, because A now requires no input voltage. Whence if E is not varying with V the negative input of A might as well be connected to E instead of to C. Then Z_1 and Z_2 can be removed, and Z_4 replaced by a wire.

Previous discussion was based on a floating signal source, which is not attractive. Further, the floating "zero volts" rail required frequent corrections to the algebra. Divan and Ghate (WW April 1977) remove these irritations, and bring the theory to a new level with the circuit of Fig. 9. They include Z_{in} together with the gain-setting element Z_f hinted at by Walker, and take A as finite. Their balance condition (6) is derived in two lines in Fig. 9, and contains all earlier results.

Invalidity

Murmurs have been heard that much of this debate is invalid. Suppose that the output current through Z_L in Fig. 9 is sinusoidal. Then the current marked i through Z_4 supplies most of it, but it is switched off during crossover. Meanwhile I−i flowing through Z_3 supplies what is wanting. Then both of these currents depart dramatically from the sinusoidal form.

Now the interest of this analysis lies largely in the study of the very successful Quad 405 amplifier design that uses the technique. But in that amplifier Z_2 is a capacitor and Z_4 an inductor. When currents and voltages depart from the sinusoidal it is impossible to attach impedance values to these components, and the symbols used above for such quantities have no meaning. Take the case of Fig. 10, where a 'square' voltage wave is applied to a capacitor and series resistor. The ratio V/I wanders through most values from zero to infinity throughout the cycle, and there is no constancy about it at all. In these circumstances one may certainly not note the current through C, and divide by jωC to obtain the voltage across this component. Fig. 10 certainly presents an extreme case, but if Z_2 is a capacitor it is just the case of Fig. 9. A quasi-rectangular voltage is applied to this component, and the current is to be derived by multiplying by jωC!

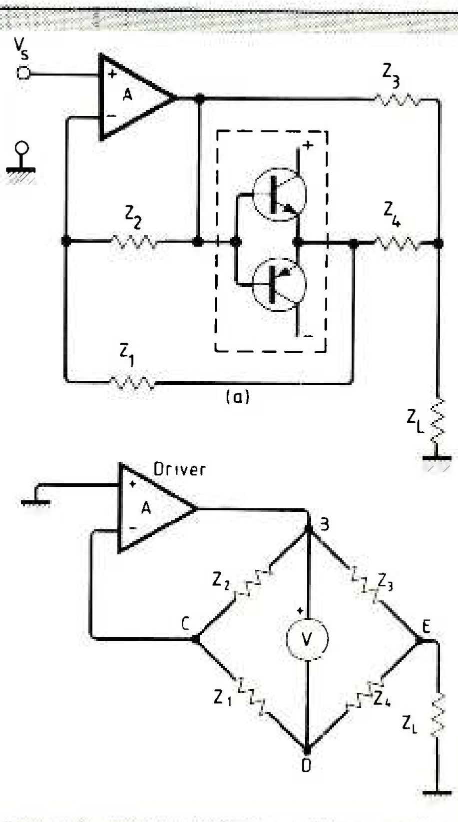
If V in Fig. 10 is a sinusoid then the current I has that form also. If we agree to make comparisons with a certain time delay between these two variables, then a constant of proportionality which does not vary with time will again emerge. And the complex number analysis has been developed to mechanize the accounting. And it would be valid in this circuit to resolve V into sinusoids, use complex numbers on each separately to deduce the consequent I, and add the results. Of course the results would be at different frequencies. But this does depend on the circuit being composed of only linear components, where the output due to a sum of inputs is sure to be the sum of what each would produce separately.

This might be tried in Fig. 9, by

Current dumping

Basic current dumping circuit Fig. 8 (a) may be redrawn as a bridge (b), with the distorting dumper V_{be} modelled as a voltage generator of similar behaviour. Signal can be neglected: it is this voltage generator that can produce no output at E.

Hypothesis: E does not vary when V does. Then it is useless to balance the bridge as normal for no change at E then implies none at C, or at B, resulting in change at E contrary to hypothesis. Slight imbalance at C is required instead. Then if V increases E remains unaltered, but there is a slight fall at C: enough to lift B sufficiently to ensure E is unaffected. The imbalance required is both slight and critical, and the arrangement is very sensitive to tolerance errors.



resolving the currents i and I–i into sinuoids, and discussing each component separately. But Fig. 9 does not show a network composed of linear elements: base-emitter junctions are non-linear in the extreme. This route is barred.

One example of the many possible consequences of reckless resolution into sinusoids is provided by the ordinary a.m. detector. Suppose that such a circuit is supplied with a carrier modulated by a tone. The output is of course the tone, plus a d.c. level. But now resolve the input into sinusoids: the carrier plus two sidebands. Taken separately each of these would produce only a d.c. levels and when added they yield only a d.c. level: the tone has vanished. Conclusion: no detector detects!

Validity

Such criticisms do appear to apply to most of the previous discussion, including of course our own treatment in Fig. 9. However the bridge model of Fig. 8 escapes untouched. Here the troublesome non-linear dumpers have been replaced by a voltage generator, and in determining' whether a circuit is composed of linear elements the generators do not have to pass any tests. (Detailed information about the behaviour with time of this generator will be required later.)

Could this trick for turning a non-linear into a linear circuit be applied elsewhere, perhaps in the a.m. detector mentioned above? It can, provided that sufficient information is available about the non-linear voltage V. In the case of the detector the diode must be replaced by V, and when V has to be specified it will be given audio elements suitable for producing the correct output, now that the r.f. cannot yield it. The procedure is valid enough, but in this case scarcely attractive.

Advance to Fig. 9 again. Replace the dumpers by transistors of constant current gain but zero V_{be}, in series with a voltage generator to be inserted at G. These odd transistors are linear elements: their emitter current in response to a sum of base currents is just the addition of what each would produce separately. And the V_{be} generator may produce such voltage as it sees fit, while the signal at A varies, without violating the linear character now

Table 1. Discontinuity in sinusoidal output E at crossover. Theory provides these figures when tolerances are taken into account. Case 1 offers two transitions per crossover, and the figure in the text has been doubled, as e=0.2 now. Using closer tolerance components would benefit the first two cases equally. Adding bias components would benefit all three cases equally.

Organisation	V pk-pk	Notes
1. As supplied	7.0mV	∝E and ∝f
2. Resistive bridge	0.6mV	at all E and f
3. Traditional amplifier	0.15mV	at all E and f

Transitions at crossover: Quad 405
e=0.2 f=13.2kHz E=1V r.m.s.

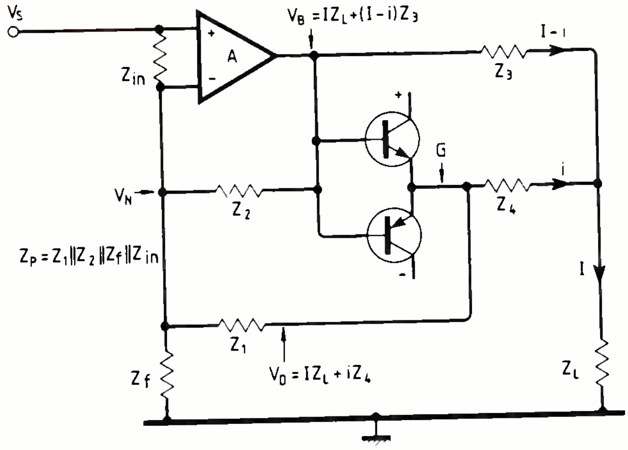


Fig. 9. In Divan and Ghate model for current dumping V_B/A must exist between the input terminals of A. So V_N may be derived from V_S. The result is equated below to V_N, as derived by Millman's theorem (proved in Fig. 6):

$$V_s-\frac{IZ_L+(I-i)Z_3}{A}=Z_p\left[\frac{IZ_L+(I-i)Z_3}{Z_2}+\frac{IZ_L+iZ_4}{Z_1}+\frac{V_s}{Z_{in}}\right]$$

This is a linear bond between V_s and I if the terms in i balance out:

$$\frac{Z_4}{Z_1}=\frac{Z_3}{Z_2}+\frac{Z_3}{AZ_p} \qquad (6)$$

possessed by the network. Naturally we shall oblige G to follow the real V_{be}. The network is now linear, but has two input signals.

When deprived of their V_{be} the two dumpers together make a single linear element. Admittedly a slight violation of linearity will occur on passage from one dumper to the other, because their current gains will not be equal. Apart from this detail, the model now offers a rigorous treatment of the bulky non-sinusoidal currents and voltages in the reactive bridge components. And on a second reading it will be possible to see that this assymetry must degrade a little further the result in the first line of Table 1, thus strengthening our conclusion there.

The two inputs at V_s and G in Fig. 9 may now be considered as sums of sinusoids, and the influence of these on output may be anlysed one frequency at a time. Or V_s and G could be considered separately. And handling one frequency at a time the usual complex number analysis may be employed, with the final output counted as the sum of the separate outputs produced by all these components. Using these tricks a valid proof of (6) can now be given, after the style of what follows.

Quad 405 circuit

The full circuit may be inspected in the operating manual, or in Walker's article Fig. 11 offers his simplified version, with Z_1 to Z_4 clearly marked, and values are attached.

Recall that the generator V in Fig. 8(a) really represents the two complementary dumpers. Their emitters are connected to D and bases to B. So Walker identifies the circuit of Fig. 11 with that of Fig. 8(a). But there is a difficulty. Not only has an extra transistor Tr_2 appeared, but Z_1 and Z_2 are connected to opposite ends of it. Now dumper V_{be} variation will inject current

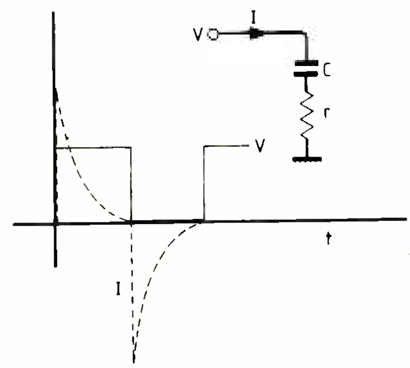


Fig. 10. Current when a rectangular wave voltage is applied to a capacitor and series resistor.

via Z_1 into Tr_2 emitter, and if the driver gain is large this current might just as well be considered as injected into the collector circuit directly. To effect this transfer is just the role of a transistor. Thus if the input signal in Fig. 11 is set at zero, then from an a.c. viewpoint Z_1 can be considered as connected directly to the collector, to identify with the layout of Fig. 8.

But if minimum figures are taken for the gains of the transistors in the driver, its input impedance is about 50kΩ, and during crossover its voltage gain is only about 77. Thus at 1kHz the capacitor C presents an impedance to Tr_2 collector of $Z_C/77$ or 17kΩ. The collector will feed such a load without difficulty. The current is provided by Z_1 = 500Ω, and is injected into the emitter with little difficulty. But that resistor could not be expected to feed 17kΩ without change: Z_1 may not really be considered to be connected to the collector, and Fig. 8 is not an accurate model for the real circuit of Fig. 11.

Vanderkooy and Lipshitz handle the difficulty in just the opposite way, by considering Z_2 to be disconnected from the collector and joined instead to the emitter. Transistor Tr_2 becomes part of the driver amplifier, and the circuit again identifies with that of Fig. 8(a). From the figures

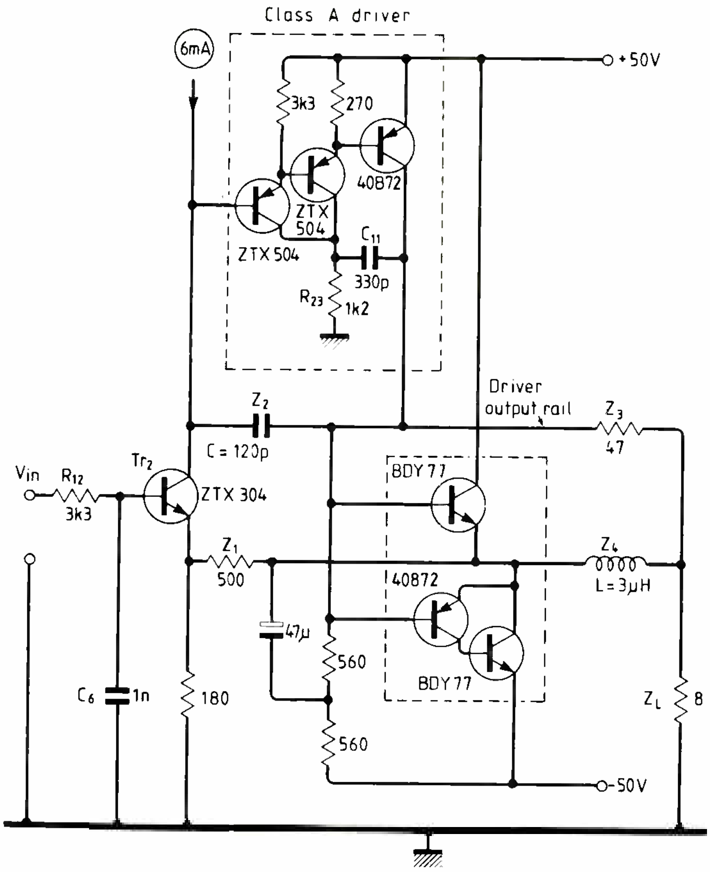
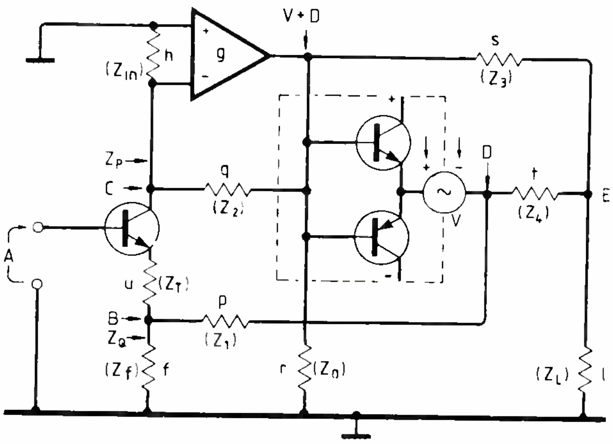


Fig. 11. Walker's simplified circuit of the Quad 405 amplifier, omitting current limiting and h.f. trim components. I have further omitted the LM301A op-amp that provides V_{in}. (It operates in class A, is not part of the current dumping circuitry, and receives only a d.c. feedback – not shown – from Z_L to centre the working point of the dumpers) Minimum h_{FE} for a BDY77 is 40; for the other transistors shown it is 50.

Fig. 12. In this current dumping model A, B, C, D, V denote voltages, small letters admittances.



DEFINITIONS

k: dumper $i_b = k i_e$

$b = q + r + s$

$m = l + s + t$

$n = f + p + u : \frac{u}{n} = \lambda \approx 1$

$g' = g - q$

$Z_p = \frac{1}{h+q}; Z_Q = \frac{1}{n}$

CONSTRAINTS

$s(V+D-E)+q(V+D-C)+r(V+D)+k[t(D-E)+p(D-B)]=-gC$

(1) $-(s+kt)E=-bV-[b+k(t+p)]D+kpB-g'C : n(s+t)(h+q)$

(2) $(s+t)D=mE-sV; nB=uA+pD : (s+t)$

(3) $n(s+t)B=u(s+t)A+pmE-psV; (h+q)C=uB-uA+qV+qD : n(s+t)$

(4) $n(h+q)(s+t)C=-u(s+t)(f+p)A+(nqt-psu)V+m(pu+qn)E$

ARGUMENT

Write $wE=xA+yV$ where (7)

$w=(h+q)[mn(-s-kt+b+k(t+p))-kppm+nl(s+kt)]+g'm(pu+qn)$

$\quad =(h+q)[mn(q+r)+kpm(f+u)+nl(s+kt)]+g'm(pu+qn)$

$x=u(s+t)[kp(h+q)+g'(f+p)]$

$y=-bn(s+t)(h+q)+[b+k(t+p)]n(h+q)s-kp(h+q)ps+g'(psu-nqt)$

RESULT

$y=0 \Rightarrow g'(psu-nqt)=(h+q)[bnt-kns(t+p)+kpps] : \div g'stn$

$$\lambda \cdot \frac{Z_4}{Z_1} = \frac{Z_3}{Z_2} + \frac{1}{g'Z_p}\left[1+Z_3\left(\frac{1}{Z_2}+\frac{1}{Z_0}\right)-k\left\{1+\frac{Z_4}{Z_1}\left(1-\frac{Z_Q}{Z_1}\right)\right\}\right] \quad (8)$$

Approximate admittances at 1kHz (moduli in mhos)

$p=10^{-3}$, $q=10^{-6}$, $r=10^{-3}$, $s=10^{-2}$, $t=50$, $l=0.1$, $f=10^{-2}$, $u=3\times10^{-2}$, $h=2\times10^{-5}$, $g=2$. $0<k<1/40$.

just given for the driver of Fig. 11 it is clear that above 1kHz it works as an operational amplifier, ensuring that most of the current supplied by Tr_2 is drawn away through C, while leaving only a small amount to work the driver itself. Now as the current gain of Tr_2 from emitter to collector is unity, C could indeed syphon off this current with similar effect at the emitter instead.

But this alteration does obscure an important factor. In Fig. 11 the element Z_1 is marked as 500Ω, but in fact any current due to dumper V variation flowing into Tr_2 emitter is also affected by the emitter input impedance found there. Owing to the presence of R_{12} this may be as high as 3.3k/50 + 25/6 = 70Ω, causing a 14% increase in the effective value of Z_1. If now Z_2 is connected instead to the emitter and there syphons off its current from that flowing into the driver, then scarcely any of the current supplied through Z_1 remains to flow into the emitter. Not much impeding voltage arises, and the 14% adjustment required in the value of Z_1 disappears. If a bridge is to be balanced then a 14% adjustment in the value of one arm is serious, and Z_2 may not be reconnected as proposed in any accurate model of Fig. 11.

It seems possible that Z_1 and Z_2 were initially connected to the same point of Tr_2, but were later separated as part of the h.f. trimming programme evident in the full circuit.

Quad 405 model

Fig. 12 offers a model for Fig. 11. The driver has been reduced to linearity by its specification in terms of mutual conductance. The dumpers are so reduced by thinking of them as transistors of equal current gain but zero V_{be}, in series with a generator to simulate the latter. The driver is equipped with input impedance Z_{in} and output impedance Z_o. Gain-setting element Z_f appears. Delivery of feedback to both ends of Tr_2 is properly represented. Finally Z_T is in series with Tr_2 emitter to stand for the input impedance found there.

The circuit may now be analysed in terms of the two input voltages A and V. Because the components are all linear these may be treated separately, and as sums of sines. Thus complex number analysis is valid. But the twin menaces of this sort of analysis are suffices and denominators. It has been possible to avoid both by giving each impedance a second unbracketed symbol to represent its admittance.

The definitions section of Fig. 12 starts by defining k to account for dumper current gain, and there follow names for concatenations of symbols that will arise. About half the remainder may be omitted at first reading, and the new balance condition (8) can be attained quite quickly.

Constraints

Solving the circuit of Fig. 12 consists in obtaining the relationship between the three voltages A, V and E. To build relationships it has been necessary to introduce voltages B, C and D, so these are to be eliminated.

Observing that the current flowing away

from the driver is equal to what it provides, then line 1 collects the variables (capitals) in this constraint, using the shorthand defined. Line 2 starts by defining E, using Millman's theorem if sV is added to both sides.

From an a.c. viewpoint the upper end of u is at potential A, and so later in line 2 Millman's theorem is used to define B. If this equation is multiplied by the factor on its right it may be rewritten as (3) by using (2).

This captures D and B in terms of desired variables. It is just a little harder to do this for C. A constraint is given for it later in line 3. If the two terms in q on the right are transferred to the left hand side, the equation is justified as a statement that the current flowing away from C is just what is delivered there by Tr_2. Multiply the equation in its present form by n(s + t) as suggested on its right. It should be possible to arrive at line 4 without a pencil, using (2) and (3) to remove D and B. Collecting first the terms in A yields a coefficient uu(s + t) − un(s + t), equal to what is written. Collecting the terms in E out of B and D is easier. And the coefficient for V is simpler than expected because two terms nqs have cancelled.

Argument

The peak of difficulty is already passed, and (8) is within reach. Focus on line 1 of constraints. If the equations at the start of the next three lines were used to remove D, B and C from line 1, a gigantic equation would result. But it would only contain the desired variables E, A and V. So it would have the form of (7). If y = 0 then certainly E and A are bound into proportionality, and the sinusoid V has no effect on E, leaving it free from distortion.

You are therefore dispensed from pursuing w and x in (7): it suffices to study y alone. Now (7) is to be considered as derived from line 1 after first multiplying that line by the factor noted on its right. This suffices to prevent the generation of any fractions. So multiply line 1 as stated, and collect on its right hand side the terms in V only, including those V found when D, B and C are substituted. Hopefully this will give y as stated.

Balance equation

First note that two terms bns (h + q) cancel out in y. Now write the result line. Then divide as stated, remembering u/n = λ. But write the result in terms of impedances rather than admittances, and (8) will appear. If this holds then y = 0 in (7), and the distorting V does not influence the output.

Relation to other balances

Equation 8 now provides the balance condition for the Quad 405. It includes the driver output impedance Z_o, and the double delivery of feedback is studied. The emitter input impedance of Tr_2 is included, and the balance is altered by the new factor λ on that account.

Suppose first that this emitter input impedance is zero (λ = 1 and Z_Q = 0). Then if Z_o is also excluded by setting it infinite, (8) reduces to the balance condition of Vanderkooy and Lipshitz. But if Z_o tends to zero while g becomes large, so that gZ_o = A, the driver has become a voltage amplifier. And then (8) takes the form of (6), though Z_P is not the same because of the isolating effects of Tr_2. Of course, setting g infinite reduces (8) to the basic $Z_4/Z_1 = Z_3/Z_2$.

But none of these things are true when λ is taken into account. If the input transistor has its minimum gain of 50, then as suggested earlier Z_T = 70Ω, and so λ = 0.65. Inserting this new factor disturbs all previous balance conditions. The gain of Tr_2 may rise to 300, yielding Z_T = 15.2Ω and λ = 0.90, which is still serious. It appears that the balance of the bridge is critically dependent on the gain of the particular transistor inserted at Tr_2.

Listed below (8) are approximate values, and it is clear that Z_3/Z_2 can be dismissed from the square bracket of (8). And the fractions that remain fall by about an order of magnitude a time: 1, Z_3/Z_o, k, Z_4/Z_1. It follows that for all attainable purposes the balance condition simplifies to

$$\lambda\cdot\frac{Z_4}{Z_1}=\frac{Z_3}{Z_2}+\frac{1}{gZ_P}\left[1-k+\frac{Z_3}{Z_0}\right]. \qquad (9)$$

Bridge balance

Many balance conditions have been published, but no-one has yet inserted the four Z values of Fig. 11 into their result. This may be because the simple condition $Z_4/Z_1 = Z_3/Z_2$ reduces to $L = R_1R_3C$, and it shows a 6% unbalance.

To find figures for g and Z_P in (9), consider the two 560Ω resistors in Fig. 11. These provide a nominal 50mA current sink for the dumper bases, and around crossover this current is provided by the driver. Now 1mV applied to the driver input mostly reaches the 40872 base, causing the usual 4% alteration in its collector current. This change is 2mA, which shows that the driver mutual conductance g is around 2 amps/volt. Assume minimum transistor gains, and follow the electrode impedances associated with 50mA current output back to the input terminal: the impedance there is just over 50kΩ. This is a fair figure for Z_P also, because even at 10kHz the reactance of Z_2 is still 133kΩ. So gZ_P in (9) is 10^5, or more if the transistor gains exceed minimum.

Take λ = 1 for the moment, and suppose f is the standard frequency of 13.2kHz at which Vanderkooy and Lipshitz run their tests: then the three terms of (9) work out in millionths as 498j, 468j, and 10 or less. The first two terms are imaginary and the third is real. Then the best that can be done is to balance off the first two terms by $Z_4/Z_1 = Z_3/Z_2$, and ensure that the third term is small. The designers appear to have done this. But there is still that unexplained 6% unbalance between the large terms.

But the two imaginary terms of (9) should really be balanced off by

$$\lambda\cdot\frac{Z_4}{Z_1}=\frac{Z_3}{Z_2}. \qquad (10)$$

Now the median gain of Tr_2 is 175, so its emitter input resistance may be 3300/175 + 25/6 = 23Ω, yielding λ = 0.852. The three terms in (9) now work out in millionths as 424j, 468j, and 10 or less. The first term is now some 10% down on the second, and the Quad 405 bridge appears to be out of balance by this amount in the opposite direction.

An easy way to correct this would be to reduce Z_1 by the same factor 424/468, which could be done by connecting in parallel a 4.8kΩ resistor. Now Vanderkooy and Lipshitz did vary the resistance of Z_1 to achieve minimum crossover distortion, and they demonstrate their results with oscillograms. Their finding: for best balance Z_1 requires a resistor in parallel of "about 5k". This confirms that there is a systematic unbalance of some 10% in the Quad 405 bridge, though the precise figure varies sharply with the gain of Tr_2.

Conclusion on circuit design

Clearly the dv/dt limiter R_{12} with C_6 that is causing unpredictable λ must be placed earlier in the circuit and not here. The low impedance source driving Tr_2 must be allowed direct access to this transistor, and resistors must be kept out of this area. Another way of making the same point is to observe that extra input currents flow during crossover, and the input impedance of a current dumping circuit varies wildly as a result.

There are only three terms in (9), and the third is by far the smallest at typical frequencies. If 5% components are used, as in the 405, then each of the first two terms can vary 10% by tolerance errors. Then one side of (9) may exceed the other by 20% on that account. Then it is useless to seek circuit sophistication to eliminate the unbalancing effects of k (dumper base current) in (9): any such effects are orders of magnitude less than tolerance errors. Although T. Hevreng has solved this problem in a way that must command admiration (May 1979), such a solution is not of practical utility. The correct conclusion is the inverse: k affects the balance of (9) so little that it is not worth using Darlington type dumpers to reduce it. And the Quad 405 designers were right not to bother. Equally, H. S. Malvar is not really practical in enquring after say 10% variations in g during the signal cycle.

Minor effects

Vanderkooy and Lipshitz point to the upper 560Ω resistor in Fig. 11 as an unbalancing element. It can be modelled as connected from V+D to D in Fig. 12. And a mesh-star tranformation with Z_3 and Z_4 shows that the effect is to reduce both these values by 8%, leaving unaltered the balance of the first two terms in (9). The lower 560Ω is effectively connected from D to ground, and a similar transformation with the new value of Z_4 and the load shows that this time Z_4 is effectively reduced about 1½%, but without other compensations in (9). Thus these resistors do not affect the possibility of bridge balance.

These two authors also point to the unbalancing effect of the compensation components R_{23} and C_{11} in Fig. 11. These load the driver output a little, but they can be included in the symbol Z_o of Fig. 12, so that the bridge can still be balanced. Their effect on the driver input can be seen as follows. Suppose the driver output rail in Fig. 11 is falling at 10^6V/s: then 0.33mA flows out from C_{11}, causing the top of R_{23} to fall 0.4V. If the first transistor in the driver has a collector impedance of 100kΩ when its base current is held constant, then 4μA will be drawn through it. An identical disturbance to its current would be produced by increasing its base current by 0.1μA or less. Meanwhile, in response to the driver output ramp, Z_2 is delivering 0.12mA, which is being fed to it from Tr_2. Then 0.1% increase in the value of Z_2 would increase the current in it by 0.1μA, which would come from the driver input terminal. Conclusion: the disturbance to the input can be well modelled by imagining Z_2 is increased by up to 0.1%. Compared with the tolerance error of that component this is a trivial correction.

An equivalent amplifier

Because reactive components have been used the first two terms of (9) are imaginary, and so the best that can be done to balance it is to insist on (10). But this means psu = qnt. So no V appears in the equation for C in line 4 of Fig. 12. Voltage C represents the mix of both signal and feedback, and it controls the output completely. And the equation for it is now

$$(h+q)C=-\lambda(f+p)A+\frac{m}{s+t}(\lambda p+q)E.$$

Provided that C is bound to A and E in this way any method of deriving it may be used, and will produce the same output voltage as before. For example, disconnect q in Fig. 12 and connect it in parallel with h. Then C will arise as just specified if a current equal to the expression on the right of this equation is injected into Tr_2 emitter. So replace f and p in Fig. 12 by f′ and p′, but connect the right hand side of the latter directly to E. The upper end of u may be considered to have potential. A. Then by studying only the components now connected to B it is easy to verify that the current entering Tr_2 emitter is correct if

$$p'+f'=p+f$$
$$p'=(p+q/\lambda)m/(s+t).$$

If these values are fitted the amplifier will have the same performance as the current dumping circuit. Further, Z_4 can now be shorted and its influence absorbed into V, about which we have never had to be specific. The amplifier is now shorn of its current dumping components Z_2 and Z_4, but with three others adjusted it will have identical performance.

These modifications alter the output load slightly, but that has never been a factor. Also a 520Ω load was removed from D in Fig. 12. A mesh-star transformation between this, Z_4 and Z_L shows that this removal is equivalent to increasing Z_4 by 1½%. Reduce it again and operation is

The problem

In 1975 a new type of audio amplifier was announced, called the "current dumping" amplifier. Described in the US patent as "distortion-free", more than 60,000 units have now been sold, with retail value exceeding £15 million, and the design has won a Queen's Award to Industry. Yet in the lively discussion that resulted in this journal, one group insists that the amplifier works by feedforward, another school disagrees and says it uses feedback, whilst a third party maintains it is all a grave error: the performance is actually worse than that of a traditional circuit.

Has then something useful been invented, and if so exactly what is it?

A solution

Part 1, September issue, explained and simplified previous contributions in this journal. The feedforward and feedback explanations are not rivals, but valid alternatives. The bridge model developed was shown to be of greater power than the others.

Part 2 now explains the central idea of the invention, with an improved statement for the balance that must hold between the four key components in the bridge. The third party in the debate appears to be correct: the idea is spoilt by errors due to the tolerances of the components. When these are allowed for, the insertion of the current dumping components actually degrades the amplifier performance. Fig. 8 explains the central idea at stake.

as before. And the new Z_4 can be absorbed into V as previously.

Infertility?

Current dumping then is doing nothing useful, because of the particular bridge balance chosen. Observations of this tenor by Halliday, Olsson and Bennett were reported toward the end of Part 1, and this view is now supported by the model of Fig. 12.

Such algebra invites an explanation. The trouble seems to start with (9). Faced with that requirement a designer unsure of his g may make it large and forget it, relying on (10). And with the Quad 405 the imaginary character of the first two terms in (9) compels the designer to resort to (10).

Now redefine Z_1 in (9) as $Z_1' = Z_1/\lambda$. This means that we propose to account for the 23Ω or so impedance found at the emitter of Tr_2 by thinking of Z_1 as altered slightly to include its resisting effects. The circuit now identifies well with that of Fig. 8 with Z_1' fitted there. Now multiply (9) by Z_1'/Z_3 to yield the alternative form.

$$\frac{Z_4}{Z_3}-\frac{Z_1'}{Z_2}=\frac{Z_1'}{gZ_pZ_3}\left[1-k+\frac{Z_3}{Z_0}\right]. \qquad (11)$$

Earlier we expected the bridge ratios in Fig. 8 to be slightly out of balance if the effect of V on E was to cancel, and (11) establishes the required difference. And this difference was expected to be inversely proportional to driver gain, as it is here.

But the designers have decided to neglect the gain term, found on the right of (11), and instead have set these bridge ratios equal by (10). But the entire purpose of current dumping is to define correctly the small amount by which the two bridge ratios need to be out of balance if the effects of V are to cancel. The idea is destroyed by any implementation that proposes to ignore the gain term in (11) and set these fractions equal. Such a move discards the essence of the dumping technique. And as shown above it is then possible to alter the amplifier into a conventional structure of identical performance.

Tolerances

The above criticism was based on the designer's decision to rely on (10). But further difficulties now arise, because the components he specifies to do this will not have their nominal values, but (in the Quad 405) may each be 5% out. This issue has been treated by T. C. Stancliffe (November 1976.)

The analysis in Fig. 12 will yield an accurate assessment of the effect of tolerances. Equation 8 there will not now balance exactly, but it may be made to do so with the actual components used if the left hand side is multiplied by (1 − e). We shall made no capital out of λ as a simple design improvement can remove this factor. Then e can reach 0.2 in magnitude. Prefacing the equation with (1 − e) is equivalent to asserting it with an extra leading term $-e\lambda Z_4/Z_1 = -e\lambda p/t$ instead. Then the previous equation can be asserted, with an extra leading term $-e\lambda pg'sn = -epg'su$. The previous line for y remains valid, but y is clearly now epg′su. Now multiply constraint line 1 by the factor on its right, do the elimination and verify that x in (7) is correctly stated. To verify the expression given for w, note that the last term in its first square bracket will be needed to reconcile the first term there. Examine w and x in the light of the approximate admittances listed. Dismiss the entire square bracket in w by writing out just its largest products

$$h[tu(r + kp + kl)].$$

The last of these is the largest, but it is many thousand times smaller than the last term of w, approximated by

$$w=gmpu \quad x=gu(s+t)(f+p) \quad y=epgsu.$$

Actually if all its products are multiplied out (7) contians initially 284 terms. But cancel gu in the expressions just given, and that equation reduces with great accuracy to

$$mpE=(s+t)(f+p)A+epsV.$$

The contribution to E from A may now be studied. As may be readily explained from Fig. 12 if V is held constant, there is a gain of $1 + Z_1/Z_f$, followed by an output impedance $Z_3//Z_4$.

Tolerance unbalance

Of greater interest here is the contribution to E from V:

$$E=\frac{es}{m}V\approx\frac{es}{t}V\approx e\frac{Z_4}{Z_3}V. \qquad (12)$$

This strikingly simple expression can be explained from the elementary model of Fig. 8. Consider the error in equation 8 as concentrated in Z_4: the value fitted is too large by a fraction e, because balance is achieved when (8) is multiplied by (1-e). Thus in Fig. 8 instead of the correct Z_4 the value is a fraction e larger. Once V is fixed, potentials B and D are in the merciless grip of the amplifier there. And as Z_4 is small, moving the tap at E off the balance point by eZ_4 yeilds (12).

Consider first the easy case where all components are resistive. Now V passes in almost rectangular fashion between −0.7 and 0.7V, the transition occuring during the length of each crossover. As the factors in (12) are real the distortion E given there will have the same waveform. Take e at its maximum value of 0.2 or so. Take Z_3 = 47Ω and Z_4 = 0.1Ω: the amplitude of the rectangular distortion contributed to E is given by (12) as 0.6 mV pk-pk.

Now suppose that Z_4 is inductive. As the square bracket term in (8) is small, errors in the others will dominate and e will still be real. Then it is legitimate to regard E in (12) as derived by forcing a current eV/Z_3 through this inductor, where V is a sinusoidal component of the distortion voltage. But the inductor is a linear compoent, so the various sinusoidal currents can be recomposed into a current eV/Z_3, where V now represents the full quasi-rectangular distortion voltage waveform. If L is an inductor and v is the rate of change of V this produces $E = Lev/Z_3$.

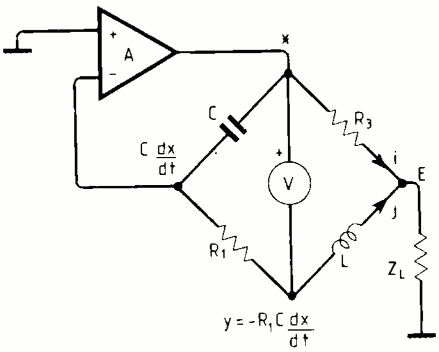
To obtain a figure for v suppose that at E the signal output is Asinωt: then near upward crossover its slew rate is Aω. To maintain this during crossover V + D has to slew an extra Z_3/Z_L times as fast (where Z_L is the load and does not refer to the inductor.) So V itself has to slew at $A\omega Z_3/Z_L$. This provides the figure for v above, yielding distortion

$$E = eA\omega L/Z_L \qquad (13)$$

constant during crossover but zero elsewhere.

Optional calculus

Calculus supports these manoevres. The argument is sketched in Fig. 13, and as investigation is concentrated on bridge unbalance the gain A has been taken as infinite. Signal has been set at zero and only the effect of V is studied. If the volts at the upper bridge vertex are x then the current through C is as stated, whence the volts at the lower vertex may be written. The two voltages must differ by V, yielding the constraint given. With the forcing function shown for V this is an easy specimen of its kind, and the full solution is sketched. As V passes the point A then x follows the broken curve shown. This may be accurately specified by saying that at A the voltage x falls by m/n, but the exponential columns shown at the origin are added back to x. At D the voltage may be said to make the same jump upward, and then to suffer the subtraction of the same columns to yield a curved transition. And y is as



Constraint:

$$\frac{dx}{dt}+nx=nV,\text{ where } n=\frac{1}{R_1C}=\frac{1}{T}$$

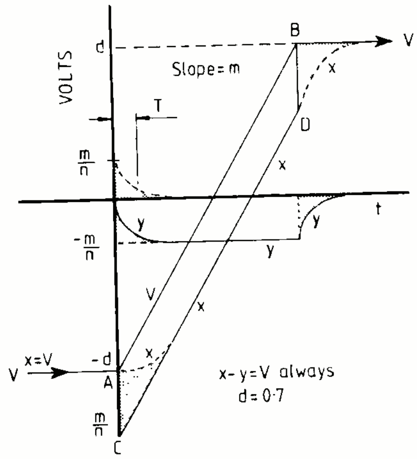


Fig. 13. With the forcing function V of slope m as drawn, x and y develop as shown. The volts y are in effect a pulse of amplitude −m/n constant during crossover but zero otherwise, as the time constant $T=R_1$ $C\approx0.06\mu s$ only.

shown: a rectangular pulse lasting for the crossover but modified briefly at each end by the same set of exponential columns.

Rewrite (8) with $Z_1=Z_1/\lambda$ in place, to the exclusion of Z_1 and λ (the final terms in the square bracket are frivolous and may be ignored.) Now suppose the error is concentrated in Z_1'.Because for balance this equation had to be multiplied by 1 −e it follows that Z_1' is just a fraction e too small. In terms of Fig. 13 the resistor R_1 after being set at Z_1/λ turns out to have a tolerance error making it a fraction e too small.

Now suppose the change in output volts E in Fig. 12 which results from a change in V is zero. Then

$$\frac{d}{dt}(i+j)=\frac{dx}{dt}\left[\frac{1}{R_3}-\frac{R_1C}{L}\right].$$

If $R_1 = L/R_3C$ as before then i + j is constant, consistent with zero change in E, and the problem is solved. But now change R_1 to 1 − e times this expression. Examine the way in which the volts y were originally established: an additional −ey volts now appears at the lower vertex of the bridge, transmitted to $Z_L//R_3$ with short time constant L/R = 0.4μs. Appeal to the sketch of y: the resultant output E is a rectangular pulse of amplitude em/n for the duration of crossover. Insert for m the slew rate v derived earlier, and (13) follows. It is true that the new volts y do alter slightly the constraint given, but this is a second order effect.

Programmed model

If Z_4 in Fig. 11 is to be recognised from the start as an inductor L, then a fourth model of current dumping naturally arises. Suppose the output volts at the load are coasting steadily upward to zero from below. Then a steady voltage exists across L, with the left hand side positive. When the lower dumper goes off, the current in L has reached zero and it stays zero. There is no final spectacular rate of change to generate a transient, and all that happens is that the steady voltage just mentioned suddenly collapses. This provides the negative-going steady voltage pulse just discovered, which is applied to Z_1 and the resultant steady current integrated into a rising voltage ramp on the right of Z_2. The simplest algebra shows that if $L = R_1R_3C$ the resultant current ramp through $Z_3 = R_3$ maintains the rate of ramp of amplifier output voltage identical with its value before the lower dumper turned off.

We are left with a picture of current dumping where as crossover approaches L is programmed with a steady voltage measuring the output ramp rate. When the dumper stops conducting this programmed voltage collapses, duly executing the measures required to hold output ramp rate unaltered.

In more abstract terms L differentiates the dumper current and C recovers it by integration, together with a negative sign. As a result Z_3 passes a current equal and opposite to any sudden change in dumper current. Vanderkooy and Lipshitz make some observations on L in their article on feedforward error correction* in which they produce oscillograms to show that while a good inductor causes no trouble, an inductor wound with thick wire on a narrow former causes sharp distortion spikes during crossover, Fig. 10. The proposed explanation is that eddy currents are at work in the inductor. You might doubt whether the gentle usage just explained is apprpriate to produce such transients, and the oscillogram does resemble their Fig. 9(b), showing what happens when the bridge is unbalanced. But if this assertion is confirmed it would be a reason to expect still worse results in the first line of Table 1, reinforcing the conclusions below.

Test case

In their WW article Vanderkooy and Lipshitz provide oscillograms of crossover distortion for A = 1.4V at f = 13.2kHz with Z_L = 10Ω. When the bridge was unbalanced by reducing Z_1 by an unspecified amount, rectangular distortion pulses did indeed appear for the duration of crossover. They observed best balance when Z_1 was reduced 10%, implying an e = −0.1 for their amplifier when Z_1 is restored to its original value. Then according to (13) there should be a rectangular pulse of just 3½mV height lasting for the duration of crossover. The oscillograms

*Feedforward error correction in power amplifiers, by Vanderkooy and Lipshitz. *Journal of the Audio Engineering Society*, January/February 1980.

(their 4c = 5a = 6a) are not easy to read, but offer 4mV pk-pk amplitude. The pulse appears to be rectangular, but to include as well perhaps a 60% overshoot on return. The overshoot then decays with time constant about 5μs. All this is encouraging, and can be made more so.

Taking median gain figures for the transistors in the driver, its input impedance would be 460kΩ, combining with C = 120pF to yield 55μs time constant. This is not likely to be the decay involved. But C_6 with R_{12} yields 3.3μs, or slightly more if the source driving V_{in} offers some impedance at r.f.

With the output described, crossover lasts 2.2μs, as seen in Fig. 11 from the effect on output of 1.4V transition at the driver output. Then initially C_6 offers a short circuit to ground for the rectangular pulse offered to it via Z_1 and Tr_2. But as the pulse developes it begins to compare with 3.3μs. Then C_6 has largely charged, and the pulse faces almost R_{12} instead of a short to ground. And when the pulse has finished C_6 has to discharge. It forces reverse current into Tr_2 and causes the overshoot noticed, which then decays as it should with time constant 4 to 5μs. The oscillogram provided is now well explained.

If the experiment were repeated with larger A, then crossover time would fall in proportion, and C_6 would not have time to develop significant charge. The circuit would tend to behave more as if R_{12} were shorted. Thus as A rises in this way the circuit moves from something like 10% unbalance in one direction, passing zero to arrive at 6% unbalance in the other.

These figures were justified earlier. Then as A rises in (13) the quantity e first falls towards zero and then rises on the other side. So initially not much increase in output distortion is expected, as these factors are behaving in opposition. But after a while distortion should rise rapidly, perhaps after the style of a square law, when both factors are pulling in the same direction. This is just what is reported: as A was increased up to 14V there was little increase in distortion, but as A climbed by a further factor of 2.5 distortion rose by a factor of five (observe approximate square law behaviour!)

Further progress would require more and clearer oscillograms.

Traditional amplifier

How does crossover distortion in the circuit of Fig. 11 compare with that present in an equivalent traditional amplifier? Some comparisons have been based on shorting Z_4 while leaving Z_2 in place but these need not detain us. It is clear that the capacitor Z_2 will then seriously inhibit the driver in its attempts to produce rapid transition of its output voltage during crossover. Hence no traditional amplifier would contain such a component.

A comparison was made above with a traditional amplifier, and it was found that there was no difference. But this supposed a dumping amplifier that had been perfectly balanced by (10). Now compare a dumping amplifier with unbalance leading to (13) with a traditional amplifier, and figures become essential.

The circuit of Fig. 11 may be converted into the equivalent traditional amplifier by shorting Z_4, and also removing Z_2. further, R_{12} should be shorted and C_6 removed: impedance cannot be tolerated in this area, and dv/dt limiting must be done earlier instead. Copy the circuit of Fig. 12 with these simplications.

Then D becomes equal to E, and if study is confined to the effects of V on E then C becomes just a multiple of E. As Tr_2 emitter input impedance is now low B can be taken as zero and all three unknown voltages that previously had to be eliminated have now vanished. The problem can be solved in two lines by applying the same current constraint as previously, and the contribution to E due to V becomes

$$E \approx -\frac{1}{gZ_{in}} \cdot \frac{Z_1}{Z_3} V.$$

As all components are resistive, E will just follow the waveform of V in this fashion. The worst figure of 50kΩ for Z_{in} produces 0.15mV pk-pk to complete Table 1.

Results

Current dumping has aroused much interest, and there have now been some 20 contributions to the discussion in this periodical alone. It has been suggested here that when the analysis takes account of the delivery of feedback to both ends of Tr_2 a new factor λ appears in the bridge balance (9). The new factor is due to the presence of R_{12} and may vary between 0.65 and 0.90 depending on the gain of Tr_2. Supposing that this gain has its median value it would appear that a 10% bridge unbalance is built into the design of the Quad 405. This result has been accurately verified by Vanderkooy and Lipshitz. Conclusion: R_{12} is causing unpredictable consequences and it must go. The bridge must be balanced.

But suppose this is accepted (or indeed rejected). Then the best attempt at bridge balance is to ensure that (10) holds. But this destroys the whole system, and an amplifier of traditional type and identical performance results if the dumping components Z_2 and Z_4 are removed, provided three other elements are adjusted.

Finally, tolerance errors prevent perfect balance of (10), and further distortion results, degrading the current dumping amplifier below its traditional equivalent. Final figures are in Table 1. It seems to be an improvement to use resistive rather than reactive dumping elements, and a further improvement to abandon them altogether.

The gain term in (9) is about 10^{-5} in the Quad 405, and it will almost certainly be small in any implementation of current dumping. Given the tolerances of the other terms it will scarcely be possible to take it into account. Then objections would apply unaltered to any alternative dumping circuit.

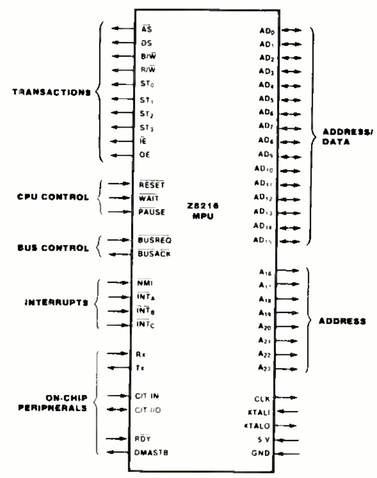
Part 1. On page 43 of the September article, the lower Z_4 in equation 5 should read Z_1. WW

The new Z80

Coinciding with the introduction of the 32-bit Z80000 mid next year Zilog plan to introduce the Z800 8/16-bit family of processors with Z80 software compatibility. With clock rates of up to 25MHz (preliminary information) and memory manipulation features, these devices will also make full use of current high-speed rams and, besides providing a stop-gap for the eight-to-sixteen bit transition, the family will act as input/output processors for the 16-bit Z8000. There are four devices: two with a 16-bit data bus, the Z8116 and 8216; and two with eight bits, the Z8108 and 8208. The 82 versions are physically larger than the other two i.cs and have four direct-memory access channels and built-in uart: all of the i.cs have four 16-bit counter timers.

The new processors have an integral memory-management unit that allows them to access either 512K-bytes or 16M-bytes, depending on the type, and they have 256 bytes of memory which, when configured as a 'cache', may be programmed to contain either instructions or data, or both. This speeds up program execution by reducing the number of external bus accesses. Operation and updating of the cache is automatic.

Although the instruction set will be expanded and augmented, all Z80 instructions are compatible with binary. Basic addressing modes of the Z80 will be augmented with the addition of a base-index mode and 16-bit displacements for indexed, program-counter-relative and stack-pointer-relative modes. These new addressing modes are incorporated into many of the old Z80 instructions. Additions to the instruction set include 8/16-bit signed and unsigned multiply and divide, 8/16-bit sign extension, and a test-and-set instruction for use in multi-processor applications. Sixteen-bit instructions include compare, memory increment/decrement, negate, add, and subtract.



Largest of the Z800 family, the 16-bit 8216, with Z80 instruction compatibility. Of the four devices, the two eigth-bit versions are compatible with the Z80 bus and the two 16-bit versions are designed for use with the 16-bit Z-Bus.

WW314 for further information

Rapid-update digital ratemeter

The normal method of digital frequency measurement is slow and inaccurate at very low frequencies, such as those encountered in medical research. This design enables pulse rate to be determined after only two heart beats.

by P. D. Coleridge Smith*
MA FRCS

It is often necessary to measure the heart rate of subjects undergoing intermittent exercise. When equipment for such application is to be used outdoors, it is essential that it should be robust, consume little power, be accurate to within 1% and indicate heart-beat between 40-240 beats per minute.

The need for robustness ruled out the use of a moving-coil meter: low power requirements and the need for legibility in daylight dictated the choice of a liquid-crystal display.

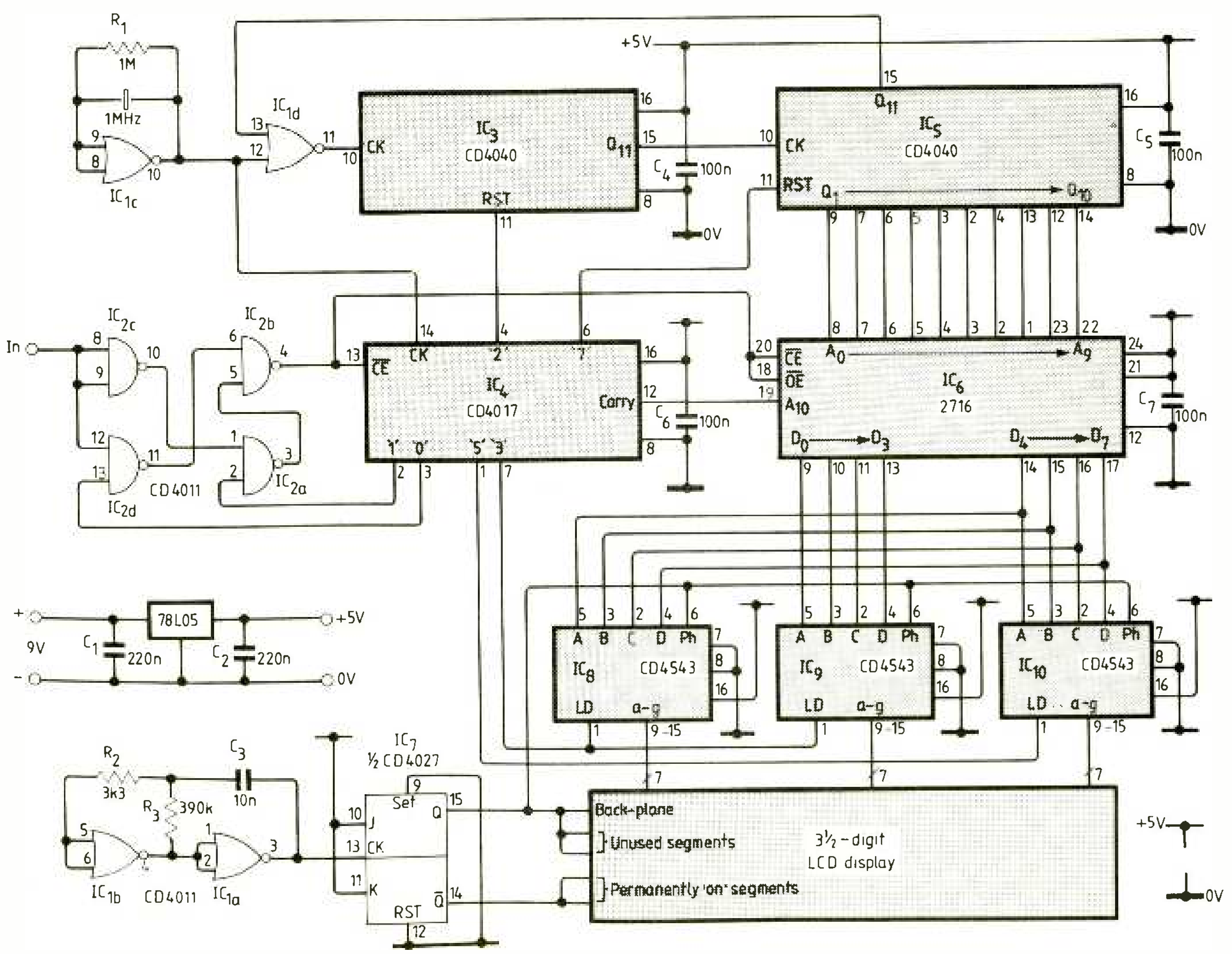
Rate conversion itself necessitated careful consideration. Rapid settling following switch-on and frequency change was required, since the subjects of the study were connected to the equipment immediately following exercise. An 'instant' indication of heart rate was essential and the meter had to be capable of closely following the change in rate.

A variety of analogue solutions were considered, from diode-pump ratemeters to analogue inverse-function generators. The simpler solutions would have taken too long to respond, the more complex suffered drift and difficult setting-up procedures. All, of course, would have required digital conversion before display.

These problems led to the final, all-digital design, in which a 10 bit binary counter measures the period between input pulses. An eprom uses the count as its address input, and contains a look-up table of rates at each of the 1024 points of the 10 bit counter, the data derived from the eprom being latched into display decoder/drivers: the circuit includes under- and overflow indication as well as leading-zero suppression. The instrument gives an accurate

*Academic Department of Surgery, Royal Free Hospital, London NW3.

Fig. 1. Circuit diagram of complete ratemeter. Layout on stripboard is not critical.



Hexadecimal dump of eprom contents. This table also includes values for addresses where n<100, for development purposes. These may be altered as suggested in the text to indicate meter "overflow" if required.

000	0F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F
010	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	7F	5F
020	6F	8F	2F	7F	4F	2F	1F	1F	2F	5F	8F	1F	6F	1F	7F	3F
030	0F	8F	6F	4F	3F	3F	3F	3F	3F	4F	5F	7F	8F	0F	3F	5F
040	6F	1F	4F	7F	1F	5F	9F	3F	7F	1F	6F	1F	5F	0F	6F	1F
050	6F	2F	7F	3F	9F	5F	1F	7F	3F	9F	6F	2F	8F	5F	2F	8F
060	5F	2F	9F	6F	3F	0F	7F	4F	2F	9F	6F	4F	1F	9F	6F	4F
070	2F	9F	7F	5F	3F	0F	8F	6F	4F	2F	0F	8F	6F	4F	3F	1F
080	9F	7F	5F	4F	2F	0F	9F	7F	5F	4F	2F	1F	9F	8F	6F	5F
090	3F	2F	1F	9F	8F	7F	5F	4F	3F	1F	0F	9F	8F	7F	5F	4F
0A0	3F	2F	1F	0F	9F	8F	6F	5F	4F	3F	2F	1F	0F	9F	8F	7F
0B0	6F	6F	5F	4F	3F	2F	1F	0F	9F	8F	8F	7F	6F	5F	4F	3F
0C0	3F	2F	1F	0F	9F	9F	8F	7F	6F	6F	5F	4F	4F	3F	2F	2F
0D0	1F	0F	0F	9F	8F	8F	7F	6F	6F	5F	4F	4F	3F	3F	2F	1F
0E0	1F	0F	0F	9F	8F	8F	7F	7F	6F	6F	5F	5F	4F	4F	3F	3F
0F0	2F	2F	1F	1F	0F	0F	9F	9F	8F	8F	7F	7F	6F	6F	5F	5F
100	4F	4F	4F	3F	3F	2F	2F	1F	1F	1F	0F	0F	9F	9F	9F	8F
110	8F	7F	7F	7F	6F	6F	5F	5F	5F	4F	4F	4F	3F	3F	2F	2F
120	2F	1F	1F	1F	0F	0F	0F	9F	9F	9F	8F	8F	8F	7F	7F	7F
130	6F	6F	6F	5F	5F	5F	5F	4F	4F	4F	3F	3F	3F	2F	2F	2F
140	2F	1F	1F	1F	0F	0F	0F	0F	9F	9F	9F	9F	8F	8F	8F	7F
150	7F	7F	7F	6F	6F	6F	6F	5F	5F	5F	5F	4F	4F	4F	4F	3F
160	3F	3F	3F	3F	2F	2F	2F	2F	1F	1F	1F	1F	0F	0F	0F	0F
170	0F	9F	9F	9F	9F	9F	8F	8F	8F	8F	8F	7F	7F	7F	7F	6F
180	6F	6F	6F	6F	6F	5F	5F	5F	5F	5F	4F	4F	4F	4F	4F	3F
190	3F	3F	3F	3F	3F	2F	2F	2F	2F	2F	1F	1F	1F	1F	1F	1F
1A0	0F	0F	0F	0F	0F	0F	9F	9F	9F	9F	9F	9F	8F	8F	8F	8F
1B0	8F	8F	8F	7F	7F	7F	7F	7F	7F	6F	6F	6F	6F	6F	6F	6F
1C0	5F	5F	5F	5F	5F	5F	5F	4F	4F	4F	4F	4F	4F	4F	3F	3F
1D0	3F	3F	3F	3F	3F	2F	2F	2F	2F	2F	2F	2F	2F	1F	1F	1F
1E0	1F	1F	1F	1F	1F	0F	0F	0F	0F	0F	0F	0F	0F	9F	9F	9F
1F0	9F	9F	9F	9F	9F	8F	8F	8F	8F	8F	8F	8F	8F	8F	7F	7F
200	7F	7F	7F	7F	7F	7F	7F	6F	6F	6F	6F	6F	6F	6F	6F	6F
210	5F	5F	5F	5F	5F	5F	5F	5F	5F	5F	4F	4F	4F	4F	4F	4F
220	4F	4F	4F	4F	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F	2F
230	2F	2F	2F	2F	2F	2F	2F	2F	2F	1F	1F	1F	1F	1F	1F	1F
240	1F	1F	1F	1F	1F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F
250	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	8F	8F	8F
260	8F	8F	8F	8F	8F	8F	8F	8F	8F	7F	7F	7F	7F	7F	7F	7F
270	7F	7F	7F	7F	7F	7F	7F	6F	6F	6F	6F	6F	6F	6F	6F	6F
280	6F	6F	6F	6F	5F	5F	5F	5F	5F	5F	5F	5F	5F	5F	5F	5F
290	5F	5F	5F	4F	4F	4F	4F	4F	4F	4F	4F	4F	4F	4F	4F	4F
2A0	4F	4F	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F
2B0	3F	3F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F
2C0	2F	2F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F
2D0	1F	1F	1F	1F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F
2E0	0F	0F	0F	0F	0F	0F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F
2F0	9F	9F	9F	9F	9F	9F	9F	9F	9F	8F	8F	8F	8F	8F	8F	8F
300	8F	8F	8F	8F	8F	8F	8F	8F	8F	8F	8F	8F	8F	8F	7F	7F
310	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F	7F
320	7F	7F	7F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F
330	6F	6F	6F	6F	6F	6F	6F	6F	6F	6F	5F	5F	5F	5F	5F	5F
340	5F	5F	5F	5F	5F	5F	5F	5F	5F	5F	5F	5F	5F	5F	5F	5F
350	5F	5F	4F	4F	4F	4F	4F	4F	4F	4F	4F	4F	4F	4F	4F	4F
360	4F	4F	4F	4F	4F	4F	4F	4F	4F	4F	4F	3F	3F	3F	3F	3F
370	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F	3F
380	3F	3F	3F	3F	3F	3F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F
390	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F	2F
3A0	2F	2F	2F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F
3B0	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F	1F
3C0	1F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F
3D0	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F	0F
3E0	0F	0F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F
3F0	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F	9F
400	00	99	99	99	99	99	99	99	99	99	99	99	99	99	99	99
410	99	99	99	99	99	99	99	99	99	99	99	99	99	99	97	94
420	91	88	86	83	81	79	77	75	73	71	69	68	66	65	63	62
430	61	59	58	57	56	55	54	53	52	51	50	49	48	48	47	46
440	45	45	44	43	43	42	41	41	40	40	39	39	38	38	37	37
450	36	36	35	35	34	34	34	33	33	32	32	32	31	31	31	30
460	30	30	29	29	29	29	28	28	28	27	27	27	27	26	26	26
470	26	25	25	25	25	25	24	24	24	24	24	23	23	23	23	23
480	22	22	22	22	22	22	21	21	21	21	21	21	20	20	20	20
490	20	20	20	19	19	19	19	19	19	19	19	18	18	18	18	18
4A0	18	18	18	18	17	17	17	17	17	17	17	17	17	16	16	16
4B0	16	16	16	16	16	16	16	16	15	15	15	15	15	15	15	15
4C0	15	15	15	15	14	14	14	14	14	14	14	14	14	14	14	14
4D0	14	14	14	13	13	13	13	13	13	13	13	13	13	13	13	13
4E0	13	13	13	12	12	12	12	12	12	12	12	12	12	12	12	12
4F0	12	12	12	12	12	12	11	11	11	11	11	11	11	11	11	11
500	11	11	11	11	11	11	11	11	11	11	11	11	10	10	10	10
510	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
520	10	10	10	10	10	10	10	F9	F9	F9	F9	F9	F9	F9	F9	F9
530	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9	F9
540	F9	F9	F9	F9	F9	F9	F9	F9	F8	F8	F8	F8	F8	F8	F8	F8
550	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8
560	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8	F8
570	F8	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
580	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
590	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7	F7
5A0	F7	F7	F7	F7	F7	F7	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6
5B0	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6
5C0	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6
5D0	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6
5E0	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F6	F5	F5	F5
5F0	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5
600	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5
610	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5
620	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5
630	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5
640	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5	F5
650	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4
660	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4
670	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4
680	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4
690	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4
6A0	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4
6B0	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4
6C0	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4
6D0	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4	F4
6E0	F4	F4	F4	F4	F4	F4	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
6F0	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
700	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
710	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
720	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
730	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
740	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
750	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
760	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
770	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
780	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
790	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
7A0	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
7B0	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
7C0	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
7D0	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3	F3
7E0	F3	F3	F2	F2	F2	F2	F2	F2	F2	F2	F2	F2	F2	F2	F2	F2
7F0	F2	F2	F2	F2	F2	F2	F2	F2	F2	F2	F2	F2	F2	F2	F2	F2

indication of rate after the arrival of only two input pulses and correctly updates it after each subsequent pulse. It can be used in any application where the frequency of the input signal is 500Hz or less, and is well suited to use below 5Hz where other techniques involve excessive integration periods.

The low-level signal amplification and pulse extraction are achieved conventionally, using a high input-impedance differential amplifier to extract the subject's electrocardiogram voltages – of the order of 1-2mV peak – peak, which is subsequently converted to c.m.o.s. levels for connection to the ratemeter.

Circuit description

$IC_{1(c)}$ forms a 1MHz crystal oscillator, which is divided by 2048 in IC_3, resulting in an output of 488.28Hz to IC_5. These counters are controlled by IC_2 and IC_4, a decoded decade counter.

When the ratemeter input (pins 8, 9 and 12 of IC_2) is low, IC_4 counts up until the decoded '1' output goes high. $IC_{2(b)}$ then applies a high level to the clock-enable input of IC_4 and further counting ceases, whereupon a high level at the input again enables counting, with outputs 2 to 9 being taken high in sequence. The low level at IC_4 clock-enable also enables the 2716 eprom.

Output '2' from IC_4 resets IC_3, preventing any change in the count of IC_5 during the look-up procedure. This ripple counter, IC_5, provides the address for IC_6, which holds the rate data in a look-up table.

Output '3' latches the high-order data from IC_6 into display driver/latches $IC_{8,9}$. The carry output of IC_4 then goes low, selecting the lower half of the look-up table in IC_6, the data from which is latched by the '5' output into IC_{10}.

Output '7' then resets IC_5 ready for the next measurement cycle, the count output of IC_4 remaining at '0' until the input goes low again.

$IC_{1a,1b}$ and half of IC_7 provide a precise 1:1 duty cycle square-wave drive for the l.c.d. driver i.cs and display. A 3½ digit device has been used for convenience, with unused segments tied to the back-plane.

The entire look-up cycle takes place at a 1MHz clock rate, and is therefore complete in less than 9μs.

Should the interval between successive positive input transitions exceed that taken to count through the first ten stages of IC_5, output Q_{11} of IC_5 will go high. This inhibits further clock pulses to the counter chain via $IC_{1(d)}$ and stops the eprom address from IC_5 at zero. This location (0) in eprom contains a range underflow indi-

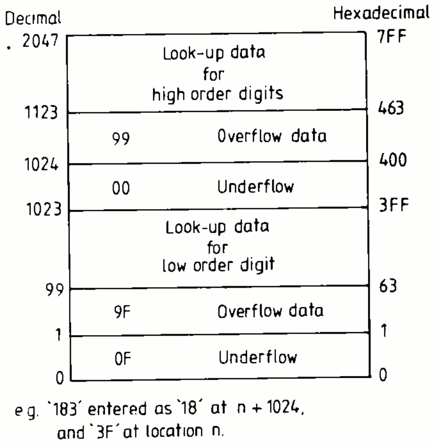


Fig. 2. Memory map of 2716 eprom.

cator – "000" in my original design.

The data in the eprom is derived from the simple formula:

$$\text{rate} = 60f_i/n \text{ (pulses per minute)}$$

where f_i is the input frequency to IC_5, 488.28 Hz in the diagram shown, and n is the eprom address in the range 0-1023. The rate for each of the memory locations was calculated and rounded to an integral number before being programmed using a microprocessor-based system. For locations with $n<100$, the entry was replaced with '999' to indicate meter overflow, since the accuracy in this address range does not fulfil design criteria.

The high-order digits are stored in the upper half of the eprom memory range in b.c.d. form, that is from 1024-2047 (decimal), while low-order digit data is located in the upper half of each byte from address 0-1023. The remaining half byte in each of these locations is not used in this application. Leading-zero blanking is accomplished by substituting a non-b.c.d. value (0-F hexadecimal) in place of the relevant zero. The CD 4543 responds to this code by blanking the digit concerned. Figure 2 is the complete memory map for the eprom.

Power is derived from a 9 volt battery via a 78L05 supply regulator to ensure that the rail requirements of the 2716 are not exceeded. The entire circuit consumes about 30mA, of which the eprom accounts for the greatest part.

Construction

The layout is non-critical and the prototype was constructed on Veroboard.

Setting-up is not required, since the clock runs within 0.1% of 1MHz without adjustment. The display oscillator should provide a final-drive frequency within the range 30-100Hz on pin 15 of IC_7 for optimum performance, and this again usually requires no adjustment.

Additional ranges

For an indication in Hertz, merely reprogram the eprom. Alternative frequency ranges can be accommodated by selecting the appropriate output from IC_3 to give a minimum of 100 counts in IC_5 at the high end of the frequency range (for 1% accuracy), bearing in mind that the meter will "underflow" after 1023 counts at IC_5. The required data for the eprom is easily calculated from the formula given above.

The remaining half of IC_7 can be used to divide the input signal by two, thus updating the display on alternate positive input transitions. The output from IC_3 must then be taken from Q_{12}, not Q_{11}, to ensure that the correct frequency is displayed. This is useful if the input frequency is slightly irregular and averaging over two consecutive periods is required.

WW

BOOKS

Electronic Prototype Construction by Stephen D. Kasten, 398 pages. Prentice/Hall International, £15.25, soft covers. How to lay out and manufacture your own p.c.bs.

Mastering Electronics by John Watson, 382 pages. Macmillan, £10.00 hard cover. Electronics for the beginner – from basic physics to radio, tv and computing.

Learning Timex Sinclair Basic by David A. Lien, 331 pages. Compusoft Publishing, 535 Broadway, El Cajon, California 92021, USA, $14.95, soft cover. For ZX81 owners.

Learning IBM Basic by David A. Lien, 421 pages. Compusoft Publishing, $19.95, soft cover. For the IBM personal computer.

Science and Engineering Sourcebook by Cass Lewart, 96 pages. Prentice/Hall International, £8.45, paper cover. Scientific and engineering programs for the Sharp PC1211 and TRS-80 pocket computers.

Beginner's Guide to Computers by T. F. Fry, second edition. Newnes, 186 pages, £4.35, soft cover. Introduction to computers, both great and small, and their uses.

What do you do after you plug it in? by William Barden jr, 198 pages. Prentice/Hall International, £9.30, paperback. Chatty guide for newcomers to the microcomputer.

The World Connection by Timothy Orr Knight, 142 pages. Prentice/Hall International, £8.45, soft covers. The romance of the micro, by a 16-year-old enthusiast.

Using 6502 Assembly Language by Randy Hyde. Prentice/Hall International, £16.95, paper cover. Aimed mairily at Apple II users.

iAPX 88 Book by staff of the Intel Corporation, 80 pages. Prentice/Hall International, £11.00, paper cover. All about the Intel 8088 8-bit microprocessor.

Microprocessors and Digital Systems by Douglas V. Hall, second edition, 464 pages. McGraw-Hill, £19.00, hard cover. Comprehensive guide for the technician.

Security Electroncis by John E. Cunningham, third edition, 255 pages. Prentice/Hall International, £11.85, paper cover. Techniques for keeping intruders out of cars, property and computers.

Basic Electrical Installations by Michael Neidle, third edition, 79 pages. Macmillan, £3.95, soft cover.

Electrical Installations and Regulations by Michael Neidle, third edition, 99 pages, Macmillan, £4.95, soft cover.

Electrical Installation by A. O. Akintante and J. M. Hyde, 146 pages. Macmillan Introduction to Technology Series, Macmillan, £3.25, soft cover.

IC Timer Cookbook by Walter G. Jung, second edition, 384 pages. Prentice/Hall International, £15.25, soft cover. Everything there is to know about the 555 and its cousins.

A Z80 Workshop Manual by E. A. Parr, 184 pages. Bernard Babani, £2.75, soft cover. Assembly language and machine code for the ZX81, Spectrum, Nascom, TRS80 etc.

Easy Add-on Projects for Spectrum, ZX81 & Ace by Owen Bishop, 182 pages. Babani, £2.75, soft cover. 17 projects including a light-pen, a model railway controller and an anemometer, with software suggestions in Basic and Forth.

Video User's Handbook by Peter Utz, second edition, 500 pages. Prentice/Hall International, £11.95, soft cover. Production methods and tv techricalities for community tv people.

Computer Communication Techniques by E. G. Brooner and Phil Wells, 142 pages. Prentice/Hall International, £13.55, soft cover. Details of the various interface standards and protocols, plus an outline of public data systems, computer networks and packet radio.

Radio and Television Servicing, 1982-83 models edited by R. N. Wainwright, 767 pages. Macdonald, £22.50, hard cover. Circuit diagrams and servicing hints for a wide range of British and foreign sets.

SPSSX User.s Guide (SPSS inc.), 806 pages. McGraw-Hill, £24.25, soft covers. Mammoth guide to the SPSSX computer language and its uses.

Microelectronics: practical approaches for schools & colleges edited by Graham Bevis and Mike Trotter, 94 A4-size pages plus two small wall-charts doubling as overhead projection transparencies. BP Educational Service, with the Microelectronics Education Programme and BBC Schools Radio, £2.75, soft cover. Lots of things to do, andhow to do them; great fun for beginners young or old.

Microcomputer companiesin the UK (eurolec 58) edited by John Beaven, 370 pages, soft cover. £32 plus £2 post and ,acking from Eurolec, 6 Woodbury Lane, Clifton, Bristol BS8 2SD. Guide to more than 1700 micro hardware and software suppliers.

A user guide to the UNIX system by Rebecca Thomas and Jean Yates, 510 pages. McGraw-Hill, £12.95, soft cover. At-the-keyboard tutorial course for users of this computer operating system, widely used on machines from mainframes to micros.

IBM Personal Computer Technical Reference Manual. International Business Machines, £31, loose-leaf with ring-binder. How the hardware works, for engineers and programmers. Includes circuit diagrams and operating system rom losting.

Microcomputer analysis of a ladder network

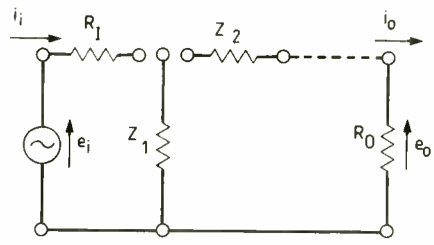
Flow diagrams enable a program for ladder network insertion loss and its delay equalization written for a ZX81 to be modified for other computers

by L. E. Weaver

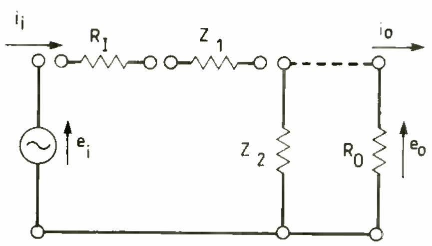
Since the publication of my article "Network analysis with a ZX81" in Wireless World (August and September 1982 issues) I have received appeals for help in adapting the program for micros other than the ZX81. Such a procedure is always full of well-concealed traps even when the dialect of Basic is nominally the same, and after many tedious hours at the v.d.u. I am convinced that in nearly every instance it pays handsomely to start by understanding how the program work, and then to rewrite it for one's own machine and in one's own way. This is all the more valid when the program was originally written for the ZX81, which has certain idiosyncracies.

What I have done, therefore, is to rewrite the program slightly in a form which is likely to be more generally acceptable to other micro-computers, while keeping the overall format the same to facilitate cross-referencing. The result is given in the form of a series of flow diagrams which point to the relevant lines in the original. As a further aid, these lines or sequences of lines are reproduced in an appendix.

First, a brief review of the method of analysis of the network and the development of the fundamental algorithm. Figs 1(a) and 1(b) show the two possible configurations, the first with shunt input and the last with series. We need to determine the ratio of the voltage across the output termination RI to that of the generator feeding the output termination RO, that is e_0/e_i, complex quantity, say $a+jb$. Then the insertion loss is $10\log_{10}(a^2+b^2)/4$, and the insertion phase shift $\beta=\arctan(b/a)$.



(a)



(b)

The starting point is the A-matrix for the input termination which, as it must always be considered to be in series, is

$$\begin{matrix} 1 & RI \\ 0 & 1 \end{matrix}$$

The A-matrix of the first reactance arm is then added by matrix multiplication, followed by all of the other arms in sequence. Finally, the output termination is added in shunt. The process can be generalized as follows.

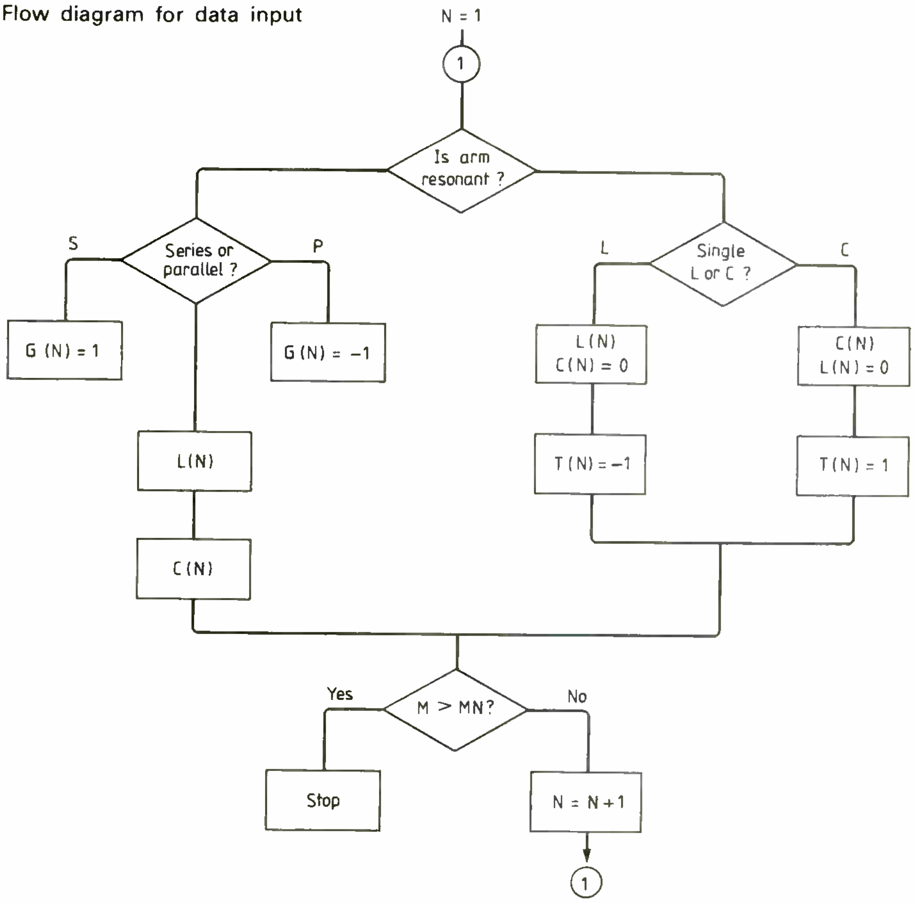
Stage 1: data input

The program can be conveniently divided into distinct stages, each with its own flow diagram. The first step is the input of the basic data, i.e.

- FO is starting frequency for the computation (MHz)
- FM is finishing frequency (MHz)
- DF is frequency step (MHz)
- D is dissipation constant
- FD is the frequency associated with D. Remember that D is a function both of the resistive component of a reactor and its reactance. Usually, FD is made the frequency of maximum D over the range of interest, also in MHz.
- RI is the value of the input termination (ohms)
- RO is the value of the output termination (ohms)
- the number of branches NM. These must be alternately series and shunt, or vice versa.

The next step is to input the reactance values into the arrays L(N) and C(N), where N is the number of the branch starting from the input. Each reactance arm is allowed one inductor and one capacitor, where either may be allocated the value zero. This is not a restriction on the applicability of the program. It was demonstrated back in the original article

Flow diagram for data input



(August 1982) that arms with three or more components can be dealt with by means of a simple device.

The method used should be clear from the flow diagram of Fig. 2. Each arm in succession is flagged by means of the arrays T(N) and G(N) to indicate unambiguously whether it contains a series resonant circuit, a parallel resonant circuit, an inductor only, or a capacitor only. Although it is not shown in Fig. 2, it is very disirable to STOP the program when all entries have been made, and GOTO a subroutine listing all inputs with the corresponding branch numbers. Without a check of this kind, errors are all too likely. If at some point in this process the matrix has become

$$\begin{matrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{matrix},$$

then after the addition of a series arm Z_s, this becomes

$$\begin{matrix} Z_{11} & Z_{12}+Z_s{\cdot}Z_{11} \\ Z_{21} & Z_{22}+Z_s{\cdot}Z_{21} \end{matrix},$$

and after the addition of a shunt arm Z_p

$$\begin{matrix} Z_{11}+Z_{12}/Z_p & Z_{12} \\ Z_{21}+Z_{22}/Z_p & Z_{22} \end{matrix}.$$

At the end, after the addition of the output termination, the matrix element $Z_{11}=e_0/e_i$ gives the insertion loss and phase. The element Z_{21} is not unimportant as it is the input impedance of the network as seen through the input termination RI. However, in the original program this was not required, so that the second row of the matrix does not enter into the computation and may therefore be ignored.

The final result is a pair of what must more correctly be called algorithms, although for the sake of convenience they will still be referred to as matrices:

$Z_{11}Z_{12}\rightarrow Z_{12}+Z_s{\cdot}Z_{11}$ addition of series arm Z_s

$Z_{11}Z_{12}\rightarrow Z_{11}+Z_{12}/Z_pZ_{12}$ addition of shunt arm Z_p

Each term can be a complex number so that an array of the form A(1,4) is required for the representation of the working matrix, where A(1,1)+jA(1,2) is used for Z_{11}, and A(1,3)+jA(1,4) for Z_{12}.

Stage 2: computation of loss and delay

This part of the program has been modified slightly from the original to make it more transportable, although the general format and the line numbering have been left unchanged to facilitate cross-referencing. The flow diagram is given in Fig. 3; bracketed numbers against the boxes are the relevant line numbers. For the sake of those without access to the September 1982 issue these program segments are provided in the Appendix, again with minimum changes. Any changes needed for a particular machine or dialect of Basic should be fairly evident.

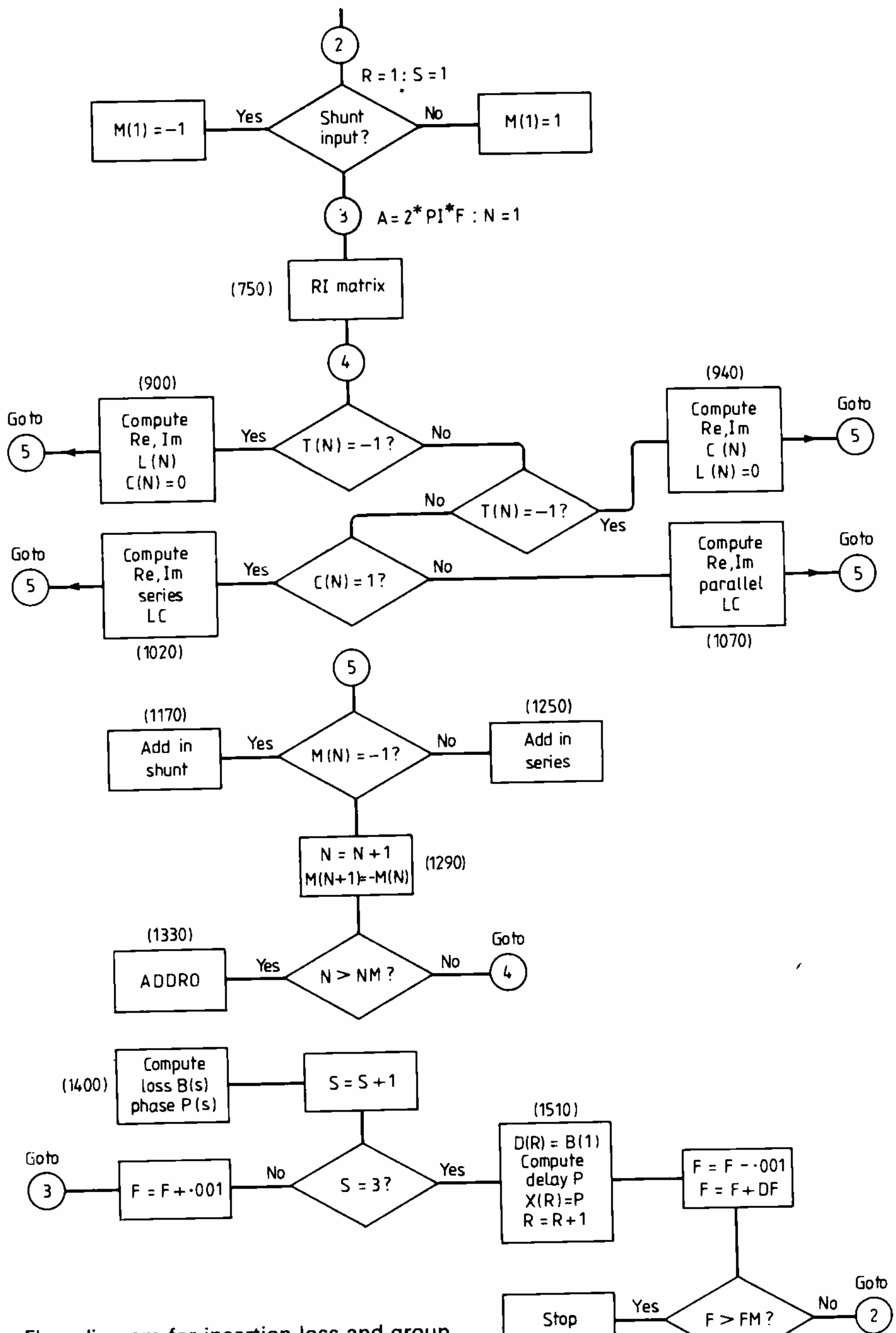
One vital piece of information is required before computation can start, that is whether the first arm of the ladder is in series or shunt. This input sets the first element of the M(N) array to −1 or +1 respectively. Execution can then proceed to the setting up of the initial matrix, that corresponding to the input termination RI. Because the 'matrix' is now only a single row, array A(1,4) suffices. At the same time, the arm number N is set to 1.

The arrays of flags T(N) and G(N) are then interrogated to determine the type of reactance arm, the real part Re and the imaginary part Im of which are then determined by the appropriate program segment. These are next combined with the matrix A(1,4) either as series or shunt impedances as directed by the array M(N). At the end of each pass N is incremented by 1 and the sign of M(N+1) is inverted compared with M(N), thus maintaining the alternating sequence of series and

Passive networks are alive and well . . .

In spite of some predictions, passive networks are still in wide-spread use, especially in the form of video low-pass filters. Their performance is defined in terms of the change in the transmission of a circuit having a definable impedance when opened and the filter inserted; the relevant parameters are insertion loss and group delay. To improve the transient response it is usually necessary to add constant-resistance delay correction sections which ideally improve the group delay characteristic without modifying the loss.

In the August and September issues, a program showed how to compute all of this on a simple domestic microcomputer. The basis was a matrix addition of the successive ladder impedances, which reduced to a simple algorithm. Dissipation could easily be taken into account. This program has been slightly modified and presented again in a more generalized form to enable readers to adapt it to individual needs.



Flow diagram for insertion loss and group delay shunt arms. This is an in-place calculation, so that as soon as N=N+1, the loss and tanβ may be computed from A(1,1) and A(1,2). However, the last-mentioned does not provide the group delay, which is defined as dβ/dω, where the d's represent infinitesimally small increments in β and $\omega=2\pi F$. Although there are a few networks whose group delay can be calculated directly, the best one can do in the general case is to add a small increment to F and recalculate β. In the present instance this was chosen to be 0.001, although even smaller values are possible depending upon the quality of the arithmetic of the micro.

The two values for tanβ are held in the arrays P(1) and ((2), hence tan Δβ can be computed from the familiar trigonometrical relation tan Δβ=(P(2) – P(1))/(1+P(1).P(2). In fact, there is no need to take the arctan of this expression to obtain Δβ: with video filters the incremental angle in radians is so small as to be equal to its tangent to a high degree of accuracy. For example, suppose the group delay is 1μs, a likely value for a video filter. Then one can see by inspection that the angle will be about 0.006rad. The second term in the expansion of tanΔβ is $(0.006)^3/3$, the first being Δβ, so the error is evidently completely negible. The group delay in μs is then Δβ/(.002I). These computed values are stored in the array X(R) for use in Stage 3 of the program.

As the variable S is incremented by 1 with each pass, S=3 indicates that the computation of the group delay has been terminated. At this point, 0.001 is subtracted from F and DF added to it, and the whole process is repeated for the new frequency unless F is found to be greater than FM, when the program is stopped. This allows the computed values to be listed, printed, or displayed as required.

One special point – the imaginary part of a capacitative impedance contains F in the denominator, so an error will be shown unless measures are taken. The simplest precaution is to replace F=0 by some very small quantity initially, and then to restore F=0 at the end of the relevant computation. This may be 1E–6, or even less depending upon the micro, so no practical error is involved. The published program used a more complex method where division by zero is avoided at each step where it could occur, but the suggested alternative is just as effective. It is not shown in the flow diagram of Fig. 3 for the sake of clarity.

Appendix: Essential Program Segments

```
750   LET A(1,3) = RI                      (initial matrix)
760   LET A(1,1) = 1
770   LET A(1,2) = 0
780   LET A(1,4) = 0

900   REM L ONLY
910   LET RE = FD*L(N)*D/2
920   LET IM = L(N)*A

940   REM C ONLY
960   LET RE = D/(2*FD*C(N))
970   LET IM = -1/(A*C(N))

1020  REM SERIES LC
1030  LET H = SQR(1/(L(N)*C(N))
1040  LET X = A/H
1055  LET RE = H*D*L(N)
1060  LET IM = H*L(N)*(X-1/X)

1070  REM PARALLEL LC
1080  LET H = SQR(1/(L(N)*C(N))
1090  LET X = A/H
1110  LET J = (X-1/X)*(X-1/X) +D*D
1120  LET L1 = H*L(N)
1130  LET RE = L1*D/J
1140  LET IM = -L1*(X-1/X)/J

1170  LET DE = RE*RE + IM*IM              (addition of shunt arm)
1180  LET A(1,1) = A(1,1) + (A(1,3)*RE + A(1,4)*IM)/DE
1190  LET A(1,2) = A(1,2) +(A(1,4)*RE - A(1,3)*IM)/DE

1250  LET A(1,3) = A(1,3) + A(1,1)*RE - A(1,2)*IM   (add series arm)
1260  LET A(1,4) = A(1,4) + A(1,1)*IM + A(1,2)*RE

1330  LET A(1,1) = A(1,1) + A(1,3)/RO       (addition of RO)
1340  LET A(1,4) = A(1,2) + A(1,4)/RO

1400  LET LO = A(1,1)*A(1,1) + A(1,2)*A(1,2)   (insertion loss
1410  LET B(S) = 10*LOG(LO/4)/LOG(10)              computation)
1420  LET P(S) = A(1,2)/A(1,1)                 ( tan β )

1510  LET X(R) = ((P(2)-S(1))/(1+P(1).P(2))/(.002*PI)   ( d β/dω )
1840  LET T = F/F(M)                      (1st order equaliser sections)
1850  LET S = PI*F(M)*(1+T*T)
1860  LET Z(R) = Z(R) + 1/S

1880  LET T = F/F(M)
1890  LET U = (1-T*T)*(1-T*T)
1900  LET S : (1+T*T)*K(M)/(U+K(M)*K(M)*T*T)
1910  LET Z(R) = Z(R) + S/(PI*F(M))
1920  LET M = M +1

2100  FOR R = 1 TO 15                     (add loss from dissipation in
2110  LET L = 17.37*PI*F*(Z(R)-X(R))*D       delay equaliser)
2120  LET D(R) = D(R) + L
2130  (output D(R) as required)
2140  NEXT R
```

Stage 3: group delay equalization

Group delay equalization is carried out by means of constant-resistance equalisers, used as a combination of first and second-order sections. Although higher orders exist, they are rarely used because of their complexity and difficulty of adjustment. In any case, all possible characteristics are feasible with only first and second orders.

First-order sections are defined by a single resonant frequency only, whereas second-order types require a shape factor K in addition to the resonant frequency FR. During the initial data entry it is convenient to make K=0 for a first-order section, providing an automatic indicator of the type of section. The only other input needed is the total number of sections V. Because of alignment problems, it is advisable to use not more than four unless unavoidable.

In the flow diagram in Fig. 4 the variable M is used as a counter, and as FR and K are entered they are stored in the arrays F(M) and K(M) respectively. Then the already-computed group delay values for the filter in Z(R) are copied into the array Z(R). The reason for this becomes evident later. A maximum of 15 frequencies is assumed, but this number is convenient rather than significant, and can readily be changed.

The next step is to calculate the group delay of each section in turn for the frequency F and to add it to the value held in Z(R). This is repeated for all frequencies up to the limit chosen of FM. But for equalization the deviations from flatness are easier to deal with if the output has the form of the equalized delay with the zero-frequency value subtracted, that is Z(R)–Z(1). This last quantity is also important and should be made available.

The program is stopped at this point for inspection of the results. Revised figures for K(M) and F(M) can then be entered, and as the original filter delay is still held intact in array Z(R), the process can quickly be repeated.

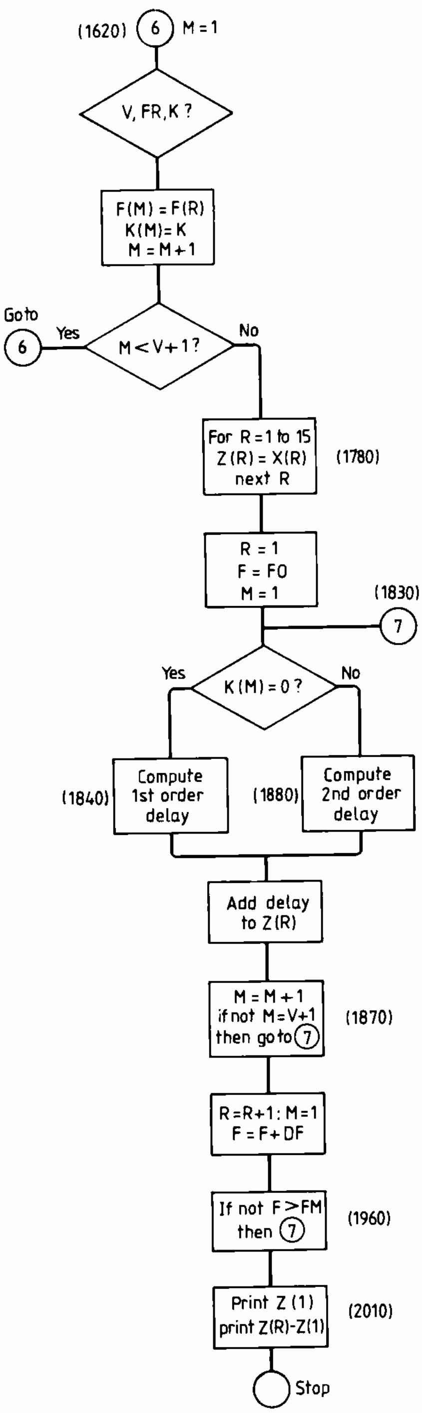
The question then remains of the dissipation of the delay equalizer, often far from negligible, and gives rise to undesirable undulations in the pass band loss characteristic of the filter. Provided D is not too large, say not greater than 0.02, Mayer's theorem is capable of furnishing a very good approximation to the variations due to the equaliser dissipation, and leads to a very simple subroutine (line 2100). The published program gives the actual variations, but by adding another line just after line 1410 to hold the insertion loss figures B(I) in a new array D(R), it is simple to provide the sum of the two, that is the filter loss plus the delay equalizer dissipation loss.

NewBrain modification

To provide some check on the portability of the program, it was typed into a NewBrain AD with only minor modifications, such as the omission of all LET commands and GOTO's in conditional statements. The general format, and the line numbering were deliberately left intact. A useful feature of this micro is the ability to choose the dimension base of arrays to be unity, as in the ZX81, or zero as in many other machines, so there was no need to change any array dimensions as the program was entered.

The results were very satisfactory. The speed of the program was very noticeably increased, and the accuracy was estimated to be at least an order of magnitude better. In addition, the high-resolution graphics were a valuable aid. The program could obviously be improved still further by re-writing it specifically for this particular computer. In general, this is the approach recommended to anyone wishing to use this method of network analysis. Even the flow diagram is not sacrosanct, and once the general principles have been grasped it may prove advantageous to modify it to suit one's own circumstances. WW

Flow diagram for delay equalization



LITERATURE RECEIVED

Flat cables and i.d.c. connectors along with suitable accessories and tools all constitute part of the Scotchflex system described in a 32-page brochure which also gives details of a breadboarding system for the rapid production of prototyping circuits. Copies are available from Carolyn Morris, Electronics Products Group, 3M United Kingdom Plc, PO Box 1, Bracknell, Berks RG12 1JU.
WW 401

Cable identification products, including cable sleeves and markers, tools to fit them, cable ties and heat-shrink tools are all described in a catalogue from Siegrist-Orel Ltd, Hornet Close, Pysons Road Industrial Estate, Broadstairs, Kent CT10 2LQ.
WW 402

A six-page fold-out brochure gives full technical information on an 'advanced' carrier frequency instrumentation amplifier which may be used with a variety of bridge transducers. It features an automatic system to balance the bridge in amplitude and phase. Once balanced, the amplifier may be locked by touching a switch. The balance values are automatically stored. The 5kHz carrier frequency allows measurements up to 2000Hz. The KWS 83 brochure is available from Hottinger Baldwin Messtechnik, Howard House, The Runway, Ruislip, Middlesex HA4 6TH.
WW 403

Advance product information has been received on the Ferranti ZN440/ZN441 video a-to-d converters. ZN440 has a 16MHz sample rate and the converters may be stacked so that the initial 6-bit resolution may be expanded to 7 or 8 bits. The ZN441 has a 10MHz sample rate. Applications include high-speed data acquisition, video and radar data conversion, digital signal storage and image processing. Ferranti Electronics Ltd, Fields New Road, Chadderton, Oldham OL9 8NP.
WW 404

A wide range of DIN two-piece p.c.b. connectors are detailed in a 26-page catalogue of the 100/101 range from Panduit Ltd, Lordswood Industrial Estate, 61-65 Revenge Road, Chatham, Kent ME5 8YT.
WW 405

British Standard 4727 is, or will be when it's complete, a glossary of electrotechnical, power telecommunications and electronics, lighting and colour terms. Group 01 of Part 1 gives the fundamental terminology of those terms common to power, telecommunications and electronics. In effect it is a useful dictionary of units, effects and functions. BSI, 2 Park Street, London W1A BS.

The components catalogue of Ambit International seems to grow bigger each time it is issued. The latest version is in two forms: an industrial version available free to bona fide professional customers, and the consumer/enthusiasts edition available through newsagents at 80p. All items are described and priced and there is the Rewtel system for ordering goods via a computer link-up. Ambit International, 200 North Service Road, Brentwood, Essex CM14 4SG.
WW 407

The services of C & S Antennas, who design and make broadcasting and specialised antennae, are described in a glossy brochure. Their extensive R & D facilities enable them to offer aerials for almost any application. C & S Antennas Ltd, Knight Road, Strood, Rochester, Kent ME2 2AX.
WW 408

Computer peripheral equipment, including cartridge tape drives and storage systems, tape communications terminals and printers is described in the catalogue of Quantex equipment. Details are also given of the Diabolo-compatible user-programmable impact printer, Model 7040; and a Model 410 high-density cartridge tape streamer and Winchester back-up system. The catalogue comes from Euro Electronics Ltd, Twyman House, 31 Camden Road, London NW1 1YE.
WW 409

A colourful wallchart provides full technical specification of the Sharp range of l.e.ds and l.c.d. devices. Some 42 types are described with type number, colour, lens (shape and type), luminous intensity, viewing angle, current requirement and package outline. The chart is available from Impectron Ltd, Foundry Lane, Horsham, W. Sussex RH13 5PX.
WW 410

Until recently the design of l.s.i. circuits has been the exclusive province of the large semiconductor manufacturers. Now i.cs can be designed by equipment engineers and to help this happen MEDL has produced a design guide, *Designing on Silicon with MEDL*. This 58-page publication introduces the subject, guides an engineer through the various stages and lists the library of gate array cells and other building blocks available. Marconi Electronic Devices Ltd, Doddington Road, Lincoln LN6 0LF.
WW 411

More on p.56

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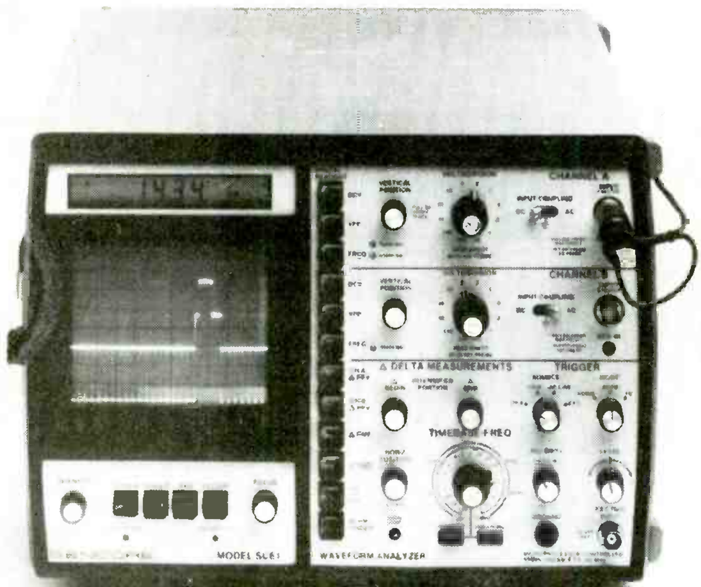

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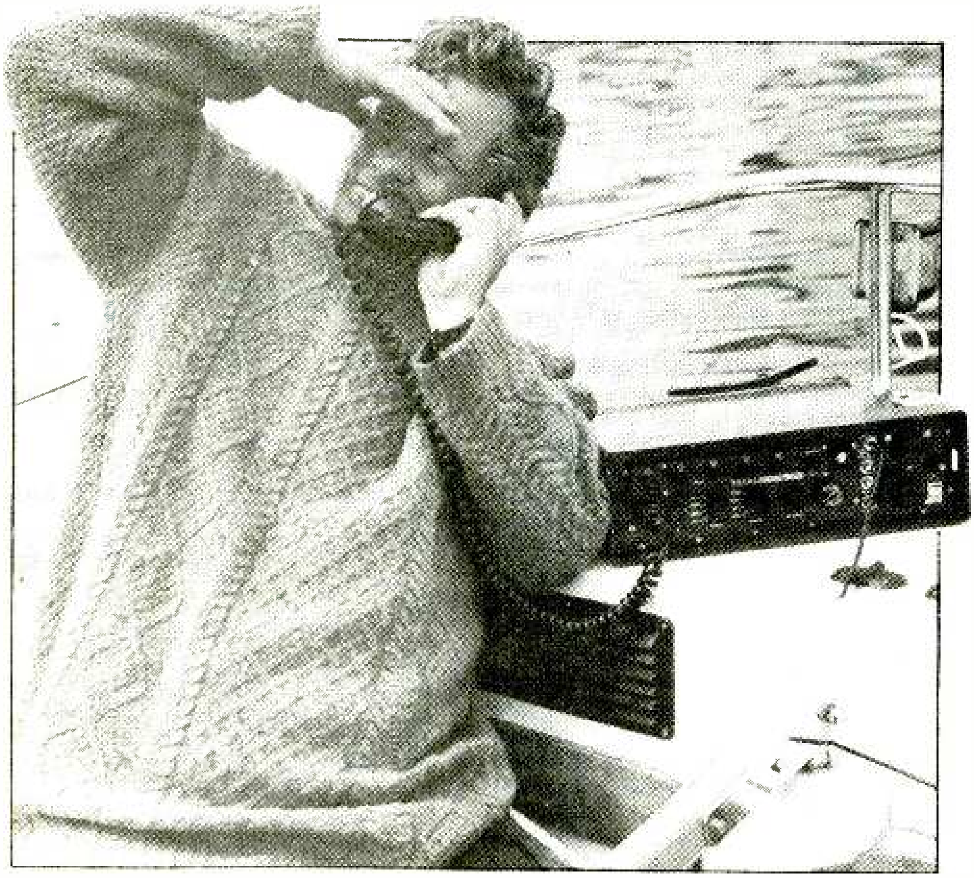
WW – 045 FOR FURTHER DETAILS

Program development with Occam

In advance of bringing out the Transputer, Inmos' advanced microprocessor, the company have launched development systems using their Occam language. The language has been available for nearly a year in an evaluation kit and has proved to be particularly useful for system designers, says Inmos, and so the 'system builders' workstation' has been developed with this in mind, giving some meaning to the phrase 'software engineering'. The language is based on the concepts of concurrency (doing different things at the same time) and communication. It is especially designed for use with multiple interconnected processors. Inmos claim that it is easy to understand, encourages structured programming with a syntax specially designed for interactive use. Many of the problems of programming microprocessors are solved with Occam by formalising the notions of input and output, interrupts, priorities and real-time. Using these eliminates the need to use real-time executives, or machine-code debugging. An Occam program by its nature reflects the structure of the application, describing how the hardware is arranged and providing the specification and implementation of each component. The formal structure of the language leads naturally to correct programs which may be transformed, preserving the function, much as logic functions may be transformed by Boolean algebra.

The workstation, based on a 16-bit 8088 processor, features 600K twin disk drives, 256K of memory, 800×400 pixel graphics. Software packages are available for the Sirius/Victor 9000 and for VAX/MMS computers. Further packages for the Intel iApX 8086, the Motorola M68000 and, of course, the Inmos Transputer, are planned.



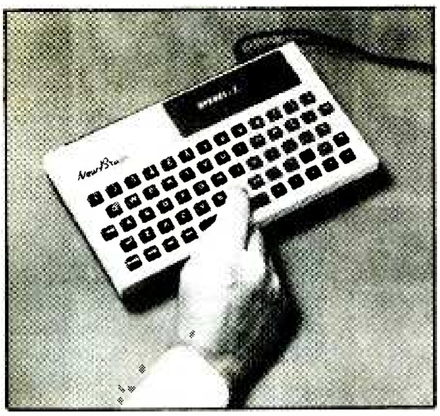
Surely one of the good things about crossing the Atlantic single-handed would be to get away from the telephone. Not so for computer programmer Mike Spring who has taken a Racal radiotelephone to the Azores and back. It provided a link back home for weather information and emergency uses. Mike was paralysed from the waist down after a motoring accident and his voyage was to help to publicise a fund-raising campaign by the Pain Relief Foundation.

Shy computer firm comes out of the closet

Founded in 1977 at about the same time as Apple Computers, the American company Alpha Micro has depended on word-of-mouth recommendations for new customers. Although sales were steady, they did not have the meteoric rise of some other manufacturers (though they did get some good customers; NASA use them for their Automated Management Information Centre, a central data base system). All this changed with the appointment of a new chief executive, the company's president Richard Cortese. He suggested an aggressive approach to sales and marketing and (for example) a UK branch of the company has been opened.

Alpha Micro computers range from the AM-1000 desk-top business computer which can support seven terminals up to the AM-1092 which can accommodate over 40 users. They are all based on the M68000 processor and offer multi-tasking facilities. Software has played an important part in the development of the company and their own operating system, AMOS is claimed to be faster than Unix, although Unix may also be used, as can CP/M and a variety of programming languages. Alphawrite is a multi-user word processing system. Alpha Microsystems (UK) Ltd, 56 Herschel Street, Slough, Berks SL1 1PY.

End of the Newbrain?



The Newbrain microcomputer may have become one of the first casualties of the home computer boom following a decision by its manufacturers to go into liquidation. Grundy Business Systems, who bought the Newbrain design from Newbury Laboratories in 1981 have blamed 'severe cash-flow problems' – caused, it seems, by their attempts to expand production too quickly.

The Newbrain was designed at Sinclair Radionics by Sir Clive Sinclair; and on his departure to form his new company Sinclair Research the design was transferred to Newbury Laboratories. The machine was put on sale in May 1982 by Grundy after Newbury had decided to redirect their efforts into computer peripherals. Described at the time as 'the most powerful hand-held microcomputer in the world', the Newbrain had come close to being chosen by the BBC as the machine to accompany their television series on microcomputers; and although the BBC went on to adopt the Acorn machine instead, the Newbrain was soon selling, according to its makers, up to 5000 machines a month at a price of £199. The Newbrain, however, lacked some of the features which home computer buyers were coming to expect – such as sound output and colour and the availability of games software. Attempts by the makers to promote it as an economical machine for small business uses do not seem to have been enough to save it; nevertheless, Grundy hope to be able to find another buyer.

Ethernet wins one race

When Xerox developed Ethernet, the local area networking system, it was generally considered to be too late and not good enough to be accepted as a LAN standard. However IEEE study group 802 has presented its standardization proposals to the International Standard Organization. It is recommending a 'carrier sense multiple access with crash detection' (csma/cd) system which is closely based on Ethernet. This has been selected in preference to the 'token ring' (IBM) system and the wideband (Wang) system. Liason between the IEEE and the European Computer Manufacturers' Association to get a closer correspondence between the Ethernet-based standards adopted by both is to be carried out by Siemens.

News in brief

The Prime Minister is particularly pleased that there are now a million teletext tvs in UK homes. She pointed out at a recent conference that it is the most accessible information technology product and "paves the way for other new products based on the home tv set!" Also a healthy home market can lead to "a vigorous attack on overseas markets". A recent survey showed that 98% of all teletext and viewdata installations throughout the world use British technology.

● The Japanese video market has found a need to be able to examine the gaps in video tape magnetic heads so that they may be manufactured to the fine tolerances required. The size of the gap varies from 3 to 0.3 microns and the makers have found that they can see these best with microscopes made by Vickers Instruments, originally developed for use in semiconductor manufacture.

● Telephones for the hard of hearing work on the induction loop principle. However the latest generation of telephones cannot be inductively coupled to present hearing aids. In answer to a Parliamentary question, Under-secretary for Industry John Butcher has said that discussions with the Royal National Institute for the Deaf and the British Association for the Hard of Hearing are being held to find solutions so that the disabled people will also benefit from advances in technology. Provisions in the Telecommunications Bill will also protect the interests of the disabled.

● Amateur radio licensing has been transferred from the Radio Regulatory Division to the Post Office. The Post Office is to computerize the operation and it is prepared to guarantee a turn-round in normal conditions of five working days and at peak times of ten. The PO currently issues CB licences over the counter but all applications for radio amateurs' licences will be processed by post from the Post Office Headquarters in Chesterfield.

● Having attracted a number of 'high technology' companies to take space in their new Science Park, the University of Warwick suffers the embarrassment of not having any buildings ready until later in the year.

To overcome this, Warwick University is offering room in the academic buildings to four companies: Warwick Computer Designs, ABCO Technology, both in the microprocessor applications field, a surface coating company and a MIY Home Systems, who make a variety of devices for use in the home.

● John Alvey, the Chairman of the advisory committee on research into information technology, has been appointed Engineer-in-chief on the Board of British Telecom. He was formerly BT's Senior Director, Technology.

● The Youth Training Scheme is providing 700 young people throughout the UK with one-year courses in electronics, data processing or 'high technology office skills'. The scheme is to be managed by Control Data, through their training Institutes, at six different cities. The courses are to include 13 weeks of practical on-the-job training, a prerequisite of the YTS scheme, will take place in factories or offices near the Institutes which are biased towards computing or electronics.

● The pioneer in cheap micros, Sinclair's ZX81, is now being sold with a 16K rampack and a software cassette for £45, inclusive. This price makes it suitable for buying as a dedicated controller, for example, being less than some control devices or time clocks currently available.

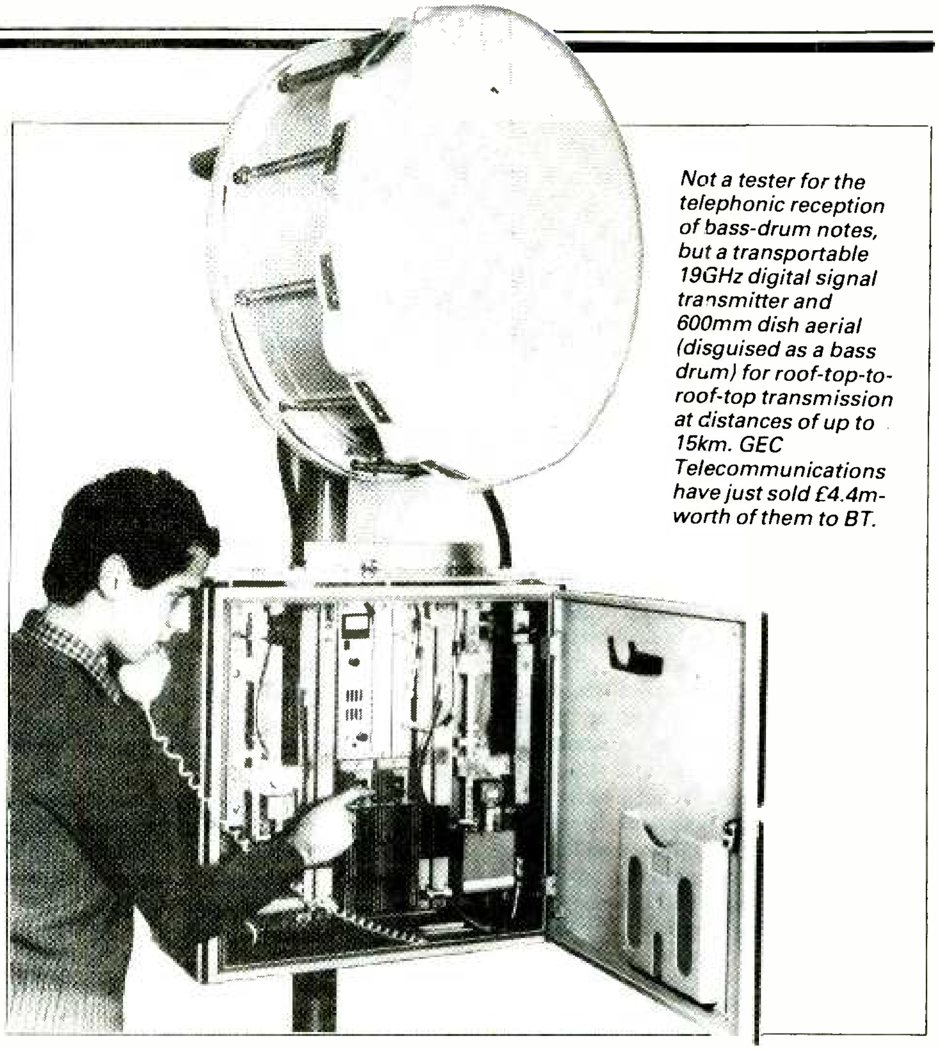
● Transatlantic teleconferencing has become possible because of some techniques developed by BT at Martlesham. Although it has been possible to send tv pictures across the Atlantic, the link capacity required, equivalent to about 1000 telephone calls, has imposed excessive costs. The new digital service saves by sending only the changes in a picture and by using a new coder/decoder to send good quality pictures on digital links at 2Mbits/s, equivalent to 30 telephone calls.

● Unemployed engineers who have had experience in industrial research and development can apply for a Wolfson Industrial Research Fellowship. Applicants must propose a project that they will work on during the tenure of their Fellowship. There is no restriction on the projects chosen, except that each should show a reasonable expectation of commercial or industrial benefit in the medium term. Preference will be given to applicants in the age range 25 to 35 years. The scheme provides each research Fellow with a stipend appropriate to age and experience and to the laboratory where the research will be carried out to provide for overheads and expenses. Fellowship of Engineering, 2 Little Smith Street, London SW1P 3DL.

● A new British transistor manufacturer is soon to appear. Concentrating their efforts into testing and supplying semiconductors to BS and defence standards, Semelab in Lutterworth, Leicestershire also manufacture transistors from supplied wafers. They use stringent quality control tests to meet those same standards. A new factory has allowed them to expand their operation and they plan to get diffusion equipment to enable them to manufacture complete devices. One area that they aim to cover is discontinued transistors that the major companies can't be bothered to make any more but for which there is a continuing demand.

Multi-function multiplexer for light fibres

Faced with the problem of getting the same information as they were getting down 200 pairs of twisted copper wires and yet using optical fibres, the BBC has developed a flexible control system for switching audio, communications and control circuits through small cables. Fibre optics were chosen because they are unaffected by electro-magnetic interference and can be routed through conduit carrying mains power cables, if necessary. A master circuit at each end of a link allows 16 data channels to be routed through it. Each channel can carry up to 255 different coded commands giving a capacity of 4080 commands. Because the system is inter-active and two-way 2040 executive actions may be switched or remotely controlled. Different interface circuits may be plugged in to allow a circuit to perform specific functions; a two-way digital control interface allows commands to individual switches, indicators and remote control devices to be coded and sent over the system, an RS232 or RS422 interface allows the system to be used with any equipment using these interface protocols as in computer peripherals, printers and display units, an analogue interface provides eight send and return lines and is for use with remote variable analogue controls. The channel port itself conforms to the Centronics 8-bit parallel standard, which enables any system to be fitted to any combination of the available interface circuits. The design is to be marketed by Pilkington Fibre Optic Technologies Ltd, and their first customer is – of course – the BBC who have ordered 50 of the multiplexers for use in remote switching of tape machines in their local radio stations.



Not a tester for the telephonic reception of bass-drum notes, but a transportable 19GHz digital signal transmitter and 600mm dish aerial (disguised as a bass drum) for roof-top-to-roof-top transmission at distances of up to 15km. GEC Telecommunications have just sold £4.4m-worth of them to BT.

Satellite news

Several hundred million pounds are to be spent by Marisat for their next generation of marine communications satellites. These will replace the current programme with capacity leased on nine spacecraft, three of which are still to be launched. They are requesting tenders from satellite manufacturers from all over the world and stipulate that the craft should be capable of being launched from Ariane, the Space Shuttle or from the Soviet rocket, Proton. The system is to have more power and more capacity than the existing system; 125 telephone channels, compared with 40 on the Marecs satellite. Possible extension to the use of the system could be in aircraft communication which could add significantly to the efficiency of air-traffic control and as the satellites will play an important part in maritime safety and distress systems, they should be powerful enough to be able to relay distress calls from small transmitters as might be carried by a life-raft or emergency beacon. Another use mooted is for land communication to particularly isolated areas, though Inmarsat stress that maritime communication must have first priority. However, exactly such access has been granted to the Australian research base in Antarctica and to an Italian offshore drilling platform in the Adriatic Sea. These services will be used chiefly for the transmission of data to analysis centres.

The European large telecommunications satellite (L-Sat) has recently been re-christened Olympus and is likely to be launched from an Ariane 3 rocket late in 1986. This has been the subject of a contract between ESA and Arianespace. Another contract between them is for the launch of three satellites which are to be improved versions of Meteosat.

Brains trust for electronic brain research

Following the Alvey Report, five members of the Alvey programme steering committee have been appointed. They are Philip Hughes, chairman of Logica Holdings; Dr Keith Warren, director of technology and strategic planning at Plessey; Colin Southgate, chief executive, Thorn EMI Information Technology; John Leighfield, managing director, BL Systems, and Professor Eric Ash, head of the department of electronic and electrical engineering at UCL. Professor Ash will also represent SERC and Colin Fielding (Ministry of Defence) with Roy Croft from the DTI will complete the panel under the chairmanship of Sir Robert Telford.

The Committee has been set up to co-ordinate research in industry, academic centres, research organisation and the Government to "mobilise UK strength in advanced information technology". Four particular areas have been selected: very-large-scale integrated circuits, software engineering, intelligent knowledge-based systems (often called expert systems), and man/machine interfaces. Much of the work will be directed towards the development of 'fifth-generation' computers.

World timing using h.f. broadcasts

Using the apparatus described, and a versatile h.f. receiver, time signals of several h.f. stations have been found to be in error – some fast, some slow, some varying from day to day.

by R. C. V. Marcario and G. R. Munro

1983 is designated World Communications Year and one of its main objectives is to stimulate the development of improved communications infrastructures, most particularly in the developing countries. Often, improved communications means more rapid communications which implies good time keeping at all places. Even in everyday life, one now tends to time activities to the nearest minute, and the modern wristwatch can maintain this accuracy over a period of one year without resetting.

The common method of re-calibrating one's watch or time keeping device, is to use the hourly broadcast time signal, or a time information service on the fixed wired network. In each country the nation's master clock is controlled by a central bureau: in the UK we have the National Physical Laboratory, who maintain Greenwich Mean Time, as well as the other standards of time, e.g. UT, CAT.

Historically, GMT is the primary time standard of the world and there clearly would be no problem of having a uniform world time if the world need not be divided into twenty-four time zones (making the one mean solar day), and if GMT could be instantaneously and easily distributed. It is this last point that requries each country to have its own time bureau, and this is the matter of principal interest in this article. In practice, one can travel from nation to nation with a dependable master (atomic) clock and keep checking each bureau. Alternatively one can compare all the receivable time markers at one place on the earth, and after making due allowance for the time delay in a signal coming from a particular nation, check whether each bureau's clock has the same time (plus or minus the time zone hours differences).

Such a procedure is also important because frequency is the inverse of time and the clock at each bureau must of necessity be its standard of frequency. Errors of frequency can in fact be more of a nuisance than an error of time. For a full discussion of the relation between errors in time and frequency refer to reference 1. (For a valuable textbook on standards of frequency and time see ref. 2.)

It is common practice to indicate zone time by means of radio 'pips' or tones. In the UK the hour is marked by the beginning of the sixth of a set of five 100ms tones plus a sixth 500ms 1kHz tone. In many countries, one also has special standard frequency and time transmission, see reference 3. In the UK the 60kHz MSF Rugby transmitter, located at 52.35°N, 1.17°W, radiates a standard frequency, on/off modulated with coded one-second signals. This enables clock calibration to an accuracy of a few microseconds to be achieved over the UK (4).

Despite direct satellite broadcasting, the broadcasting of national news and views by means of short wave radio is as active today as ever. The World Radio & TV Handbook lists the frequencies and times of each nation's transmissions in an extensive manner, and indeed if one receives such signals the hourly time marker tones are often heard. One therefore has access to that particular nation's time bureau, except for the propagation delay. Fig. 1 illustrates the basic arrangement for comparing a local clock with a distant clock. With access to a number of hf receivers, multiple comparison can be arranged. This article describes some simple circuitry for setting up such an arrangement.

Comparison apparatus

Because of h.f. sound bradcast signals often being noisy, and also to more clearly separate the time marker tones from the programme material, a tunable bandpass filter, centred at say 1kHz is placed between the h.f. receiver's audio output and the signal recorder, as shown in Fig. 1. The most suitable signal recorder is a

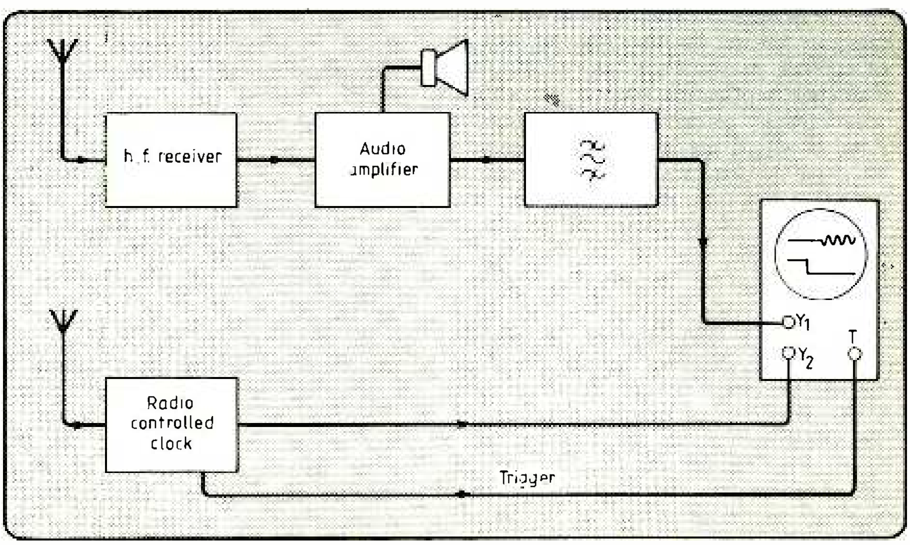


Fig. 1. Signal received on h.f. receiver is compared with a minute pulse marker generated from an MSF 60kHz receiver and displayed on a storage oscilloscope.

The authors are in the department of electrical and electronic engineering, University College of Swansea

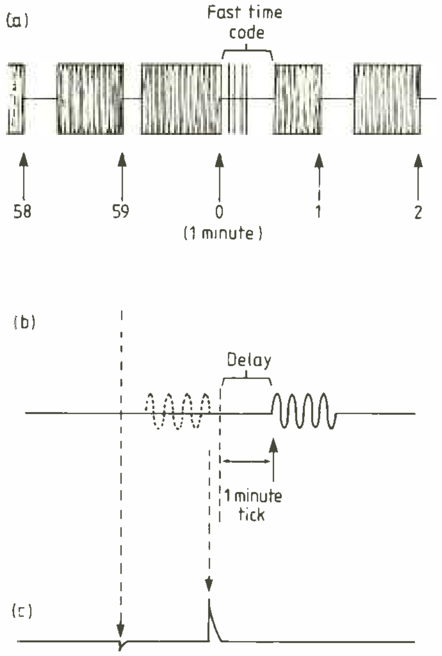


Fig. 2. Trace (a) in timing waveforms is part of the MSF signal format, but is not necessarily displayed: trace (b) is the style of the time pip tone received from an overseas h.f. station; trace (c) is generated within the MSF receiver and acts as the oscilloscope trigger pulse.

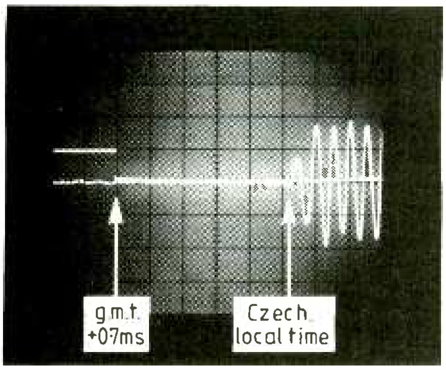


Fig. 3. Minute marker in this typical time comparison display is seen followed by the time tone waveform, from Radio Prague on 5.93MHz in the example shown at top. Time scale is 2ms/div. (09.15h 18 March 1983).

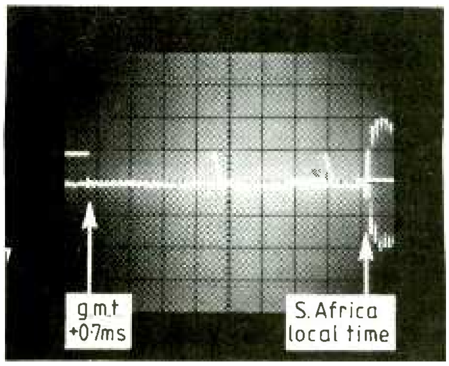


Fig. 7. Second time comparison display, bottom is over a distance of about 9250km, observed for Radio South Africa on 27.79MHz (14.00h 18 March 1983). Time scale 8ms/div.

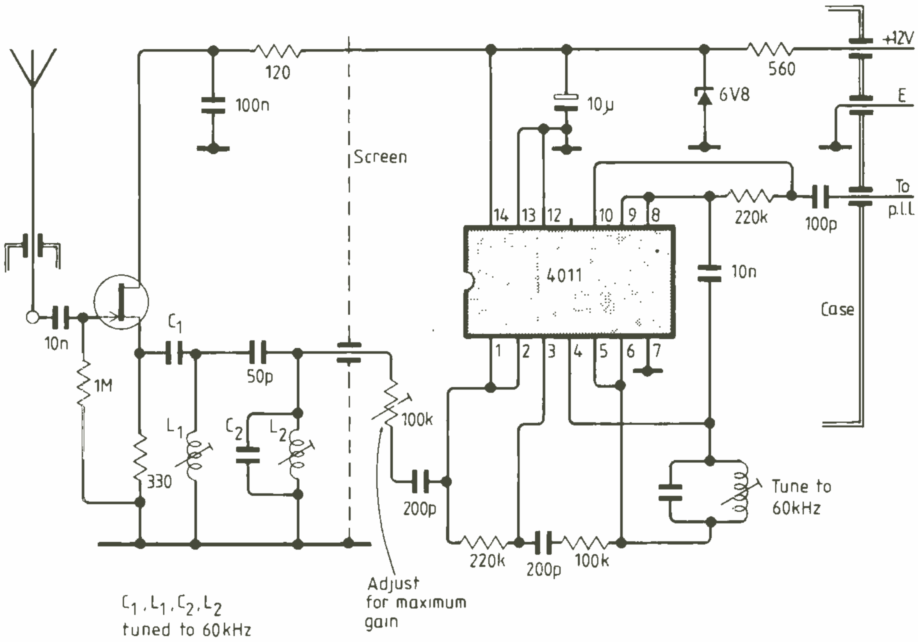


Fig. 4. Aerial amplifier for the 60kHz MSF signal. FET gives a high impedance input and so works off a short whip antenna. The cmos gates are operated in a linear mode and provide sufficient gain at 60Khz to drive a phase-locked loop detector, Fig. 5. This unit should be screened.

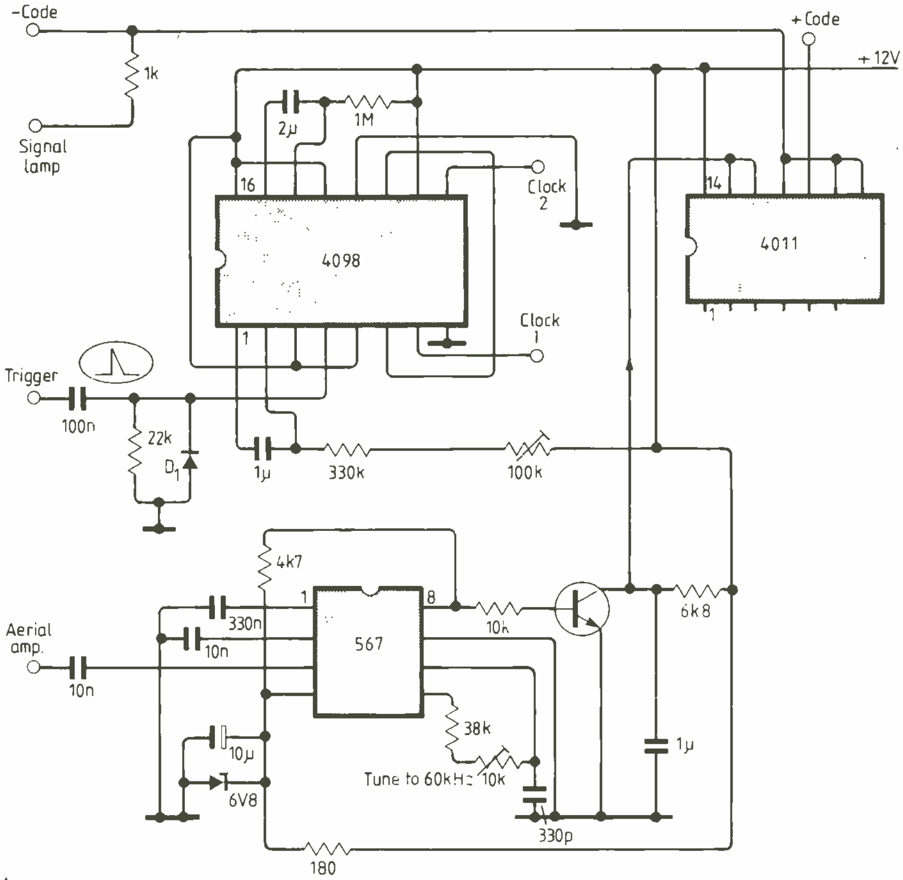


Fig. 5. MSF signal format is reconstituted from the 60kHz on/off carrier using the Signetics 567 tone detector. Output is raised to cmos level using 4011 gate. Trigger timing is set using a dual 4098 monostable.

storage oscilloscope because the time scale appropriate for the study is a few milliseconds. Examples of records are given below. In the other path is part of a receiver for the 60kHz MSF transmission and some logic for triggering the display on the minute on the hour, for example. One does not need to build a complete time-code receiver (5), just part, and an easily constructed system is described next.

That part of the MSF signal which occurs around the minute time is shown in Fig. 2(a). The slow time code information is distributed over the 60 second interval, each second occurring at the negative edge of these long pulses. After the 60th second a set of short pulses (10ms duration) constitute the fast time code. The edge of interest is the negative 60th second edge, which is displayed on the oscilloscope and gives the marker for GMT Fig. 2(b). The oscilloscope is required to trigger on the fifty-ninth second plus a suitable delay. Therefore the trigger circuit counts 58 pulses from the last trigger, and after a variable delay triggers the oscilloscope ahead of the one minute marker (c). The

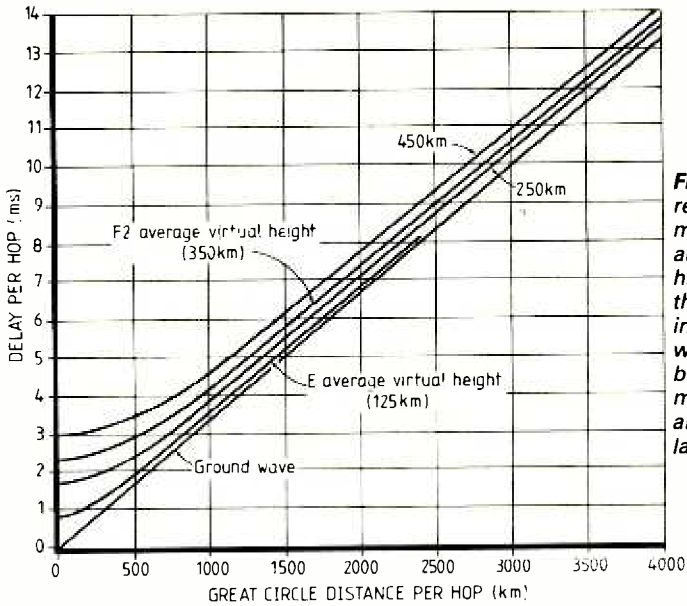


Fig. 6. Graph taken from reference 1 gives delay in milliseconds per hop for an ionospheric supported h.f. transmission, versus the great circle distance in kilometres. Delay time will vary during the day because the propagation may be supported by alternate ionospheric layers as indicated.

type of received time tone from the distant h.f. transmitter is shown at (d).

When these signals are combined together on the oscilloscope a pattern like Fig. 3 is observed. In this instance this was a time signal from Prague on 5930kHz at 21.30h UK time. The delay between the local g.m.t. and the received signal should correspond to the great circle path propagation delay, discussed below.

Trigger and timing circuit

A practical front-end circuit for receiving the MSF signal using a short-wire antenna is shown in Fig. 4. The circuit conveniently fits inside a standard Eddystone box. The f.e.t. provides a high input impedance, followed by a double-tuned circuit. Because linearity is not important for the receiver a cmos-linear amplifier using a feedback-coupled 4011 gate is used, providing a clean MSF signal carrier, except under very noisy signal conditions.

The carrier envelope contains the time information. The Signetics 567 p.l.l. time decoder will operate directly from the preamplifier, and a circuit is shown in Fig. 5. With buffering, a positive or negative code option at cmos level is available.

There are several options for triggering the display oscilloscope depending on how far one intends to make the system partially or fully automatic, because one needs to prime the trigger on the 58th second of the hour and have the 59th second produce a trigger pulse, delayed by about 990ms. We had the advantage of having a complete MSF time-code receiver and display and several options. The receiver would recognise the 59th second and give a delayed trigger pulse, using a 4098 monostable. The advantage of having a complete clock is that one now has a record of the time plus most of the required circuits already built; the type of display shown in Fig. 3 was therefore not difficult to arrange. To avoid further cmos circuitry we therefore leave the description of these circuits, as those already described set up the MSF code signal at cmos level (Fig. 2(a)) and one can arrange the required signal pattern according to any particular requirement.

Expected results

The negative edge marker is the local MSF GMT minute time, plus the propagation delay between Rugby and one's location. In our case NPL inform us that the delay is 695±2μs; allowing for some circuit delay, we therefore took the delay as being 0.7ms. The start of the distant station time marker (usually on the hour or the half hour) was assumed to be the first cycle peak of the received tone; therefore their local time would be the distance between the two marks, less the great circle h.f. path delay, plus 0.7ms. The h.f. path propagation delay would cause the distant station to appear later than the GMT marker, if its clock was on time.

The h.f. path delay can be estimated to within about ±0.5ms using the data from reference 1 shown as Fig. 6, assuming the great circle path distance can be calculated from a knowledge of one's own position and that of the distant transmitter. One does not know the transmitter's exact location, as an error of a few hundred kilometers will only produce a time delay error of, say, ±0.5ms (Fig. 6), which is not too important in some cases. The calculation of the path distances requires access to haversine tables (references 1 and 6) and a procedure is given in the Appendix.

Using the apparatus described and a versatile h.f. receiver one can collect interesting results. For example, Fig 3 showed Radio Prague, which is some 1350km distance, whilst Fig. 7 shows the recording for Radio South Africa on 27.790MHz, and distanced at 9250km. The delay on the received time tone is such that the first marker pulse of the MSF fast code can also be seen on the display.

We do not intend to discuss which stations have clocks running exactly in synchronism with GMT, as many results and careful calibration would be necessary. But we should say that several stations appear to be in error by orders of tens of milliseconds, some fast, some slow, some varying from day to day. A study on the basis of the method of national clock keeping would appear to fit in with the spirit of WCY83.

Appendix

Calculation of great circle distance

Require longitude of receiving and transmitting site, i.e. L_{OR} and L_{OT}, then let $L_{ORT}=L_R - L_T$. Require latitude of receiving and transmitting site, i.e. L_R and L_T. If the two locations are on the same side of the equator, let

$$L_{RT}=L_R - L_T$$

If the two locations are on the opposite sides of the equator, let

$$L_{RT}=L_R+L_T$$

Then the great circle distance (D) equation is

$$\text{hav } D=\cos L_R \cos L_T \text{hav } L_{ORT}+\text{hav } L_{RT}$$

where hav is haversine, from tables 1,6 and one second of arc is 1.853km.

The single hop mode delay, for distances less than 4000km, can be read off Fig. 6. For greater distances, a multihop model is required. This if distance is D(>4000km), and the number of hops is N(>2), then the total delay is

$$\Delta t=N \times \text{delay per distance } D/N$$

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2. P. Kartaschoff, Frequency and Time, Academic Press 1978.
3. J. McA. Steele, Standard frequency transmissions, *Wireless World*, Sept. 1967, p.443.
4. Time and Frequency Service Notices, National Physical Laboratory, Teddington, Middx, TW11 0LW.
5. P. G. Giles, P. J. Hart, and I. Thomas, Radio clock for the reception and display of MSF time-code transmission, *Mullard Tech. Comm, No.140*, Oct. 1978, P.402.
6. D. A Moore. Basic Principles of Marine Navigation, Kandy Publications 1964.

LITERATURE RECEIVED

The new edition of the MS Components' Catalogue has increased considerably in size to reflect the addition of some 2,500 new products. A useful addition is the index to semiconductor i.c.s. MS Components Ltd, Zephyr House, Waring Street, West Norwood, London SE27 9LH.
WW 412

A 625-page hard cover book is needed to describe the full range of Wandel and Goltermann precision electronic measuring instruments. It includes details of a.f. and r.f. voltage and level generation and measuring equipment, analogue and digital data communications meters, distortion measurement, some general-purpose instruments and automatic measuring systems. Wandel and Goltermann, Postfach 45, Muhleweg 5, D-7412 Eningen, F.R.G.
WW 413

Interfacing the Real World to Your Computer is the title of a 16-page booklet which illustrates methods of interfacing sensors, transducers, output actuators and other devices. Products described include signal conditioners, two-wire transmission, alarm systems, analogue input/output sybsystems and remote, intelligent i/o subsystems. Analogue Devices Ltd, Central Avenue, East Molesey, Surrey KT8 0SN.
WW 414 *More on p.48*

CIRCUIT IDEAS

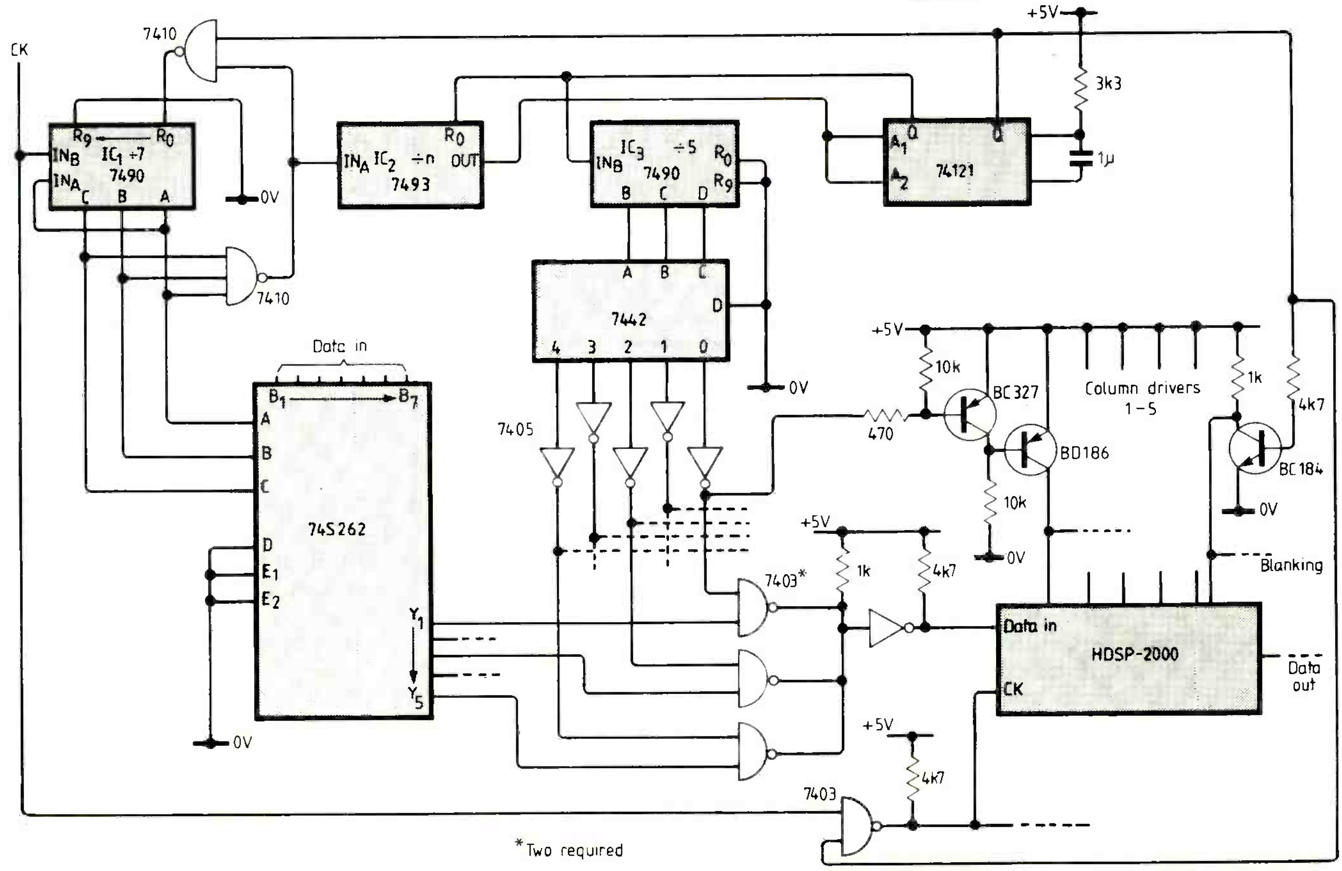
Multicharacter dot-matrix display

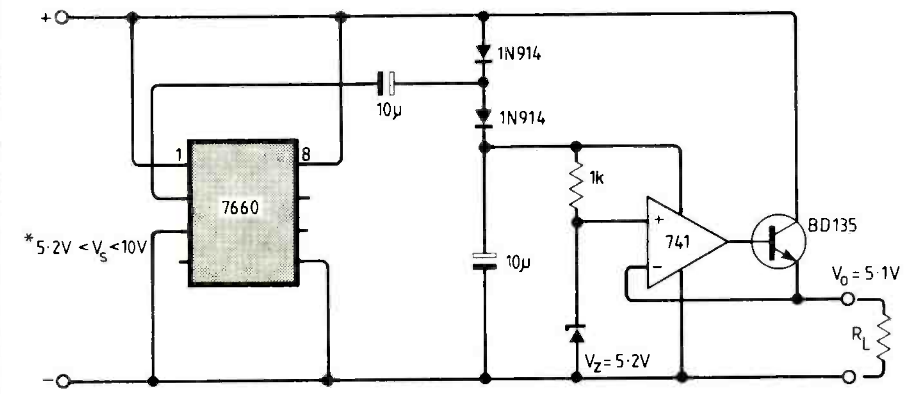
Designed as the display section of a terminal emulator for computer fault diagnosis, this expandable circuit drives a 16-character alphanumeric display from ASCII code. The four character Hewlett Packard HDSP2000 display is a seven-by-five dot-matrix type comparable in cost to 16-segment devices but it has constant-current l.e.d. drivers and is larger and easier to read. LCD modules with more functions exist but would limit the circuit to very low data rates. Electrically the display is a 28-stage first-in-first-out shift register with programmable constant-current l.e.d. drivers; character display is by external column strobing.

ASCII data may be asynchronous or read from ram addresses by the 7493 counter whose division factor n is equal to the number of display characters. Upper-case characters generated by the 74S262 are selected on lines B_{1-7} and converted to serial form by gating on each column output (shown abbreviated for clarity) while IC_1 cycles through row addresses n times. Display blanking occurs while data is clocked in. On completion of the character count the divide-by-n period signal goes low, triggering the 74121 monostable i.c. which stops the clock and unblanks the display for 2ms. After the pulse, column address counter IC_3 is incremented and the cycle repeats. Quinary counter IC_3 ensures that any random state at switch on synchronizes with $IC_{1,2}$ during the first count sequence. This method will not work with 2513 character generators which have no row address-zero output.

For flicker-free display each column must be strobed at at least 100Hz hence the choice of a 2ms display period; clock frequency determines the duty cycle by seven times the number of display characters. Component values shown drive a 16-character display.

N. A. C. Simons
London W10





* For $\beta > 20$, $V_{S\,(min)} = V_Z + V_{sat}$

Regulator with negligible i/o voltage

When high or medium current is required from a voltage regulator, input/output voltage difference must usually be greater than 1V. Using a converter to increase the input voltage allows this differential to be reduced to the series-pass transistor saturation voltage. The basic circuit shown for a load of a few hundred mA can be used to provide a regulated 5V supply from a 6V battery. Ratings of the 7660 limit the input to below 10V.

A. Kerim Fahme
Autolight
Aleppo, Syria

6-digit decade counter

This circuit for up to six digits counts up or down between .000000 and 999 999 and gives over and underflow indications. Positive edge transitions on the count-up line increment the least-significant digit and positive-edge transitions on the count-down line decrement the same digit. Buffered signals C_u and C_d represent carry and borrow indications respectively from the second most-significant digit.

When the counter under or overflows the 74156 decimal-point, decoder 1Y3 output goes low, causing the under/overflow line to go high. This keeps C_u and C_d inputs of the lowest-order counter low and disables decimal-point decoder outputs. In this situation the counter is disabled and must be reset by the active-high clear input.

G. A. M. Labib
Cairo
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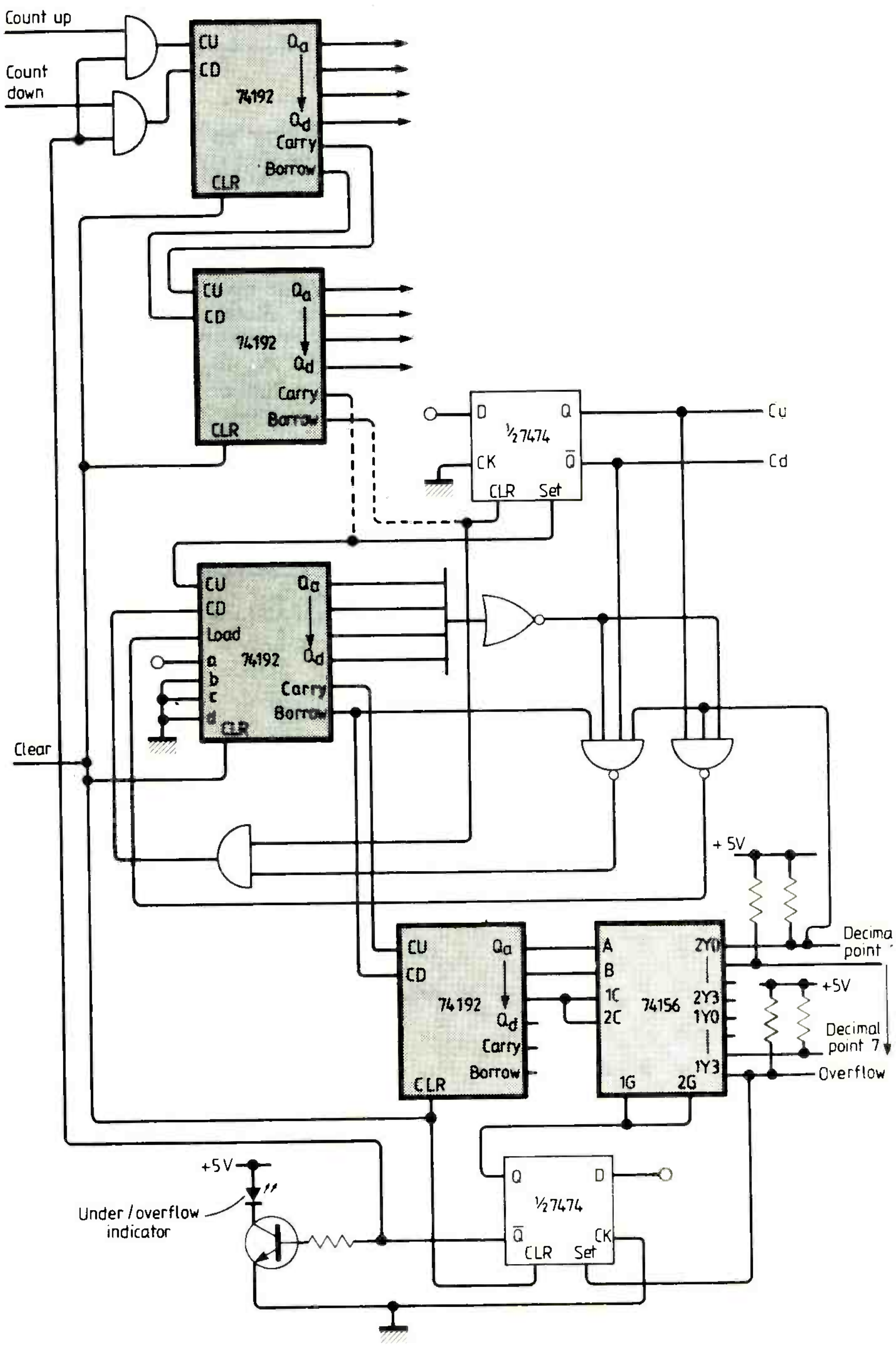
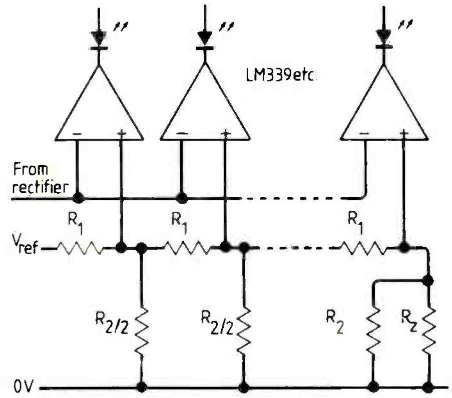
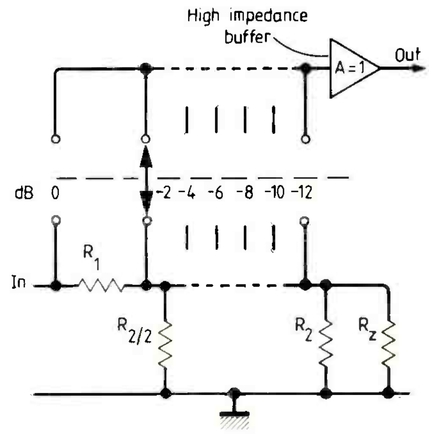




For 3dB steps: $R_1 = 12k$, $R_{2/2} = 100k$,
$R_2 // R_z = 29k23$



For 2dB steps: $R_1 = 1k2$, $R_{2/2} = 22k$,
$R_2 // R_z = 4k53$

Logarithmic dividers using equal resistors

These circuits, one a bar-display VU meter and the other a step attenuator, illustrate a logarithmic potential divider in which only the last section of the ladder, consisting of R_2 and R_Z in parallel, need contain a non-preferred resistor value. All other resistors in the ladder are one of two values. Where A is the voltage drop for each stage equations for values are as follows

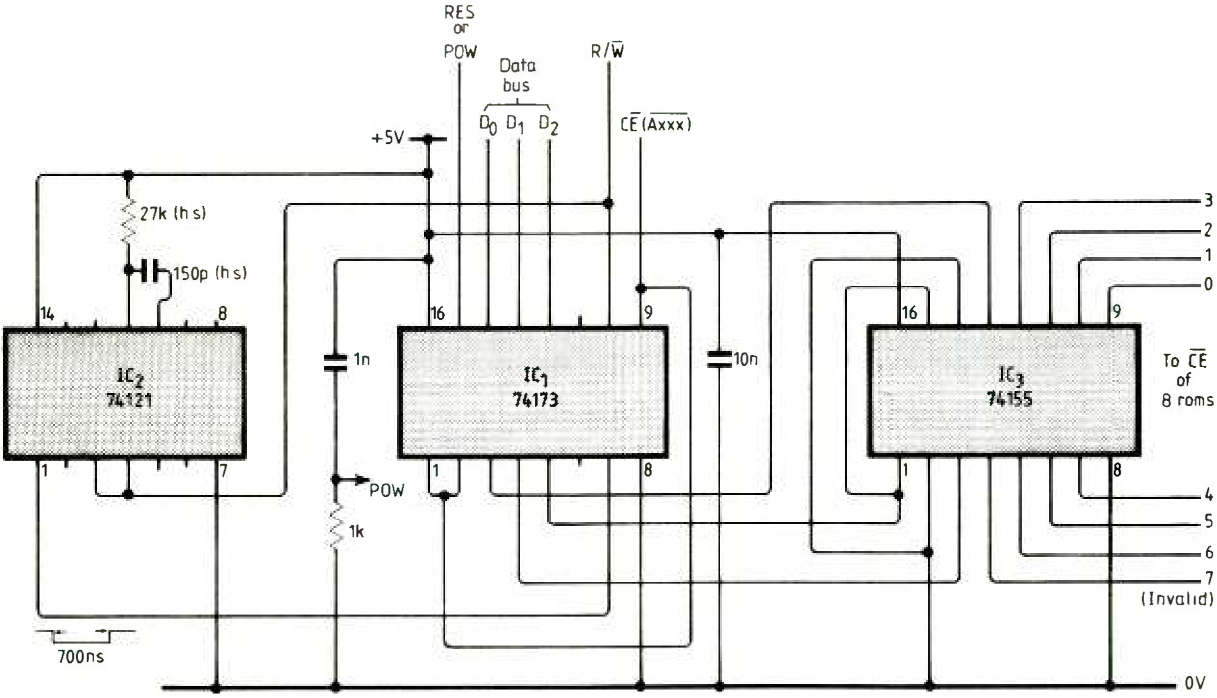
$$(dB) = 20\log_{10}A$$

Z is the ladder impedance. As only one resistor is equal to Z it is better to choose either R_1 or $R_2/2$ as a standard value so that resistor packs may be used.

$$R_1 = \frac{Z(A^2-1)}{2A}$$

$$R_2 = \frac{Z(A+1)}{A-1}$$

John D. Thompson
Lewes
East Sussex



One-out-of-seven rom selector

Designed for the Acorn Atom which has only one spare rom socket though several roms are available, this circuit selects one rom from a possible total of seven by poking address $A000_{16}$ with the required rom number (0-7). Zero is automatically selected on power up (and reset if required) allowing a specific rom to be selected by default, e.g. a utility rom.

The circuit is based on the fact that a rom is never usually sent data from the processor. A write operation to the block Axxx is indicated by R/W̄ and C̄Ē both being low; this is detected by the two enable inputs of IC_1 – a 74173 four-bit register which latches the data lines D_0, D_1 and D_2 to its outputs on a rising edge at its clock input.

Now R/W̄ and C̄Ē are both set when the address lines are stable (ignoring propagation delays of about 50ns), however, the data is not present and stable for 650ns. IC_2, a 74121, is a monostable which provides a rising pulse 700ns after R/W̄ goes low latching the data bus contents to the outputs of IC_1.

The latch outputs provide the input data for IC_3, a 74155, which is a dual 2-to-4 decoder configured as a 3-to-8 decoder (active low). IC_3 has a clear input which is active high and can be driven in one of two ways. Firstly it can be taken to RES giving a clear operation (sets decoder output 0 low) on any system resets including power up. However, remember that if the rom is part of the operating system (e.g. a utility rom) then system vectors will have to be changed before a new rom is selected. This can be overcome by using the second method, that is, clear on power up only (POW). The system vectors can be reset by executing BREAK from the keyboard immediately after selecting a new rom. For example say rom 5 is wanted then:

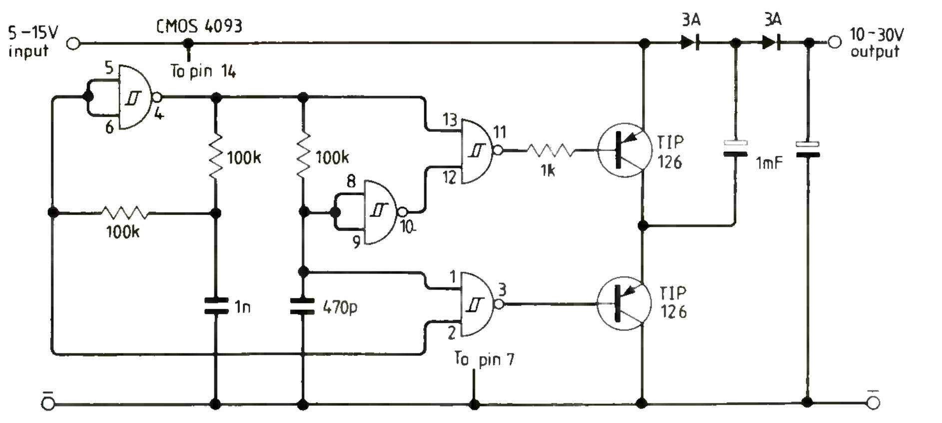
?#A000=5

is typed in direct mode followed by RETURN and BREAK. Any rom can be elected from within a program by:

?#A000=n(n=0, 1 . . . 7)

All the control lines required are available at the original rom socket (IC_{24}) with the exception of R/W̄ which can be taken from b30 of p16. The circuit should work with any 1MHz 6502 processor.

D. C. Grindrod
Sutton Coldfield
West Midlands



4093 i.c., pin 14 to V_{in}, pin 7 to V-

Cheap voltage doubler

Originally designed to enable a 12V stack of NiCd cells to be charged from a 12V car supply without splitting the stack, this doubler can deliver around 2A depending on the type and value selected for the pump capacitor.

To prevent a large current flowing through the two output transistors during the transition period, a four-phase clock is used. The slave RC network has a 90 degree phase lead over the oscillator. The outputs of the slave RC network and the oscillator may thus be combined to produce non-overlapping output pulses. These pulses are fed direct to power Darlingtons which have sufficient gain for the power stage.

The pump capacitors actually require a value of only a few microfarads, but must be able to handle the currents involved. The cheapest solution is to use larger-value electrolytics.

Paul Stephenson
Hull

Improving stereo at l.f.

Spatial effect in a stereophonic sound system decreases at frequencies below 800Hz in comparison with a concert hall. This method for increasing the l.f. spatial impression of two-channel stereo reproduction can also be used to add ambience in mono reproduction.

by Y. Hirata

The spatial impression obtained when listening to sound in a room is related to the human biaural hearing property. When one hears sounds of the same amplitude and phase at both ears one, has no spatial impression and the sound image centres. On the other hand, hearing sounds of the same amplitude but several different phases at both ears, one has a spatial impression. The degree of spatial impression with steady-state random noise can be related directly to the interaural cross-correlation coefficient (i.c.c.), viz. the simple cross-correlation coefficient between sounds at both ears introduced by Damaske[1]. Curves of equal spatial impression using an i.c.c. depending on frequency of an applied random noise were given by Anazawa[2], but this measure cannot express well the difference between the spatial impression given by mono and stereo sound reproduction. In a room of reverberation time of more than 0.3s, there is no clear difference between the coefficients in mono and stereo sound fields. The spatial impression discussed here is the sort usually called ambience or 'surrounding sound' in audio.

The spatial sensations created by musical sound that involves many transient or pulsive sounds and steady-state random noise are different providing that the i.c.cs are the same, which is easily examined by experiments. Our hearing has an ability to locate a pulsive sound that is followed by many echoes of different incident angles. In other words, our hearing is less sensitive to early reflections that reinforce the direct sound[3]. Such a hearing property is important and should be reflected in quantifying spatial impressions for musical sound[4]. The rate of subjective intensity of a direct sound reinforced by early reflections is approximately given by the definition of Thiele[5] as the ratio of the energy of early reflections within 50ms, including the direct sound, to the total energy arriving at a given location in a room. We use this definition, D, tentatively as the weighting of the subjective intensity of a direct sound, and define the perceptual interaural cross-correlation coefficient (p.i.c.c.) by:

$$\mathrm{PICC} = DR_0 + (1 - D)R_E \qquad (1)$$

where R_0 is the i.c.c. of the direct sound, unity for normal incidence, and R_E the i.c.c. of reverberant (incoherent) sounds, expressed by

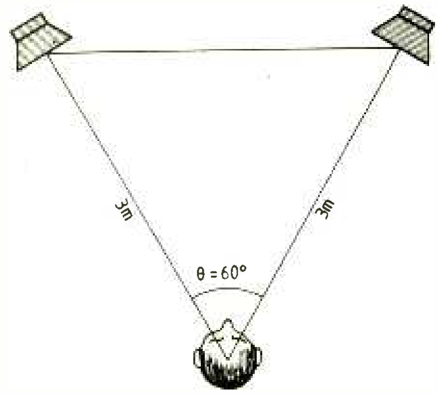


Fig. 2. Plan view of arrangement of loudspeakers and a listener for compiling p.i.c.c. curves shown in Fig. 3 for stereo reproduction.

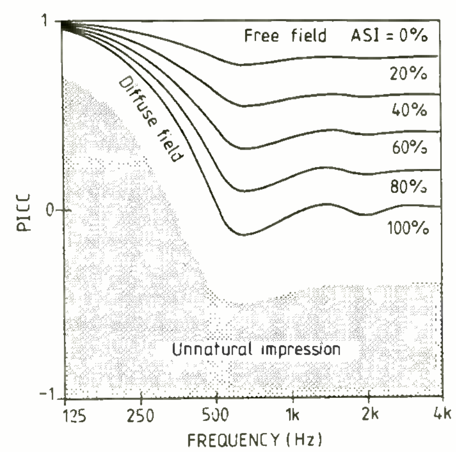


Fig. 1. Family of perceptual interaural cross-correlation (PICC) curves of equal acoustic spatial impression (ASI). Full spatial impression is indicated by ASI=100% and no impression by ASI=0% (below).

The author

Born in Tokyo, 1940, Yoshimutsu Hirata graduated from Waseda University in 1965 and received the degree of Dr Eng. by work on the acoustic property of mufflers with air flow in 1970. He was a researcher at Waseda University from 1970 to 1981, and from 1982, Dr Hirata became an independent researcher and consultant in the areas of room acoustics, noise control, electroacoustics, signal processing, and audio in general. A previous article investigating listening tests of amplifier sound in the October 1981 issue, described a new technique for quantifying amplifier sound using an asymmetric test signal with no d.c. component. We reported one of his earlier techniques back in 1974 when we met Dr Hirata at a London acoustics congress presenting a paper on multiplexing by digital comb filtering (News, October, 1974).

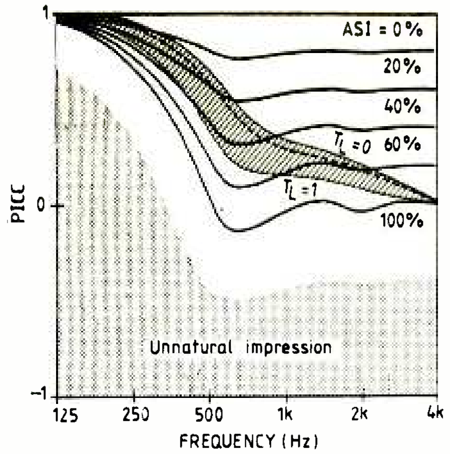


***Fig. 3.** PICC curves for stereo sound reproduction in a listening room of reverberation time O T_L 1s shows small ASI in low frequency band compared with an ASI=60% for the middle seat of a concert hall. Broken line shows T_L=0.3s.*

$$R_E = \sin kr(f)/kr(f) \qquad (2)$$

where $k = 2\pi f/c$ is the wave number' c the speed of sound' and r(f) the acoustic distance between both ears, which is approximately 30cm[6,7]. Early reflections very close to a direct sound make a sound source appear somewhat more extended, which may be accounted for by the reduction of R_0. Such an effect, neglected here, should be given special consideration[8].

From equation 1, PICC = 1 for a single source in an anechoic room (free field) where D = 1, and PICC = R_E in a reverberation chamber (diffuse field) where D = 0. In an anechoic room one gets no spatial impression, while one gets full spatial impression in a diffuse field such as a reverberation chamber or stone cathedral which might have a reverberation time as long as 10 seconds. For convenience we introduce here ASI as the index of acoustic spatial impression, expressed by

$$ASI = (1 - D) \times 100\,(\%). \qquad (3)$$

Full spatial impression is indicated by ASI = 100% and no spatial impression by ASI

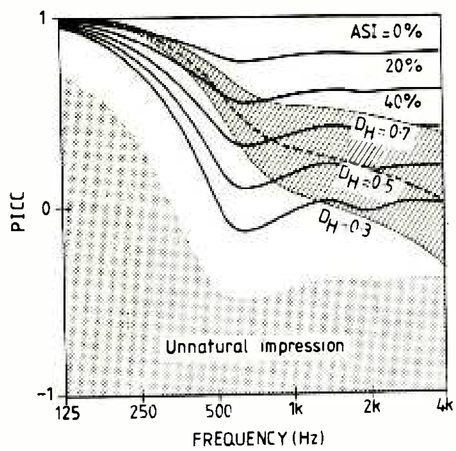


***Fig. 5.** Spatial impression of reproduced sound at low frequencies cannot be increased simply by reducing the recording source definition. PICC curves are for stereo sound reproduction where D_H = 0.3 implies too reverberant source and D_H = 0.7 too dry source. (Broken line shows the normal case of D_H = 0.5.) Reverberation time of listening room is T_L = 0.3s (a typical value).*

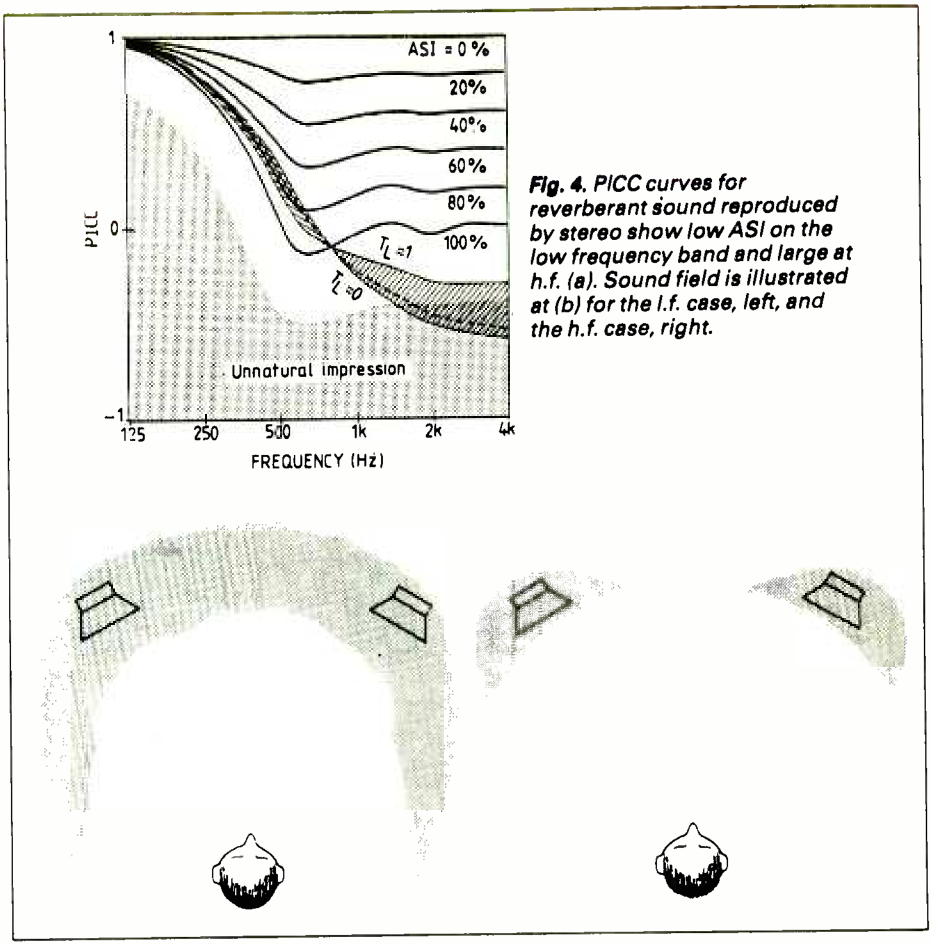


***Fig. 4.** PICC curves for reverberant sound reproduced by stereo show low ASI on the low frequency band and large at h.f. (a). Sound field is illustrated at (b) for the l.f. case, left, and the h.f. case, right.*

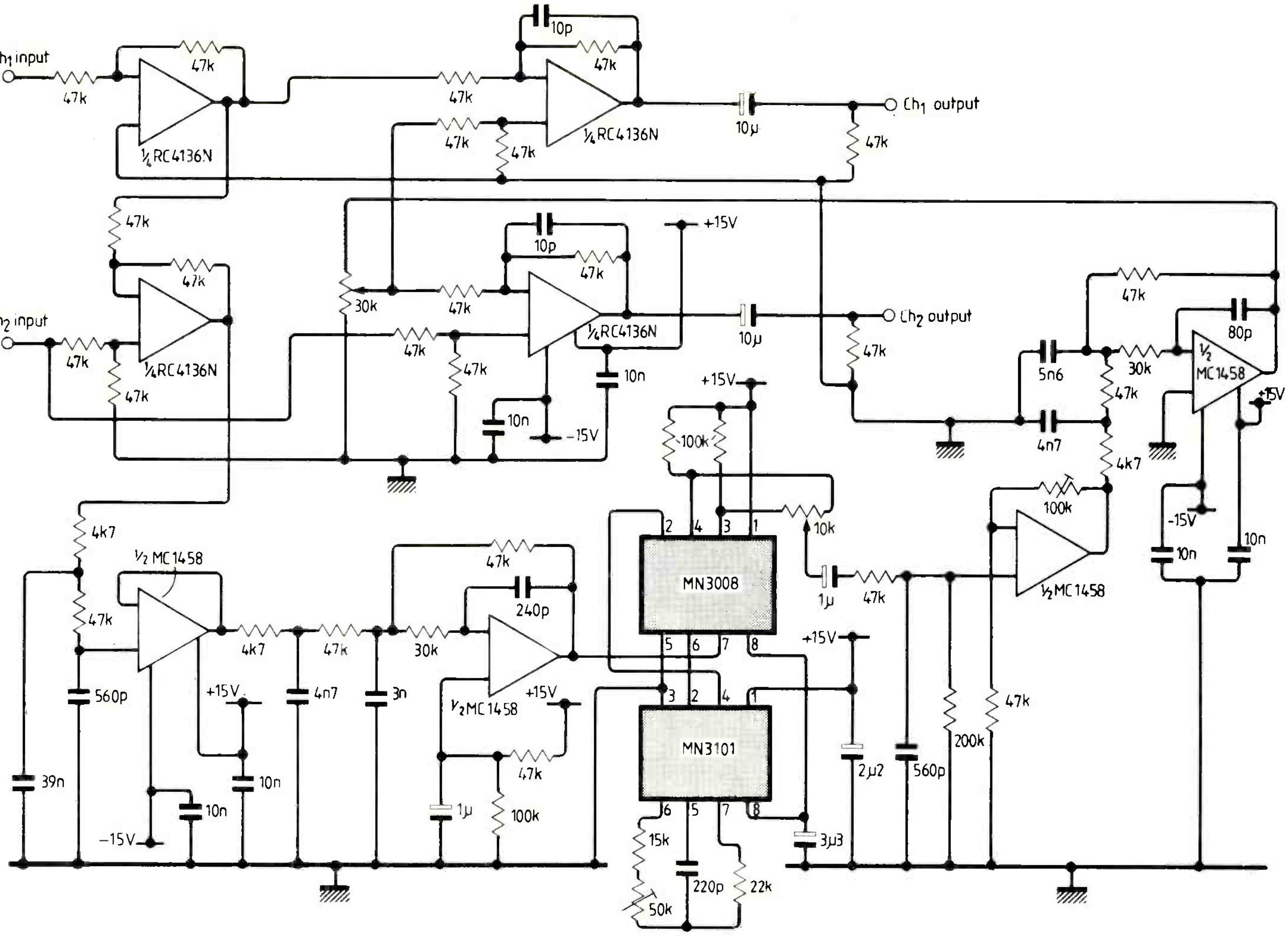
= 0. Fig. 1 shows a family of p.i.c.c. curves depending on the frequency with ASI as parameter. The definition at a middle seat position in a concert hall is typically 0.4, where the p.i.c.c. is given by the curve indicated by ASI = 60%. Because one does not localize reverberant sounds, one gets the maximum ASI of 100% instantaneously at all seats in a hall for reverberant sounds heard, for example, at a rest after the stop of a *fortissimo*. Widespread plural sound sources of the same timbre also gives one a spatial impression, expressed by eqn 1, where the mean ICC value for plural direct sounds of several incidence angles is used for R_0. The grey area of Fig. 1 indicates the region where one gets a feeling of unnaturalness, viz. an excessive spatial impression or a separate impression when PICC approaches −1.

In a typical listening room of reverberation time 0.3s, the definition at a location 3m apart from a single source is about 0.9, where the p.i.c.c. is given by the curve indicated by ASI = 10%, assuming the reverberant sound is diffuse[9]. Thus, one gets but insufficient spatial impression for mono sound reproduction in a listening room. The p.i.c.c. for stereophony using two loudspeakers is

$$PICC = D_L R_{rep} + (1 - D_L) R_E \qquad (4)$$

where R_{rep} is the i.c.c. of the direct sounds emanating from two loudspeakers, which is a function of D_H, R_H, r(f) and θ, D_H being the definition of a recorded sound, R_H the cross-correlation coefficient between sounds recorded from two microphones placed at a distance from one another in a concert hall, and θ an angle at the listener of the configuration shown in Fig. 2. In the case of stereophonic recording, two microphones (or two sets of microphones) for picking up reverberant sounds in a concert hall are usually placed at a distance so that R_H = 0, which is empirically done by recording engineers. The typical value of the definition of a recorded source for symphonic music is 0.5, given by Yamamoto at NHK[10]. Using the values $R_H = 0$, $D_H = 0.5$ and $\theta = 60°$, and assuming that the distance between a listening position and each loudspeaker is 3m, one gets the p.i.c.c. curves for stereo sound reproduction from eqn 4. The results are shown in Fig. 3 in the range $0 \leq T_L \leq 1$s, T_L being the reverberation time of a listening room, where a broken line shows T_L = 0.3s. Figure 3 shows that the ASI in the stereophonic sound field is small at frequencies less than 800Hz and large at frequencies greater than 800Hz in comparison with that in the concert hall, where ASI = 60%. The maximum spatial impression given instantaneously by the reverberant sound reproduced in a stereo system is expressed by the p.i.c.c. curve with $R_H = 0$, $D_H = 0$ and $\theta = 60°$ in eqn 4 and shown in Fig. 4. In comparison with the curve indicated by ASI = 100%, which is the maximum spatial impression given in the concert hall, the spatial impression for reverberant sounds reproduced by a stereo system is small at frequencies less than 800Hz. Fig. 4 also suggests that the reproduced reverberant h.f. sound gives an impression such as hearing two different reverberant sounds emanating from each loudspeaker.

Curves for stereo sound reproduction where the definition of a recorded source D_H is varied from 0.3 (too reverberant source) to 0.7 (too dry source) are shown in



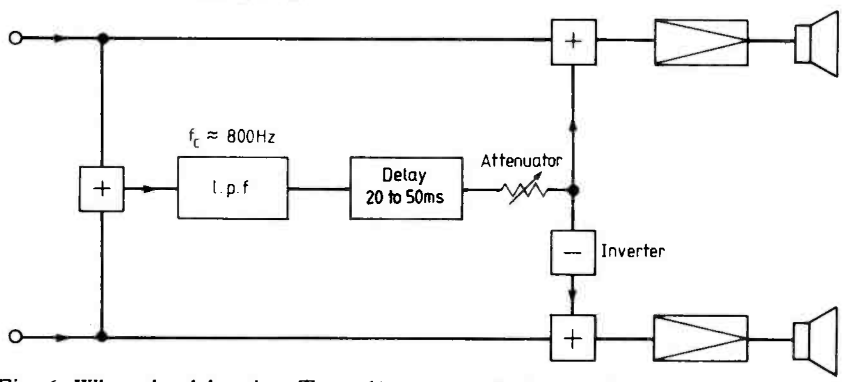


***Fig. 6.** Block diagram of the circuit for increasing spaciousness for frequencies less than 800Hz. Delay line consists of an analogue shift register in the form of a bucket-brigade device. Delay time from b.b.d. is 45ms in circuit shown.*

Fig. 5, a broken line showing $D_H = 0.5$, and the reverberation time of a listening room is fixed at 0.3s. This indicates that one cannot fully increase the ASI of reproduced sound at low frequencies by simply reducing the definition of the recording source. To create natural spaciousness, one must decrease the p.i.c.c. at frequencies less than 800Hz and increase it at frequencies more than 800Hz. The p.i.c.c. decreases when the distance between two loudspeakers increases and vice versa.

One method for getting a natural spaciousness uses additional loudspeakers, some for low frequency and some for high frequency reproduction. But this brings the disadvantage (to a listener, an advantage to the maker) of spending money for the additional amplifier and loudspeaker system. To avoid increasing the number of loudspeakers, one can create natural spaciousness by using a simple circuit for decreasing the p.i.c.c. at low frequencies together with the geometrical method for increasing the p.i.c.c. at high frequencies. The block diagram of the circuit is shown in Fig. 6. When the delay time T_D and/or the magnitude of the delayed signal increases, the spatial impression increases, which is explained by the decreasing of the p.i.c.c.[11]. Incidentally, dropping the 'p' in p.i.c.c. makes this effect inexplicable, i.e. the i.c.c. remains unchanged for variable T_D.

The circuit of Fig. 6 is also available for adding ambience to the mono sound transmitted by a.m. radio or tv stations. This may bring up the basic question of whether a.m. or tv stereo broadcasting is really necessary.

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Problems in special relativity

Arguments that have been used to defend the special theory of relativity against criticism contain many inconsistencies. These problems should be thoroughly and objectively examined by scientists and philosophers to attempt to ascertain the truth of the matter.

Ever since Einstein's special theory of relativity became a prominent part of physics, it has been a subject of some controversy. One of the foremost critics of the theory was the late Herbert Dingle (1890-1978), who spent much of his time and energy during the last two decades of his life in trying to persuade the scientific world that the special theory, although mathematically valid, contains an inconsistency in its physical application. Although most scientists seem to be convinced that the controversy stirred up by Professor Dingle's criticisms has been conclusively settled in favour of the theory, a close examination of the relevant literature shows many inconsistencies in the arguments by which the special theory has been defended. The present article does not attempt to settle the matter; in fact it shows that the issue has not yet been satisfactorily settled. It is hoped that scientists and philosophers may be encouraged to continue the search for the truth of the matter, whatever it may be.

Simple example of inconsistency

Readers who are not experts on relativity may feel convinced that the inconsistencies that have been mentioned are beyond their understanding; on the contrary, many of them are perfectly obvious to anyone who takes the trouble to read them. To take a specific example, consider two inconsistent statements that were made in the British journal *The Listener* in 1971.

Professor J. Taylor claimed[1] that the results of the well-known experiment of Hafele and Keating, which had then been recently performed, supported Einstein's special theory. Professor Dingle published a letter rebutting Taylor's article, and further correspondence continued to be published, in the course of which another scientist, Professor M. A. Jaswon, published a letter[2] which disagreed with some of Dingle's points, but which agreed with Dingle that the experiment in question had "no relevance whatever for the special theory". Although that statement was directly contrary to Taylor's claim, Taylor later published another letter[3] which continued to criticise Dingle but which took no notice whatever of Jaswon's statement.

Professor McCausland is in the department of electrical engineering, University of Toronto, Ontario, Canada.

Some observers of the controversy may believe that inconsistent statements like these result from attempting to express abstruse technical matters in simple language, and that such inconsistencies may therefore be dismissed as being inconsequential. But the inconsistency between the statements mentioned above cannot be dismissed in that way. A statement that the results of a particular experiment support a certain theory is a perfectly simple factual statement (however abstruse may be the reasoning by which that statement is justified), and the same applies to the contrary statement. The fact that Taylor's and Jaswon's statements are contrary to one another (that is, they cannot both be true, though they could both be false) shows that, unless there is an inconsistency in the special theory itself, one or other of the two scientists (or both) misunderstood either the theory or the experiment (or both).

by Ian McCausland

It will also be clear to any reader, scientist or not, who reads the whole of the correspondence that includes the above items (refs 1-3), that no attempt was made to resolve the inconsistency between Taylor's and Jaswon's statements. If science is the search for truth, wherever the search may lead, the serious inconsistency between the statements of the two scientists ought to be followed up to find out which statement, if either, is true. The fact that both statements have been accepted in spite of their obvious incompatibility is evidence that there is not enough scientific curiosity about the truth of the matter. The remainder of this article presents further evidence in support of the same point of view.

Further examples of inconsistency

Professor Dingle's criticisms of special relativity are presented at length in his book *Science at the Crossroads*[4], and it is in the published reviews of that book that many of the inconsistent attempts to defend the theory have been made. To study some of these attempts, consider Dingle's crucial question, which is central to his book, and which is worded as follows:

> "According to the special relativity theory, as expounded by Einstein in his original paper, two similar regularly-running clocks, A and B, in uniform relative motion must work at different rates. In mathematical terms, the intervals dt and dt′, which they record between the same two events are related by the Lorentz transformation, according to which $dt \neq dt'$. Hence one clock must work steadily at a slower rate than the other. The theory, however, provides no indication of which clock that is, and the question inevitably arises: How is the slower-working clock distinguished?"

In a review[5] of Dingle's book, Professor J. M. Ziman quoted the above question and then wrote: "This is a perfectly reasonable question to which science should indeed give an answer." Later in his review he gave his own answer, in the following words: "In fact, the answer to Dingle's 'question' is simple: the fastest-working clock between any two events is one that travels between them by free fall." But, as Dingle subsequently pointed out[6], neither of the events need be at either of the clocks concerned. Also, since the question asked for a distinction between two clocks, not for a choice among all possible clocks, Ziman's answer, whether or not it is a true statement, is simply not an answer to the question that was asked.

Dingle also supplemented his question by referring to a specific example in Einstein's original paper on special relativity, in which Einstein had stated that a balance-clock at the equator would work more slowly than an exactly similar clock at one of the poles. Dingle stipulated that any answer to his question should specify what it was that entitled Einstein to conclude, from the special theory, that the equatorial and not the polar clock worked more slowly. Dingle stressed that the special theory did not take any account of possible effects of acceleration, gravitation, or any difference at all between the two clocks except their state of uniform relative motion. It should be strongly emphasised, however, that he did not assert that acceleration and gravitation were *absent* from the situation described by Einstein, but that those phenomena are not dealt with by special relativity, and consequently it is not legitimate to invoke those phenomena to explain what entitled Einstein to conclude *from the special theory* that the equatorial clock worked more slowly.

The attempts to answer this supplementary question show an interesting diversity. In the first place, it is obvious that Ziman's answer, quoted above, does not apply to this situation; after the two clocks are in their positions at the pole and at the equator, there is no event at which both clocks are present, so there is no way in which Ziman's criterium can distinguish between them unless some pair of events is specified.

Consider now some of the other attempts to answer the question about the polar and equatorial clocks. For example, Professor G. J. Whitrow wrote as follows[7]:

"For a supporter of relativity, the essential difference between the two clocks is that relative to the centre of the Earth (which for the purpose concerned can be regarded as the origin of an inertial frame) the clock at the equator describes a circle and so cannot be associated with an inertial frame, whereas the polar clock is at rest and can be associated with an inertial frame for a period of time during which the curvature of the Earth's orbit can be neglected. The time difference mentioned by Einstein can be demonstrated by means of the Minkowski diagram, in which the track of the polar clock will be rectilinear whereas that of the equatorial clock will be curved."

Two comments may be made about this. First, if the equatorial clock is not in an inertial frame, then its motion lies outside the scope of the special theory, which applies only to inertial frames[8]; it is therefore invalid to deduce from the special theory *any* conclusion about the relative rates of the two clocks. Second, the answer raises the equally difficult question of why a clock that moves in a large closed curve is in an inertial frame, while one that moves in a smaller closed curve is not.

Compare Whitrow's answer with the following answer, which is found in an unsigned editorial article in *Nature*[9]:

"It seems now to be accepted that Einstein's original argument was uncharacteristically loose. The point of the illustration is that a clock at the pole of rotation may be taken to be in an inertial frame which is nearly (but not quite) properly defined by the direction of the Earth's motion around the Sun. The clock at the equator is in another. Einstein's lack of clarity concerns the inertial frame of the observer of the two clocks."

This statement implies that the answer to the question about which clock works more slowly depends on the observer. But Einstein's statement clearly implies that the slowing of the equatorial clock is a real effect and not merely an effect of observation, and this is confirmed by the fact that he added a footnote to say that his statement did not apply to pendulum clocks[10]. The answer[9] also states that the equatorial clock is in an inertial frame, and this explicitly contradicts Whitrow[7], who states that it is not.

Another answer to the same question is given by Stadlen[11], who writes:

"But the relative motion involved in this case, being circular, is non-uniform. I submit, therefore, that Einstein was wrong in saying that his prediction followed from the special theory, which deals only with the effects of uniform motion. This is not to say that the prediction was invalid. For Einstein was, intuitively, anticipating his later general theory, according to which the equatorial clock runs slower because of the centripetal force exerted upon it."

This answer is inconsistent with *both* the previous answers, since it disagrees with Whitrow[7] about whether the result follows from the special theory, and it disagrees with the *Nature* editorial[9] about whether the slower working is real or dependent on the motion of the observer. Furthermore, the fact that the prediction follows from the general theory does not make Einstein's prediction *from the special theory* valid, as Stadlen implies it does. As is well known to logicians, the fact that the conclusion of an argument is true does not guarantee that that argument is valid.

Another interesting attempt to identify a false step in one of Dingle's arguments was made by McCrea[12], who wrote:

"The false step is that Dingle regards the situation treated by relativity as the symmetric comparison of one single clock with another identical single clock (in relative motion). This is not the situation. Actually many colleagues have pointed this out, or given an equivalent answer."

Unfortunately McCrea does not identify any of the "many colleagues" whom he claims to support his argument, but it is clear from the foregoing that Ziman, for example, does not. Ziman states[5] that Dingle's question is perfectly reasonable, and the question, as he correctly quoted it, includes a statement that if there are two clocks in uniform relative motion, the special theory requires one to work steadily at a slower rate than the other. McCrea's statement is also inconsistent with Einstein's statement that a (single) clock at the equator would work more slowly than an exactly similar (single) clock at one of the poles.

Other illogical arguments

In addition to the inconsistencies already mentioned, some of the arguments used in defending special relativity are lacking in logical rigour. To illustrate this, consider some examples.

In one of the earliest attempts to refute Dingle's criticisms, Born[13] wrote as follows:

"The simple fact that all relations between space co-ordinates and time expressed by the Lorentz transformation can be represented geometrically by Minkowski diagrams should suffice to show that there can be no logical contradiction in the theory."

As the Lorentz transformation is contained in the special theory, but is not the whole theory, it is not logically valid to claim that some property of the Lorentz transformation is a sufficient condition for the whole theory to be free of logical contradiction.

In another attempt to refute Dingle, Professor I. Roxburgh[14] discusses Dingle's argument that if there are two clocks A and B in uniform relative motion, the special theory requires A to work faster than B and B to work faster than A, and this makes the theory internally inconsistent. Roxburgh states that Dingle does not even discuss what he means by "faster", and then goes on to say:

"Secondly, why is it impossible for A to go faster than B and B to go faster than A? This depends on the definition of faster. To illustrate this, consider the following two statements:

The moon is bigger than the sun.
The sun is bigger than the moon.

Are these statements mutually contradictory? This depends on the meaning of bigger. For terrestrial beings the first statement is true, for Martians the second is true. The relative size depends upon the position of the observer. So it is with time and clocks."

If it is important to define "faster", it is also important to use other words precisely; yet it is clear from the quotation that Roxburgh does not literally mean "is" in the two contrasted statements, but something like "appears to be". Thus, the two contrasted statements are not analogous to the two statements that Dingle claims to be inconsistent. Or, if Roxburgh does mean the pair of contrasted statements to be taken literally, then he, as a terrestrial being, is asserting that the moon is bigger than the sun. Although we are terrestrial beings, we know that the sun is bigger than the moon, and we know it from observations that have been made from the earth.

To put the matter in terms of logical relations, the expression "is bigger than" represents an asymmetrical relation, whereas Roxburgh's pair of contrasted statements asserts that "is bigger than" is not an asymmetrical relation[15]; there is therefore a contradiction inherent in what Roxburgh has written. Of course, a contradiction between any two statements can be avoided if one is free to disregard literal meanings of words and interpret the meanings of the statements in such a way as to avoid the contradiction. This is similar to the technique described by Dingle (ref 4, page 180) for avoiding the inconsistency in special relativity: "When the theory appears to lead to incompatible objective results, they are written off as merely different *appearances*, but claimed as *realities* when some actual phenomenon has to be explained."

Whitrow has also published an argument[7] which purports to refute Dingle's claim that the special theory is inconsistent in requiring each of two relatively moving clocks to work faster than the other. The last sentence of his argument is:

"Dingle's requirement is therefore equivalent to introducing the Newtonian concept of universal time, and this is incompatible with special relativity."

Now whether or not Whitrow's statement about Newtonian time is true, the sentence quoted does not prove that Dingle is wrong; all it states is that either Dingle is wrong or special relativity is wrong. As the point at issue is the validity of special relativity, and as the context obviously implies that the argument that ends with the quoted sentence proves that Dingle is wrong, Whitrow's argument shows an excellent example of the textbook fallacy known as begging the question[16]. Since Whitrow has subsequently published the same argument two more times[17,18], in obituary notices on Professor Dingle, the pointing out of this logical fallacy is overdue.

The foregoing examples of inconsistencies and logical fallacies in the arguments used to defend special relativity do not in themselves prove that Dingle is right, or that special relativity is wrong. However, if two scientists make inconsistent statements about the same theory, one or other of them must have made an error in deduction, or else the theory itself contains an inconsistency. In other words, the inconsistencies in the statements that have been made by the defenders of the special theory actually support Dingle's case that there is an inconsistency in the theory, rather than refuting it.

Although scientists may be convinced that the conclusion they have already reached is true, they should also be concerned with whether the arguments by which that conclusion has been reached can withstand scrutiny without revealing inconsistencies. I suggest that the scientific ideal toward which science should strive in this case is that stated by T. H. Huxley when he wrote[19] that "the scientific spirit is of more value than its products, and irrationally held truths may be more harmful than reasoned errors." It is time for the truth of this matter to be actively and carefully sought.

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Next month

Richard Lambley describes the Wireless World NiCd Battery Charger, capable of recharging cells of all common sizes in about an hour. Up to 15 cells in series can be charged at once and there is an unusual shutdown circuit to prevent overcharging. For maximum efficiency, the charging current is delivered from a switch-mode source.

Ron Slater investigates career possibilities for electronic engineers. Training, qualification requirements, salary to be expected and the areas of the country where jobs are on offer are all considered by Mr Slater, who has a great deal of experience in finding work for engineers.

David Taylor-Lewis presents a versatile tone-burst gate, which provides an integral number of on and off cycles, each adjustable from 1 to 9999. It will also give a variable duty cycle square wave between 1:9999 and 999:1 and pulse bursts or gaps from one trigger.

Philip Barker describes a method of using a computer, a video disc player and a television receiver to construct an interactive information display system for education, training or archival purposes.

On sale October 19

Using a micro to process 30 line Baird television recordings

Early television recordings on gramophone records – Phonovision – were crude in the extreme. The author describes a method for improving picture quality by correlation and digital filtering

In the late 1920's, J. L. Baird performed some experiments on the recording of television pictures onto wax discs.* This he called 'Phonovision' and for a time caught the imagination of the prospective viewing public with this and other television-related inventions. Surprisingly few of these early recordings are still in existence.

It is hoped that this article will allow people to 'look back' to those early television pictures and will show that the old and the new technologies can be brought together by anyone having access to tape copies of the recordings and a personal computer.

The requirements for the computer are not strict. A minimum specification would include sufficient memory for a long sequence of frames, some sort of graphics capability allowing the pictures to be displayed with a few grey levels, an analogue-to-digital converter and a sampling clock for the converter and the computer. In my case, there is enough memory for 32 frames at less than 1Kbyte per frame and a converter capable of sampling at 15kHz to 8bits of accuracy (256 levels of voltage) under control of the computer and the sampling clock. For more detailed pictures either the sampling rate can be increased or the playback speed of the recording decreased.

Although the author had known about mechanical television for some time, it was only comparatively recently that examples were first heard on a BBC documentary record. Out of interest, I decided to display the sounds on this record as images, using a computer, as it was able to store the pictures as a sequence of samples. These pictures could be 'replayed' over and over again to check for movement, features and details. The replay was viewed on a graphics display, but an oscilloscope with control of X,Y,Z modulation by the computer would have been just as good.

It was clear from the start of these experiments that there were no synchronization

*See references 1-6 for details of 'Phonovision'.

by D. F. McLean
B.Sc. (Hons)

pulses for identification of the start of lines and frames: the frames appeared to roll and drift in position due to playback speed variations. Synchronization of the early disc recordings was obtained by having the record platter rotation directly linked through a gearing arrangement to the scanning apparatus – figs. 4 and 5 show this arrangement clearly. The more common recordings of the mid 1930's were not linked in this way and relied on the record platter inertia to reduce picture 'hunting' or slippage.

If the original synchronous recordings had been available for these experiments a sampling clock for the computer could have been derived from the rotation of the record player, to ensure synchronization independent of playback speed. In their absence, I have evolved a method for re-aligning the sequences of pictures and inserting new synchronizing pulses, in an attempt to get nearer to re-creating the original scene quality.

30 line Baird standard

In a similar fashion to broadcast television today, the 30 line picture was created by scanning a spot of light of varying brightness in a particular pattern to form the display area. To re-create the scene as recorded, the spot had to follow this raster pattern exactly in synchronism with the video signal. If exact synchronization was not maintained, the picture would roll or slip in a similar fashion to an out-of-adjustment 'vertical hold' control on a modern tv receiver. Modern tv standards include provision for sync. pulses to 'tell' the receiver where the start of line and frame is: hence picture slippage is rarely a problem. A form of sync. on 30 line transmissions was obtained from a mixture of the inertia of the scanning disc and the actual scene content (as the television waveform was used to control the disc's rotational speed). Synchronizing the transmitter and receiver to mains frequency was only successful within the area served by a particular generator.

The scanning action on Baird 'Televisor' types of receiver was performed by a rapidly spinning disc which had a spiral pattern of holes spaced at equal angles around

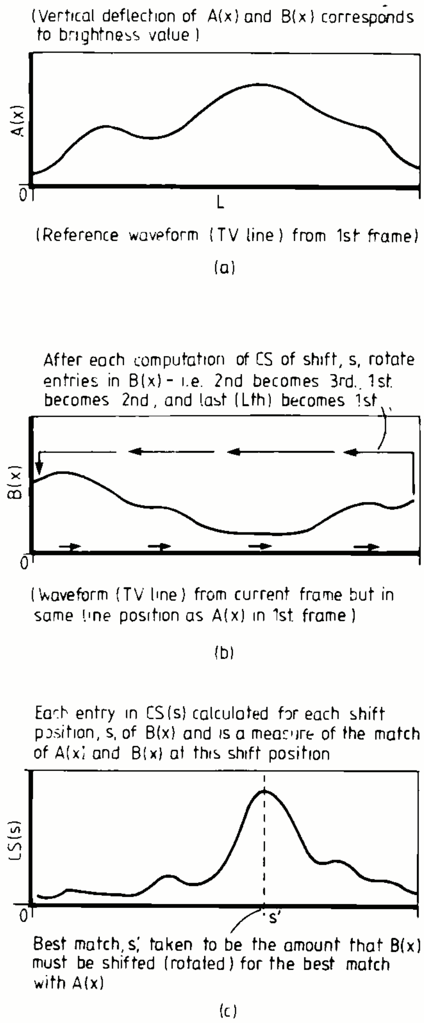

***Fig. 1.** Line matching. First two waveforms are reference and line to be matched by shifting. Samples of A multiplied by B samples produce 'score' at (c).*

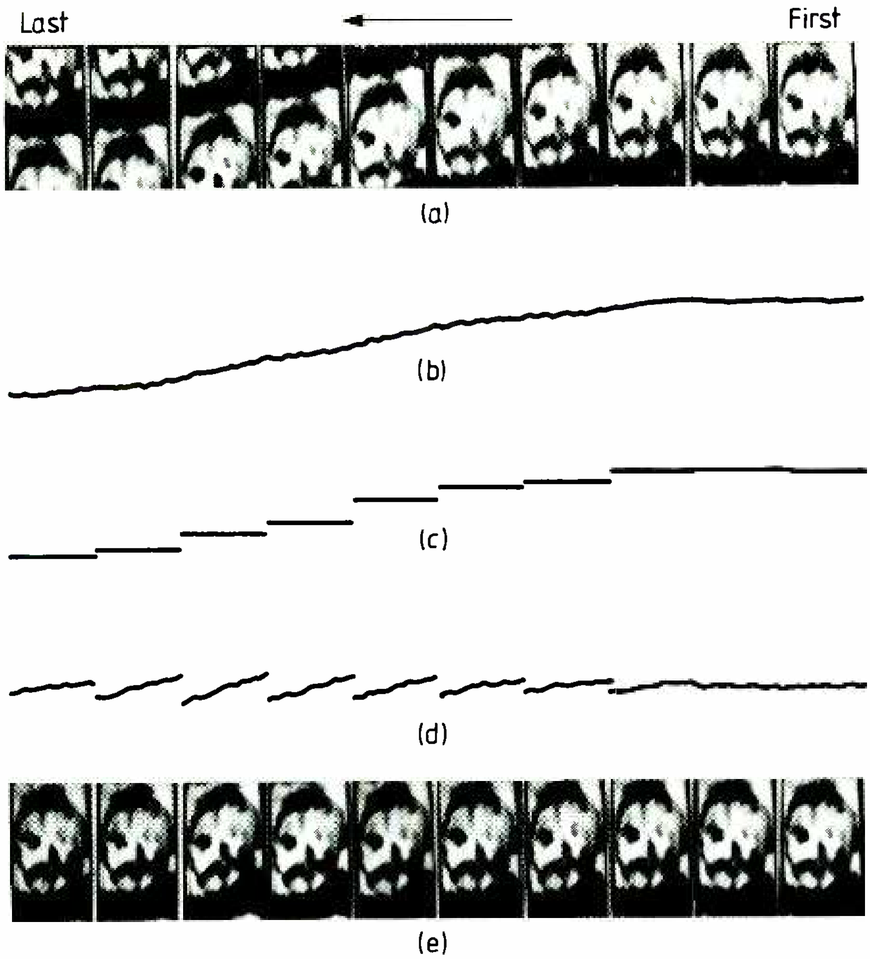

Fig. 2. Performance of one-dimensional line-matching system.

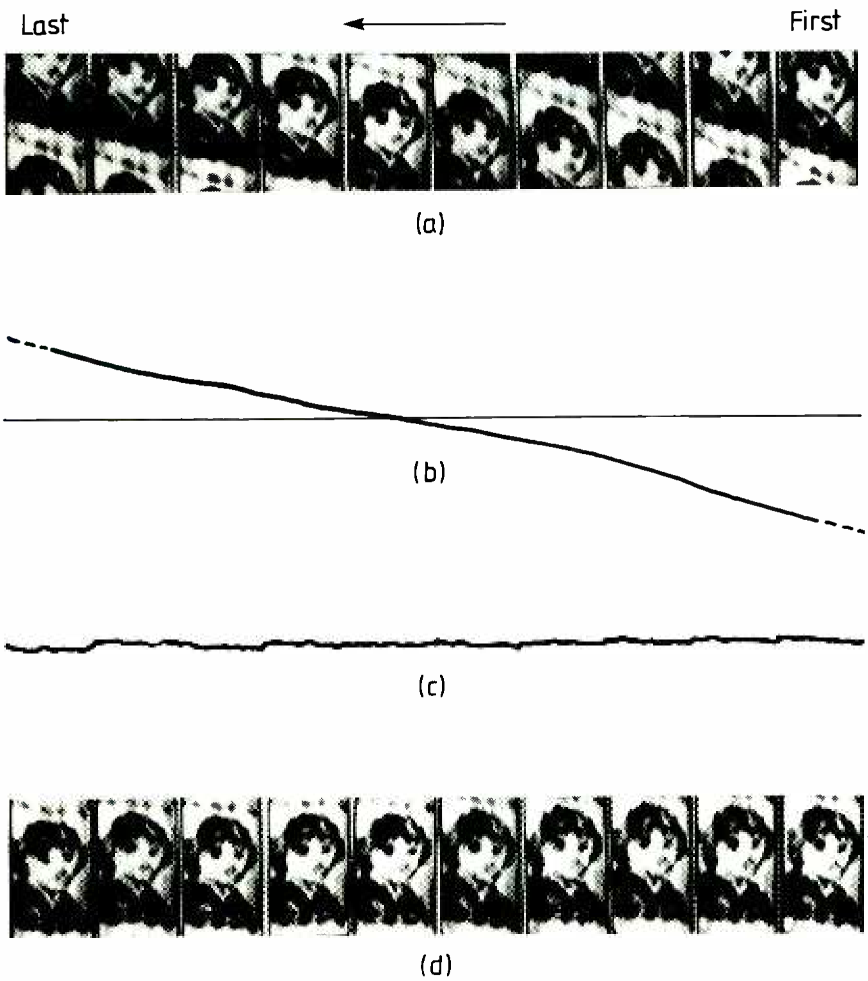

Fig. 3. Linear interpolation between adjacent frames instead of single-value shift of Fig. 2 (c). Picture tilt in each frame of (a) and removed at (d).

the disc, to give a small display area with a height-to-width ratio of 7:3. The frame or picture repetition rate was 12½Hz, each frame being made up of 30 lines. The spot of light that built up the raster scanned vertically from bottom to top to build up one line, each new line being placed slightly to the left of the previous line until a total of 30 had been scanned. The spot then returned to the position of the first line to start the next frame.

Correction of picture drift

In many applications of signal processing, the correlation or matching technique has grown in use throughout the years to become today a very powerful tool. Its main ability is, given two signals, to calculate a value whose magnitude indicates how similar the signals are. If one of the signals is delayed or shifted with respect to the other, repeated application of this matching technique can indicate how much one signal has to be shifted to match the other.

Variations of this technique were applied to short sampled extracts of recordings of early mechanical television pictures stored in computer. The aim was to find a method of accurately re-aligning a free-running sequence of frames for viewing and further processing.

Figure 2(a) shows a typical sequence of 10 frames digitized and stored in the computer memory: the first frame is on the right and all subsequent frames are to the left. The nature of the drift in frame position is quite evident. In the short space of time represented, the left and right edges of each frames have not drifted detectably, but, the images suffer from severe vertical drift in the position of line start and end (top and bottom), caused by wow and flutter in the recording medium of between 1 and 2%. The extremes of this variation would be equivalent to the difference between an image being perfectly level and one that is tilted by about 60°, corresponding to a change in the line start position from beginning to the end of a frame of about ⅔ line length. Figure 2(b) shows an estimate of the line-by-line positional error.

Also of importance is the frequency spectrum of this playback speed fluctuation. Figure 2(b) shows that fast fluctuations in speed are of much smaller amplitude than the slower frame-to-frame variations. The difficulty lies in obtaining correction methods able to cancel out *all* of these variations.

Method

Line matching. Figure 1 shows two waveforms, A and B. A is considered to be the reference and B is to be shifted to find the best match. As these waveforms represent two tv lines, the starts and ends of lines define limits. For this method to work, line B is assumed to be periodic, so that when shifted in one direction, the last sample in the line wraps around to become the first sample in the shifted line. Thus, the shifting appears to be a rotation. Waveform B is rotated a sample at a time. For each rotation, a matching score is calcu-

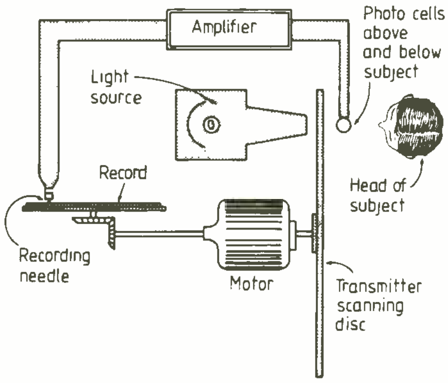

Fig. 4. Mechanical gearing of original apparatus provided steady sync.

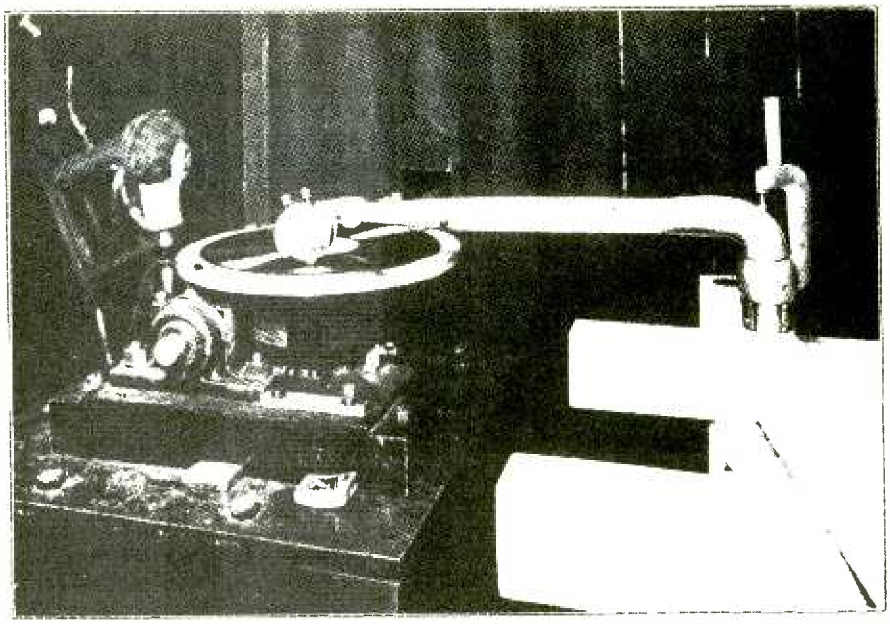

Fig. 5. System of Fig. 4 in use, recording the 'dummy head.'

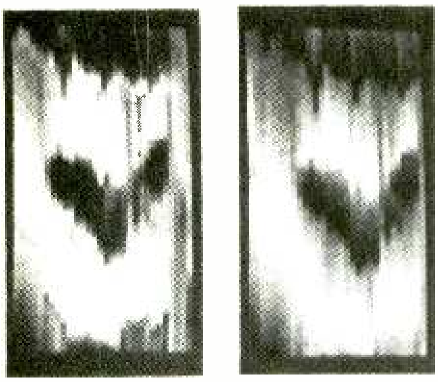

Fig. 6. Phase correction by all-pass filter.

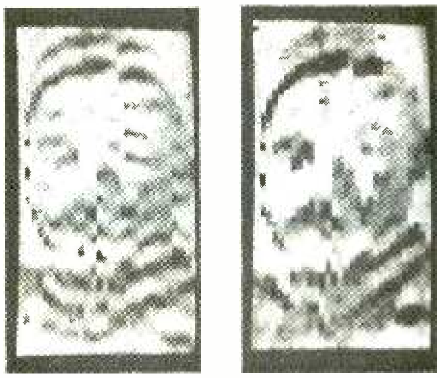

Fig. 7. Digital filtering was carried out within the computer.

Fig. 8. Further examples of digital filtering to reduce effect of head-cutter resonance.

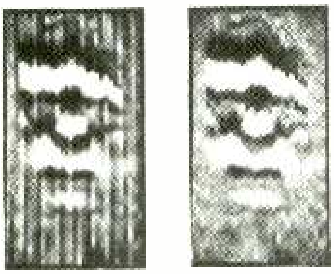

Fig. 9. Digital filter also used to reduce effect of low-frequency noise.

lated by multiplying each sample in the rotated line B by the corresponding sample in line A. The sum of these products is the matching score. The process is repeated by rotating line B and calculating another score for this new shift position, s. The equation below describes this sum of products.

$$CS(s) = \sum_{x=1}^{L} A(x).B(x-s)$$

where CS is the matching score, x is sample position from start of line, s is the current shift value in samples and L is the number of samples in the line.

The matching scores are stored in a list so that, at the end of one complete rotation of line B back to its starting position, the position in the list of the maximum score can be taken to be the number of samples by which B must be rotated to be 'lined-up' with A.

For each line in the current frame, the current line was matched against the corresponding line in the reference frame. The position of maximum score for the above equation was taken to be the value by which the current line had to be shifted to match best the line in the reference image. Initially the reference frame corresponded to the first frame in the sequence. After each line was corrected, the line in the reference frame was averaged with a fraction of the current line to take into account any scene change at the horizontal position of the line. The average was stored back in the reference frame.

The results of one-dimensional matching were somewhat mixed in success. For clear, stable and simple scenes, the results were excellent, leaving an extremely stable sequence of rectified frames with very low jitter in vertical position from one frame to the next. However, for fast-moving complex scenes, the performance was poor with unstable breaking up of the picture structure and consequent severe degradation in image quality.

Line-jitter removal. One of the recordings suffered from severe timebase jitter, causing large changes in the position of the start of the line on subsequent lines within a frame. In this case only it was considered worthwhile to use a different form of one-dimensional matching.

Instead of matching the current line in the frame being processed with the same line in the reference frame, the current line was matched against the previous line in the *same* frame. I have used this technique successfully with slow-scan television pictures received on the amateur bands[8]. Line-to-line jitter is removed in a fairly uncontrolled way at the expense of geometrical distortion of the picture. As it was considered important to maintain the picture geometry, this technique was not used on the other recordings.

The one recording which was processed using this technique suffered from static errors in the position of the start of each line in any frame. This was presumably caused by errors in the position of the holes in the scanning disc, causing some lines to start earlier or later than adjacent lines. Figure 11 shows a typical frame before and after correction of this fault.

Frame matching. The problem with the line matching technique was that it could only allow a small amount of lateral movement in the scene before instability degraded the picture quality. Because the matching algorithm was essentially one-dimensional in nature, it could not cope with any sideways movement. The algorithm had no 'knowledge' of any structure in adjacent lines. To attack this problem, a variation on the original method was devised and tested with excellent results.

This new method was based on the fact that the scene content (not position) varied little from frame to frame. There was no abrupt scene changes. Each frame can be thought of as a two-dimensional brightness distribution where each point (x,y) has an associated brightness value B(x,y). Using one frame as a reference, the idea was to 'slide' the frame to be corrected horizontally (in x) and vertically (in y) until a best match was found. The equation for calculating the matching score at any shift value (s,t) was derived from the one-dimensional equation given earlier and is given below

$$CS(s,t)=\sum_{x=1}^{L}\sum_{y=1}^{M}A(x,y).B(x-s,y-t)$$

where A(x,y) is the brightness in the reference frame at point (x,y), B() is the brightness in the current frame being processed at the shifted (x,y), L,M are the max. no. of samples and lines in x and y respectively, and CS (s,t) is the score for a possible match at shift value (s,t).

The 'sliding' of the frames is similar to the cyclic shift used when matching lines (Fig. 1) but is extended to two dimensions. A cyclic shift of the current frame was performed for each shifted position (s,t), and all possible shifted positions of one frame with respect to the other was used to create a list of scores for matching.

Using the position of maximum score, the current frame was cyclically shifted from its original position in both x and y directions to match it with the reference frame. Each point of the current and reference frames was then averaged with a user-selected weighted value. The averaged result was stored to become a new reference frame for the next frame in the sequence, which served to accommodate increasing differences between the successive and reference frames.

The positional errors that had to be corrected were only in the vertical direction, however. During the time taken for a short sequence, the horizontal drift could be ignored as it was 1/30th of the amplitude of the vertical drift in this case. Correction only in the vertical direction was achieved simply by removing the calculated lateral (x) shift *after* the full two-dimensional matching and shifting had been applied and the reference frame updated with the weighted average. The averaging of the reference frame with a fraction of the current frame had to be done by using the current frame shifted in *both* horizontal and vertical directions to track lateral movement in the scene.

The effect of using two-dimensional processing but only correcting vertically was to allow horizontal motion without any loss of stability in the processed sequence of frames. It is indeed most fortunate that the line scanning direction of the early mechanical television experiments was vertical as most scene motion in natural objects is typically only from side to side.

Figures 2(a) to 2(e) show the performance of the basic two-dimensional correction method described in the previous subsection. Figure 2(a) is the original digitized sequence showing significant vertical rolling of the frames in the sequence. Figure 2(b) shows an estimate of the actual positional error in the vertical direction on a line by line basis. Figure 2(c) displays the actual calculated result of how much each line in each frame had to be shifted. Each line in a particular frame was shifted by the same amount so that the correction function (Fig. 2(c)) shows only a stepped approximation to the actual positional error. Figure 2(d) is the residual error after applying the offset of Fig. 2(c) and Fig. 2(e) is the corresponding corrected sequence of frames.

By comparing Figures 2(b) and 2(c), a closer approximation to the actual positional drift could be made by performing a linear interpolation between the vertical shift values of adjacent frames. The method was quite simple to implement and provided considerable improvement to frames distorted by sampling at a slightly incorrect sampling rate.

Figures 3(a) to 3(d) show the result of processing a sequence digitized at slightly too high a sampling rate. The result here is equivalent to a 0.7% increase in the desired sampling rate. Figure 3(b) shows the linearly-interpolated error derived from the vertical shift calculated using the matching equation: the error wraps around as the shift value has cyclic symmetry. Applying this interpolated set of values (Fig. 3(b)) to the original sequence gave rise to the processed sequence as shown in Fig. 3(d). Figure 3(c) shows the residual error. The most significant result from this example is the removal of the overall tilt from each frame.

A natural extension of the original line matching idea resulted in a stable and robust method of accurately re-aligning a sequence of tv frames with no further information than the scene being transmitted. The restriction of only applying vertical correction resulted in the

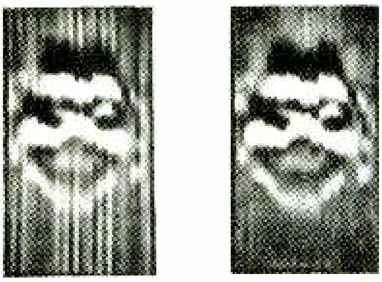

Fig. 10. *Good example of removal of hum by digital filter.*

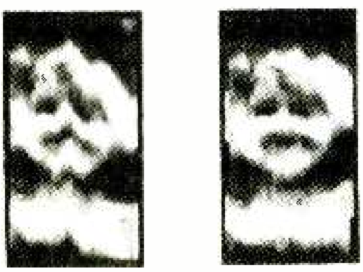

Fig. 11. *Correction of variation of position of line starts within a frame.*

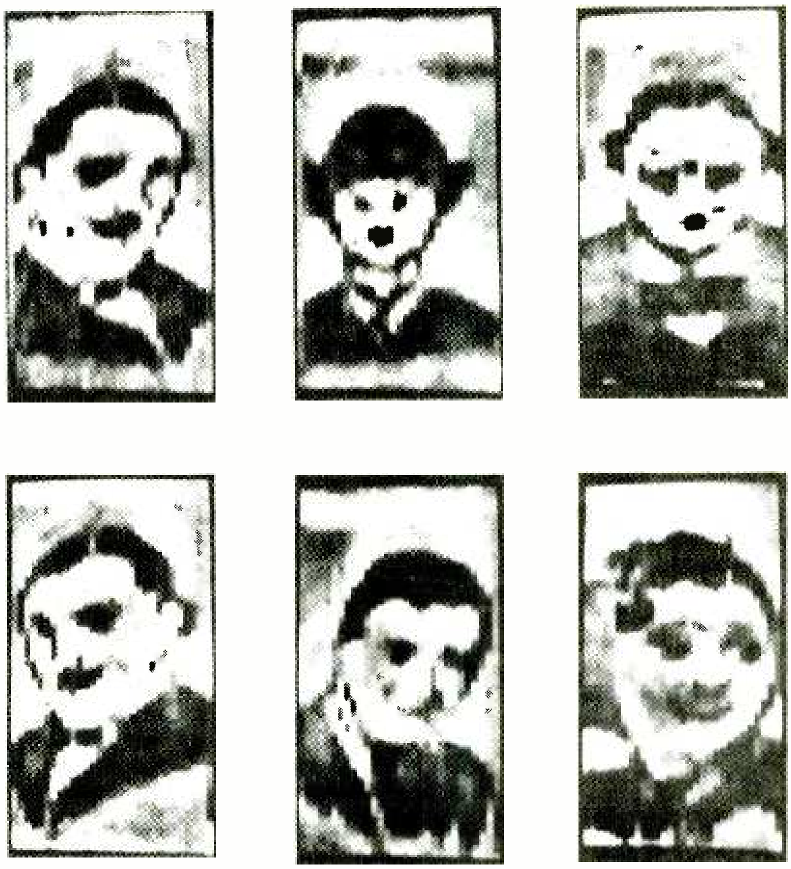

Fig. 12. *Set of pictures produced by system from noisy and distorted taped recordings. Pictures are still crude, but are enormous improvement on untreated versions.*

preservation of horizontal motion with no loss in stability. Further correction for speed variations proved to be a powerful method for removing the 'tilted' effect on certain frames. This required little computational overhead.

Although not able to remove fluctuations faster than the frame rate, the frame matching technique has proved to be a useful tool in assisting the analysis of these early mechanical recordings.

Image quality

The quality of recording on wax discs in the 1920's was adequate for voice or music reproduction although it was far from hi-fidelity. When used for recording Baird's 30 line television signal, wax discs proved themselves to be quite a poor recording medium. The recording apparatus was not capable of recording the very high or the very low frequencies in the signal, and yet the shape of the recorded waveform – much less important for voice or music recording – had to be free of distortion for accurate reproduction of the scene being televised.

The limitations of base-band (unmodulated) recording on wax discs resulted in various types of distortion of the television waveform. The most common types observed on the discs of the period are: phase distortion – poor low frequency response, giving rise to phase shifts; low-frequency noise – eg, main hum aggravated by reduced signal level at low frequencies; high-frequency instability generated by head cutter resonance; noise caused by disc surface granularity; and residual timebase errors, giving rise to ragged edges to each frame.

Image filtering

One-dimensional filtering. Most types of distortion present on these recordings can be reduced by one-dimensional digital filtering techniques. This means that the television signal is treated as if it were an audio signal: the relationship between lines and frames is not used in the processing.

Phase distortion can be reduced by processing the signal through an all-pass phase shifter. It is the author's experience that using a simple electronic circuit to perform this function relieves the computer from time-consuming processing and gives instant feedback on the correction being applied to the signal. Figure 6 shows the result of phase correction.

Head-cutter resonance is predominant on one particular recording. Although external pre-filtering can reduce the effect of the resonance, digital filtering within the computer was found to be much more flexible and was able to reduce the resonance without adversely affecting the resolution of the picture. Figures 7 and 8 show the reduction possible by digital filtering.

Low-frequency noise was more effectively reduced again by using digital filtering. In one of the recordings, mains hum was present at a high level after attempting to recover low frequency information in the signal. The reduction of interfering signals on early Baird recordings is demonstrated well on Figs 9 and 10.

Although the waveform is by nature one-dimensional, the correlation between lines and frames can be used to suppress some types of irregularities in the signal. One particularly powerful technique involves processing the points in the scene exactly one frame apart, a process called temporal filtering.

Temporal filtering. One of the most effective processes on the frame- or line-matched sequence of frames was the temporal filter. Both surface noise and residual errors in the position of the lines were considerably reduced without affecting detail in the individual frames significantly.

The idea is that points having the same position along the same line on adjacent frames should be very close in their value of brightness. The filter creates a new point from the brightness values of the same point on three successive frames, chosen to be the middle value in brightness amongst the three. Using this median value allowed isolated errors to be corrected completely: line jitter, noise and to a lesser extent movement were suppressed without the blurring action of a spatial filter (i.e. one acting along or across lines). Reference 9 describes this technique applied to high resolution television.

Temporal filtering is both difficult and expensive to implement in high-resolution television because of the large amount of high speed memory required to store two (or more) frames. The memory and speed requirements for 30 line television however makes it very much simpler to demonstrate powerful image processing techniques such as this.

The author

After graduating from Glasgow University, the author spent several years with EMI Central Research Laboratories before joining Logica as an image-processing consultant. With a strong grounding in television, he has worked on digital video and audio systems, automatic inspection methods and, more recently, on the image-processing system for a fingerprint identification system. In his spare time, he explores aspects of television techniques.

Software

A program for acquiring data, displaying the result, re-aligning and processing a digitized sequence of 30 line television was written in machine code for acquisition and re-transmission: the processing routines could have been written in any language. A decisive factor in using machine code for the matching algorithms was the vast number of calculations required to match-up and re-align the frames. For line matching, this included about one million multiply operations for a sequence of 32 frames. Matching up 32 frames took 150 seconds in Z80 machine code with the processor running at 4MHz. Performing the multiply operation in hardware reduced the execution time to 65 seconds for a 32 frame sequence.

The implementation of the two-dimensional frame matching took considerably longer to execute than that of the one-dimensional line matching, since frame matching needed a greater number of multiply and accumulate operations (30 times) plus higher precision in the score value for matching. Considering that an image or frame in this case had 960 samples, point-by-point multiplication and score accumulation gave the staggering figure of just under one million of these operations per frame. The software implementation took 3 minutes per frame – 96 minutes in total for a complete 32 frame sequence. Performing just the multiply operation in hardware reduced this execution time to 80 seconds per frame – 40 minutes per sequence. A similar routine in Basic was estimated to take about 75 hours per sequence, while a compiled PASCAL routine on the same machine took 17 hours per sequence.

The one-dimensional and temporal filtering all required between 2 and 10 seconds to process a 32 frame sequence of 960bytes per frame. For high-resolution processing with 1920 bytes per frame, fewer frames could be held in memory. Because the amount of data was similar in both the low and high-resolution sequences, the processing time for each was similar. Fourier analysis of the signals to determine which filter to use took a few minutes for each frame.

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3. Newnes 'Television and Short-Wave Handbook' 1st edn., 1934, pp 47-50.
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5. Patent no. 289104, 16-APR-29, J. L. Baird.
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Assembly language programming

Parts of these lists were illegible when originally printed in Bob Coates' sixth tutorial in the September issue. We apologize for any inconvenience caused by the poor printing.

List 1. Assembly language for summing numbers on the Picotutor.

```
024   4F                CLRA             CLEAR SUMMING REGISTER
025   AE52              LDX    #VALUE1   INIT. POINTER WITH 1ST 8 BIT VALUE ADD
027   FB        LOOP    ADD    0,X       ADD 8 BIT VALUE TO SUMMING REG.
028   5C                INCX             INCREMENT POINTER
029   3A51              DEC    VALUES    DECREMENT COUNTER
02B   26FA              BNE    LOOP      BRANCH IF COUNTER NOT ZERO
02D   B750              STA    RESULT    STORE RESULT
02F   BC80              JMP    START     RETURN TO MONITOR
```

List 2. Summing numbers using the 6800.

```
1000  4F                CLRA
1001  CE1052            LDX    #VALUE1
1004  AB00      LOOP    ADDA   0,X
1006  08                INX
1007  7A1051            DEC    VALUES
100A  26F8              BNE    LOOP
100C  B71050            STA    RESULT
100F  7E7D97            JMP    START
```

List 3. Summing numbers using the 6809.

```
1000  4F                CLRA
1001  8E1052            LDX    #VALUE1
1004  AB00      LOOP    ADDA   0,X
1006  3001              LEAX   1,X
1008  7A1051            DEC    VALUES
100B  26F7              BNE    LOOP
100D  B71050            STA    RESULT
1010  7E7D97            JMP    START
```

List 4. Z80 number summing program.

```
2000  3A5120            LD     A,(VALUES)
2003  47                LD     B,A
2004  AF                XOR    A
2005  215220            LD     HL,VALUE1
2008  86        LOOP    ADD    A,(HL)
2009  23                INC    HL
200A  10FC              DJNZ   LOOP
200C  325020            LD     (RESULT),A
200F  C30000            JP     0
```

List 5. Multiplication program for the 6805.

```
024   3F62      MUL     CLR    PROD
026   3F63              CLR    PROD+1
028   AE08              LDX    #8
02A   3863      MUL1    LSL    PROD+1
02C   3962              ROL    PROD
02E   3861              LSL    MPLIER
030   240B              BCC    MUL2
032   B660              LDA    MCAND
034   BB63              ADD    PROD+1
036   B763              STA    PROD+1
038   4F                CLRA
039   B962              ADC    PROD
03B   B762              STA    PROD
03D   5A        MUL2    DECX
03E   26EA              BNE    MUL1
040   BC80              JMP    START
```

List 6. 15-by-7-bit division using the 6805.

```
024   AE08      DIV     LDX    #8        SET COUNTER
026   3861      DIV1    LSL    DDEND+1   SHIFT L QUOT./LS 8 BITS OF D/DEND
028   3960              ROL    DDEND     SHIFT L MS 8 BITS OF D/DEND
02A   B660              LDA    DDEND
02C   B162              CMP    DISOR     DO TRIAL SUBTRACTION
02E   2506              BCS    DIV2      BRANCH IF NOT SUCCESSFUL
030   B062              SUB    DISOR     SUBTRACT D/SOR FROM 8 MS BITS D/DEND
032   B760              STA    DDEND     STORE RESULT AS D/DEND
034   3C61              INC    DDEND+1   AND INC. QUOTIENT
036   5A        DIV2    DECX             DEC. LOOP COUNTER
037   26ED              BNE DIV1         BRANCH IF NOT FINISHED
039   BC80              JMP    START     FINISH
```

List 7. Simulation of the 6800 DAA instruction included in the Picotutor.

```
                        * DAA - THIS ROUTINE SIMULATES THE DAA INSTRUCTION OF THE
                        *       6800 ETC.   IT SHOULD BE CALLED AFTER AN ADD OR AI
                        *       INSTRUCTION AS....    JSR DAA.
                        *       UPON EXIT, A IS BCD CORRECTED AND C IS SET FOR
                        *       MULTIPRECISION BCD ADD.
                        *
386   B71E      DAA     STA    TEMPA     SAVE INPUT VALUE
388   BF1F              STX    TEMPX
                        *
                        * CALCULATE CORRECTION FACTOR
                        *
38A   5F                CLRX             BUILD CORRECTION IN X
38B   101D              BSET   0,BITSTR  SET CARRY STORE
                        *
38D   2506              BCS    DAAHG
38F   111D              BCLR   0,BITSTR  BUT CLEAR CARRY STORE IF CARRY ISN'T SET
391   A199              CMP    #H'99'
393   2302              BLS    DAALOW    INPUT <=H'99'
395   AE60              LDX    #H'60'      HIGH NIBBLE NEEDS CORRECTION
                        *
397   2906      DAALOW  BHCS   DAAL6
399   A40F              AND    #H'F'
39B   A109              CMP    #9
39D   2304              BLS    DAADNE    NO LOW NIBBLE CORRECTION
39F   9F        DAAL6   TXA
3A0   AB06              ADD    #H'6'       LOW NIBBLE CORRECTION
3A2   97                TAX              TOTAL ADJUST BACK TO X
                        *
                        * CORRECT ACCUMULATOR NOW
                        *
```

continued over

List 7. *(continued).*

```
3A3   9F       DAADNE  TXA                  CORRECTION GOES INTO A
3A4   BB1E             ADD    TEMPA         AND IS ADDED TO ORIGINAL VALUE
3A6   BE1F             LDX    TEMPX
3A8   2504             BCS    DAA2          BRANCH OUT IF CARRY ALREADY SET
3AA   011D01           BRCLR  0,BITSTR,DAA2 OR IF IT WAS CLEAR ON ENTRY
3AD   99               SEC                  BUT SET CARRY IF IT WAS ON ENTRY
3AE   81       DAA2    RTS
```

List 8. Adding two numbers using the simulator of List 7.

```
024   A699     LDA   #$99
026   A849     ADD   #$49
028   83       SWI
029   BDB3     JSR   DAA
02B   83       SWI
```

List 9. Converting decimal 2748 to binary form using Picotutor.

```
024   A627     LDA   #$27
026   B71A     STA   POINT
028   A648     LDA   #$48
02A   B71B     STA   POINT+1
02C   AE60     LDX   #$60
02E   BDB9     JSR   BCDBIN
030   BC80     JMP   START
```

List 10. Assembly language for Picotutor subroutine BCDBIN.

```
                *  BCDBIN - CONVERTS A 4 DIGIT PACKED BCD NUMBER IN
                *           POINT TO 14 BIT BINARY, AND PLACES
                *           RESULYT IN 0,X/1,X.  BCD NUMBER
                *           UNALTERED. SETS CARRY IF A NON-DECIMAL
                *           DIGIT ENTERED.
                *
404   7F        BCDBIN CLR   0,X          CLEAR RESULT REGISTERS
405   6F01             CLR   1,X
407   131D             BCLR  1,BITSTR     CLEAR OVERFLOW FLAG
409   B61A             LDA   POINT        PUT 1000'S DIGIT IN POINTS
40B   44               LSRA
40C   44               LSRA
40D   44               LSRA
40E   44               LSRA
40F   B71C             STA   POINTS
411   AD47             BSR   BCDCHK       CHECK DIGIT IS <=9
413   270A             BEQ   BCB2         BRANCH IF DIGIT = 0
                *
415   A603      BCB1   LDA   #3           ADD H'300' TO RESULT
417   FB               ADD   0,X
418   F7               STA   0,X
419   A6E8             LDA   #H'E8'         ADD H'E8' TO RESULT
41B   AD32             BSR   BCDADD       (TOTAL ADD=H'3E8', 1000 DEC)
41D   26F6             BNE   BCB1         BRANCH IF 1000'S NOT ZERO
                *
                *
41F   B61A      BCB2   LDA   POINT        PUT 100'S DIGIT IN POINTS
421   A40F             AND   #H'F'
423   B71C             STA   POINTS
425   AD33             BSR   BCDCHK
427   2706             BEQ   BCB4         BRANCH IF DIGIT = 0
                *
429   A664      BCB3   LDA   #H'64'         ADD H'64' (100) TO RESULT
42B   AD22             BSR   BCDADD
42D   26FA             BNE   BCB3
                *
                *
42F   B61B      BCB4   LDA   POINT+1      PUT 10'S DIGIT IN POINTS
431   44               LSRA
432   44               LSRA
433   44               LSRA
434   44               LSRA
435   B71C             STA   POINTS
437   AD21             BSR   BCDCHK
439   2706             BEQ   BCB6
                *
43B   A60A      BCB5   LDA   #H'A'          ADD H'A' (10) TO RESULT
43D   AD10             BSR   BCDADD
43F   26FA             BNE   BCB5
                *
                *
441   B61B      BCB6   LDA   POINT+1      ADD 1'S TO RESULT
443   A40F             AND   #H'F'
445   AD13             BSR   BCDCHK
447   AD06             BSR   BCDADD
                *
                *
449   98               CLC
44A   031D01           BRCLR 1,BITSTR,BCB7 BRANCH IF NO ERROR
44D   99               SEC                SET CARRY AS NON-DECIMAL NO.
44E   81        BCB7   RTS                RETURN, CONVERSION COMPLETE
                *
                *
                *
44F   EB01      BCDADD ADD   1,X          ADD NUMBER IN A TO RESULT
451   E701             STA   1,X
453   A600             LDA   #0
455   F9               ADC   0,X          PASS ON CARRY
456   F7               STA   0,X
457   3A1C             DEC   POINTS       DECREMENT THE DECIMAL DIGIT
459   81               RTS
                *
                *
                *
45A   A109      BCDCHK CMPA  #9           SET ERROR FLAG IF DIGIT >9
45C   2302             BLS   BCDCH1
45E   121D             BSET  1,BITSTR     SET FLAG
460   4D        BCDCH1 TSTA
461   81               RTS
```

Forth language

Complementing his description of a 6809-based microcomputer, Brian Woodroffe details the language used – Forth – and why he chose it, in this second series.

by B. Woodroffe

Forth is a language well suited to modern microprocessors and is widely used in such diverse applications as word processing, data-base management, instrument and process control, video games and data acquisition. In a kernel of less than 10Kbyte the following features are provided

– An interactive system.
– A high-level compiler with all standard control features.
– Fast execution, comparable with machine code because of the compiler.
– The language system is largely processor independent; only around 20% of the code written in assembly language need be changed to suit the computer.
– Virtual memory and application-oriented program modules.

Further, the system may be readily extended to suit new applications because the compiler can be modified by the user and new data structures introduced. These features are achieved by defining a virtual machine which is easily simulated by any target machine. Using 'threaded code', transferring control in the host from one virtual machine instruction to the next is quick and easy. Instructions of the virtual machine are used to build the monitor and compiler. Using the monitor the user may examine the effect of a series of Forth instructions and using the compiler this series may be added to the instruction set for future use.

Background

Forth is a computer language for fourth generation computers[1]. The language would have been called Fourth but six letters would not fit in the IBM1130 job-control language that its inventor, C. H. Moore, was then working with. Today Moore's company Forth Inc. is foremost in marketing FORTH for many different applications, besides the field of astronomy where it first found favour[2]. Other companies such as Miller Microcomputer Services and Laboratory Microsystems sell their own versions of Forth but the prime mover of Forth in the home-computer/hobby field is the Forth Interest Group* (FIG). They have made versions of Forth available for many computers including the PDP-11 and for 8080/Z80, 6800, 8086/8088 and 6502 processors. There are many versions of Forth and while all are similar no two are necessarily identical. For example, Poly Forth, FIG Forth and Forth 79 are all Forth but they are not the same. They differ primarily because of differences in the processor on which they run (16 or 8 bit memory, port or memory mapped i/o, etc.). FIG Forth will be used in all following examples.

*Forth Interest Group, PO Box 1105, San Carlos, CA94070, USA.

Forth is a collation of different sofware concepts forming a coherent whole. As an operating system, it is not as powerful as most but it takes care of all terminal and disc input and output. Small assembly-language routines must be supplied by the user to interface his hardware to the relevant system calls. It is also possible that memory-allocation changes may also have to be made. Most of Forth is written in Forth. It may seem strange that a language may be defined in terms of itself but one would use English words to explain the English language. Defining the language in this way means that programs may be transferred between different computers and implementations. There is a base instruction set which must be written in the machine code of the host computer. This is the only machine code required and the process is known as simulating a virtual Forth machine.

Most computer languages are programs which, recognizing statements in a source language, convert them into a target language. Usually the source language is text readable by humans in ASCII form and output is machine code of the computer. This is not always the case: cross compiling results in the target code being different from the host computer machine code. More exceptionally there are cases where the machine code can only be executed by a hypothetical computer, an example being O-code for the language BCPL[3] and P-Code for certain implementations of Pascal[4]. This is also the case for Forth and the virtual-machine execution mechanism will be explained first.

Threaded code

Explanation is simplified by visualizing a machine-code program for the processor concerned as a succession of subroutine calls. These calls transfer program control to each subroutine in turn. A stack, i.e., last-in-first-out list, would be the mechanism by which each subroutine returns control to the correct point in the main program. Knowing that the main program is solely a succession of calls it is now possible to reduce the main program to a list of subroutine addresses by removing the subroutine op-code, and to have a special program known as an address interpreter to transfer control down the main program address list. This is called threaded code, for the main program is the thread into and out of which the address interpreter threads control[5], List 1.

List 1. Comparisons of hard code and direct threaded code.

Normal code	Threaded code	
	Address interpreter	Thread
call A	1: ip+1 –> ip	A
call B	call [ip]	B
call C	jmp 1	C

In List 1, letters A, B and C denote machine-code subroutines, ip is the threaded-code instruction pointer and parentheses indicate one level of indirection. Threaded code trades the cost of the code for each call saved for address interpreter speed. In a long program the code cost of the address interpreter will be negligible. Further savings can be made by replacing the subroutine return statement by a jump to the address interpreter and changing the address interpreter as shown below. This releases the stack pointer used for subroutine calls and returns. It is important that the instruction pointer can be speedily accessed, for example by keeping it in a processor register, so as not to slow down the address interpreter by causing unnecessary memory activity.

If the lists are considered to be the actions of a virtual machine then a software routine NEXT represents the hardware execution fetch of the virtual machine. In a threaded-code computer the time of interpreting these lists is dominated by the time of the NEXT operation so it is best to run threaded code on a computer that handles NEXT efficiently or to use microcode.

```
Code routine including return
A:  xxx
    jmp NEXT

New address interpreter
NEXT:  ip+1 -> ip
       jmp [ip]
```

Indirect threaded code

The next improvement is to allow called routines to be not just pure machine code but also address lists. This is done by having a special routine that knows that the following data in the list are not code but addresses that must again be interpreted. Further, the routine must suspend interpretation of the main program while interpreting this new list of addresses. Return of control to the suspended list is done using a stack to save and restore the instruction pointer which is similar to the machine-code subroutine call/return operation. There must be an equivalent code routine to return control to the main list.

```
Normal code routine
A:  machine code
     . . .
    jmp NEXT
```

```
Threaded routine
P:  sp-1 -> sp
    ip    ->[sp]   (push current ip)
    #L-1 -> ip     (start interpreting new
                    list)
    jmp NEXT
L:  A              (code routine)
    B
    C
```

```
Return routine
[sp] -> ip         (pop ip)
sp+1 -> sp
jmp NEXT
```

As most routines are likely to be lists and not machine code this stacking method, similar to subroutine calling, will take a lot of code area. Considerable space would be saved if there was just one copy of this routine. The address interpreter would normally jump to this routine but it would also have to execute code routines. This is done by making the first element of each list a pointer to code rather than the code itself. In the case of lists the pointer points to the stacking operator but with code routines it points to the next code address.

```
New address interpreter
NEXT:  ip+1 -> ip
       [ip] -> w
       jmp [w]
```

```
Stacking operation
DOCOL: sp-1 -> sp
       ip   -> [sp]
       w+1 -> ip
       jmp NEXT
```

```
Destacking operation
SEMIS: [sp]   ->ip
       sp+1 -> sp
       jmp NEXT
```

```
Code routine
A:  $+1   (point to next location)
    xxx
    . . .
    jmp NEXT
```

```
List routine
DOCOL
P
Q
SEMIS
```

This is the equivalent of machine-code subroutine call and return instructions. In Forth, the stacking and destacking operations are called DOCOL and SEMIS respectively. At the beginning of each address list, the extra address introduces a level of indirection – this is indirect threaded code[6]. In Forth the lists are divided into two parts, one being the code field which points to the address and the other known as the parameter field where the code is. These two parts and dictionary data, to be described, form a WORD. Code pointed to by the code field determines how the parameter field is interpreted. In the case of code words, the code field points to the parameter field. When the code field points to DOCOL, the parameter field is to be interpreted in a similar way to a subroutine. It is possible for the code field to point to some other routine which may make different use of the parameter field. Two examples of this in Forth are DOCON and DOVAR. The former treats the value in the parameter field as a constant and pushes it onto the data stack, to be described, whereas DOVAR pushes the address of the parameter field which is used as the storage location for that variable. To enable these routines to access the parameter field a third register, known as 'w', is required.

The address interpreter for indirect threaded code is more complicated than that for direct threaded code and so it is even more important to choose a processor with a suitable instruction set. Surprisingly for direct threaded code, NEXT can normally be coded using the processor subroutine-return op-code provided that the processor uses a stack that may be placed anywhere in memory. As the stack pointer is pointing to the thread, the processor must not receive interrupts for the status cannot be saved without destroying the thread. NEXT for indirect code is more complicated as it involves an extra level of indirection.

Choosing a processor, stacks and language-control structures are subjects of the next Forth language article.

An i.c. in the Forth computer switch-mode power supply on page 61 of the July issue was incorrectly designated the MC3045. The correct designation is MC3405.

References

1. C. Moore, *Forth dimensions*, vol. 1, no. 6, FIG
2. C. Moore, *Astronomical Astrophysics Supplement*, 1974, vol. 15, pp.497-511
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4. D. Barron, Pascal, the language and its implications, Wiley, 1981
5. J. Bell, *Communications of the ACM*, vol. 16, no. 6, pp.370-372
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WW

Glossary

Machine code. The representation, usually in hexadecimal, of the instruction and data encoding that is understood by the computer.

Assembly code. A human readable form of machine code. There is a one-to-one correspondence between assembly code and machine code.

Instruction fetch. A computer works by successively fetching and executing instructions. The instruction fetch is made from the location pointed to by the program counter. The program counter is incremented one instruction at a time unless a jump (branch etc) occurs.

Virtual machine. At any level of analysis the computer will have a repertoire of instructions that it can execute. This is normally the machine/assembly level instructions. However by running a program on this machine it can be made to look as though it has a different instruction set. It is possible to time share the computer between two or more users so that they both think they have a separate computer. These techniques are known as creating a virtual machine.

Op-code. Each different instruction is encoded into a unique symbol (usually binary, known as an op-code.

Host computer. The computer on which the program is currently executing.

Target computer. The computer on which the program being developed will execute.

Cross compilation. A cross compiler runs on one machine and produces output for another. Host and target machines have either different op-code encodings or instruction sets, or both.

Compiler. A program recognizes that the input language agrees with a defined grammar. If it agrees it will usually produce an output in some other defined language, or error messages as to why the input is not in the source language. Normally, input is English-like (e.g. Forth/Pascal) and output is machine code.

Microcode. Microcode is a mechanism used to build computers to understand machine-code instructions. Within a microcoded computer there is another computer with its own microcode instruction set. By writing new microcode, the assembly-level machine can be made to have new instructions.

Kernel. A central program on whose resources all application program rely and interface to.

Operating system. A computer program which manages the computer's resources. (It will take care of all input-output etc, so that the application programmer need not worry about how to get characters to and from a terminal, etc)

Software driver. A small program specific to each input/output device that is included in the operating system.

Terminal. Visual-display unit and keyboard, teletype.

Indirection. An addressing mechanism. An instruction requires data to act upon – the instruction gives details of how to find that data. Normally it will give the address of the data, but in the cases of indirect addressing it will give the address at which the address of the data may be found. That is one level of indirection. Up to three levels, ie the address which contains the address which contains the address which contains the data, are common.

Call. A subroutine call is a mechanism whereby machine-code execution is temporarily suspended while the subroutine is executed. Execution will restart at the instruction after the call when the subroutine finishes. The restart address (return address) is often kept on a stack.

Code field. A part of a Forth Word definition. The contents of the code field always point to machine code of the target machine.

Machine. Computer, (state machine).

Monitor. A program that monitors user requests as typed in at the terminal. Usually gives message (<OK>) when the command has successfully executed. Monitor is also the name given to a technique used in real-time programming, developed by C.A.R. Hoare et al.

Virtual Forth machine. The assembly-language programmer creates a virtual machine that executes lowest-level Forth instructions.

Virtual-machine execution mechanism. The means by which the assembly-language programmer makes the virtual Forth machine transfer control from one Forth instruction to the next.

Nanocomp to teletypewriter interface

Hard copy of Nanocomp programs can be obtained cheaply using a teletypewriter and this simple interface with its machine-code driving program. Software presented is for the 6502 Nanocomp.

by P. C. Barton

A surplus teletyprewriter provides a very economical means of obtaining good quality hard copy of Nanocomp programs, the only drawbacks being the unit's size and its relatively low speed and somewhat noisy operation. Two points on the Nanocomp connector, p.i.a. line PB_7 and 0V, feed the input of this simple interface and its output consists of two connections which drive the teletypewriter selector magnet. Hard and software described was designed around the Creed 7E teletypewriter which has a 230V a.c. motor and is probably the most common on the second-hand market.

Hardware

The complete circuit consists of the teletypewriter-drive interface, Fig. 1, the power supply. Construction is straightforward. Two rails are provided by the p.s.u., between 80 and 100V to drive the teletypewriter selector magnet and 5V supplying the 7400 i.c. An alternative 5V source might be the Nanocomp's own p.s.u. In the original power supply I used a 20VA transformer built from a kit (RS207-728) with secondary windings consisting of 845 turns of 36 s.w.g. wire, centre-tapped, to provide 65-0-65V and 46 turns of 34 s.w.g. wire for the 5V secondary winding.

Software

Designed for the 6502 Nanocomp, the 397-byte program shown in List 1 resides in the top ram area starting at address 1264_{16}. When run the program displays an S to prompt entry of the printing start address and when that is entered an F prompt appears to indicate that the finishing address is to be entered. When the finishing address is entered the teletypewriter prints all memory contents between the specified addresses. Prompt functions make use of the Nanocomp monitor BADDR subroutine at 7C5B.

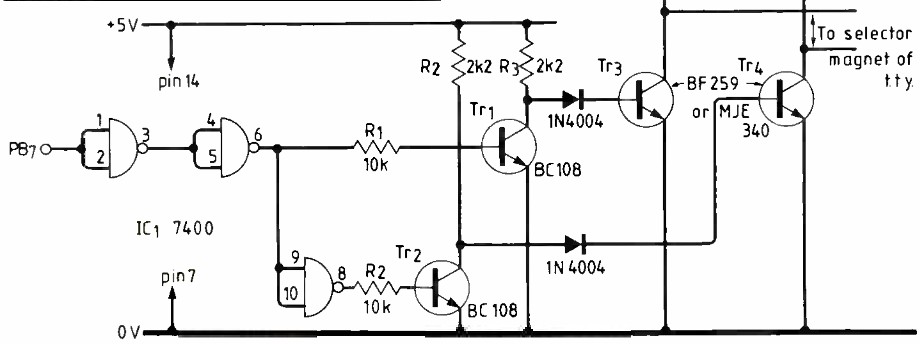
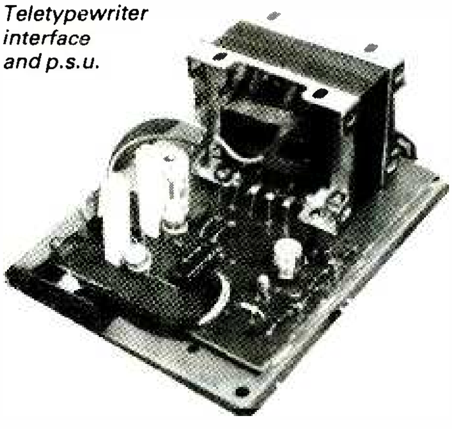


Fig 1. Nanocomp-to-teletypewriter interface in which high-voltage output transistors are driven by a phase-splitting circuit consisting of a 7400 i.c. and buffers.

One inconvenience with using teletypewriters is that when letters have been printed a figures code has to be sent before figures can be printed and likewise a letters signal has to be sent before letters can be printed. Unfortunately, hexadecimal notation consists of approximately ⅔ numbers



Teletypewriter interface and p.s.u.

Address	Function
0001	position counter
0002	data store (one hex. digit)
0003	figures/letters flag
0004 0005	start address
0006 0007	finish address
0008	drop memory
0009	temporary store (4 m.s.b. data byte)
000A	temporary store (4 l.s.b. data byte)
000B	byte flag
000C	byte count (CR, LF, spaces)
000D 000E	look-up table temporary store
13C9	start of look-up table
Address	**Subroutine**
1353	letters/figures
1382	byte separation & storage
13AA	transmit

***List 2.** Memory locations used by the 397-byte interface program starting at location 1264, and subroutines.*

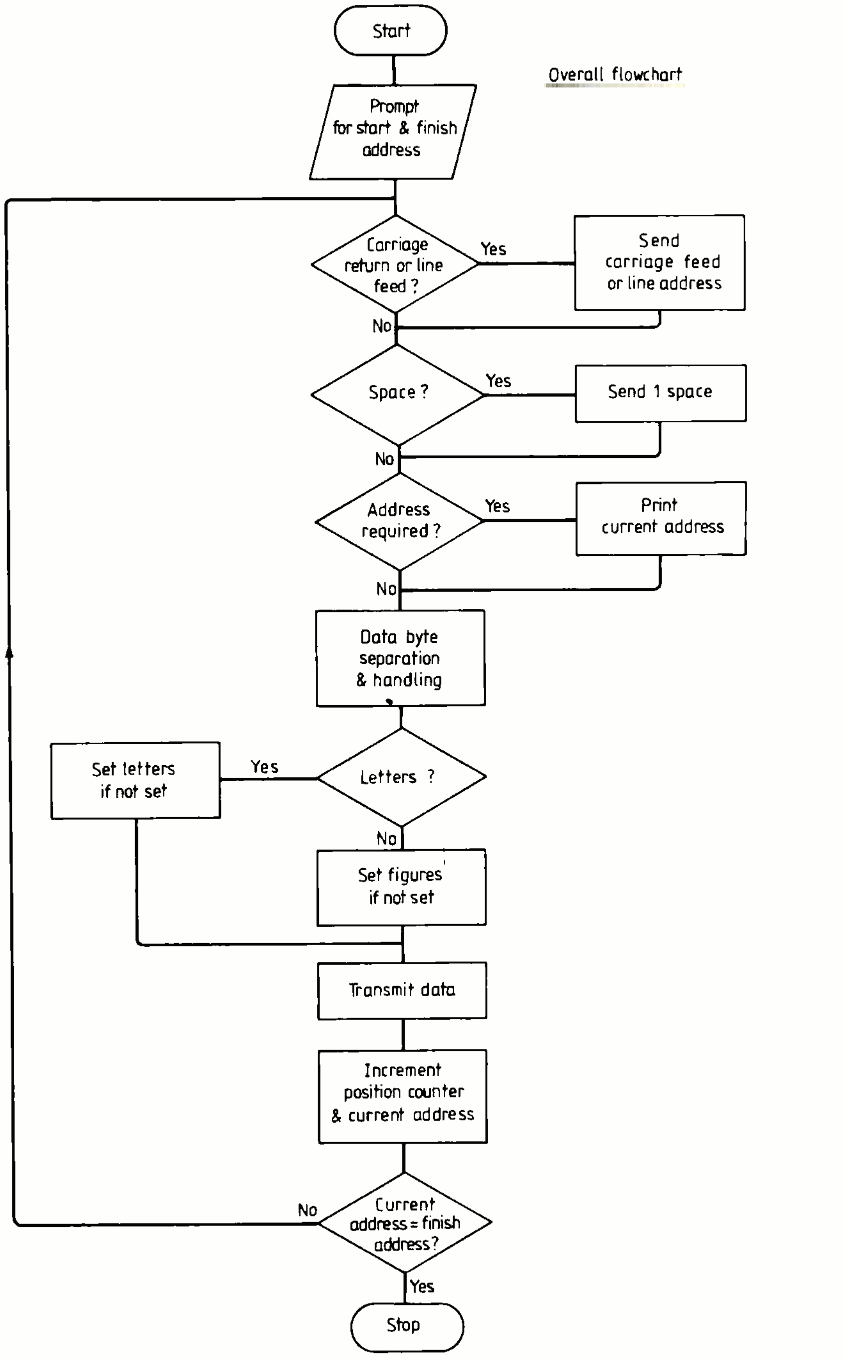
```
1260  00 00 00 00 86 3D 97 7F BD 7C B5 DF 04 86 69 97
1270  7F BD 7C B5 DF 06 4F 97 0C 97 03 97 0B 86 FF 97
1280  01 D6 01 C1 22 22 25 C1 04 22 02 20 30 86 0C 4C
1290  97 0C 01 01 01 81 02 22 02 20 22 86 13 97 08 BD
12A0  13 AA 4F 97 0C 4C 9B 01 97 01 20 11 86 0B 97 08
12B0  BD 13 AA 86 23 97 08 BD 13 AA 4F 97 01 01 96 01
12C0  81 05 22 5A 96 04 44 44 44 44 97 02 BD 13 53 96
12D0  02 97 08 BD 13 C9 BD 13 AA 96 04 84 0F 97 02 BD
12E0  13 53 96 02 97 08 BD 13 C9 BD 13 AA 96 05 44 44
12F0  44 44 97 02 BD 13 53 96 02 97 08 BD 13 C9 BD 13
1300  AA 96 05 84 0F 97 02 BD 13 53 96 02 97 08 BD 13
1310  C9 BD 13 AA 86 13 97 08 BD 13 AA 86 05 97 01 BD
1320  13 82 BD 13 53 96 02 97 08 BD 13 C9 BD 13 AA BD
1330  13 82 BD 13 53 96 02 97 08 BD 13 C9 BD 13 AA 96
1340  01 4C 97 01 DE 04 08 DF 04 9C 06 27 03 7E 12 81
1350  3F 01 01 96 02 81 09 22 08 86 00 91 03 27 15 20
1360  1E 86 00 91 03 27 18 86 7F 97 08 BD 13 AA 86 00
1370  97 03 20 0B 86 6F 97 08 BD 13 AA 86 01 97 03 01
1380  39 01 DE 04 A6 00 84 0F 97 0A A6 00 44 44 44 44
1390  97 09 D6 0B C1 00 26 0A 96 09 97 02 86 01 97 0B
13A0  20 07 96 0A 97 02 5F D7 0B 39 96 08 7F 40 03 C6
13B0  80 F7 40 01 C6 04 F7 40 03 C6 07 B7 40 01 CE 07
13C0  FF 09 26 FD 49 5A 26 F3 39 86 13 B7 13 DE 7F 13
13D0  DF 96 08 B7 13 DF FE 13 DE A6 E0 97 08 39 13 00
13E0  37 77 67 43 2B 07 57 73 33 0F 63 4F 3B 4B 43 5B
13F0  3F 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

***List 1.** Machine code for driving a teletypewriter using the 6502 Nanocomp see List 2 for details.*

and ⅓ alphabetical figures and the extra code characters required to change between the two slows down printing.

Carriage returns, CR, and line feeds, LF, are sent as needed and if the position counter is below six the address is also printed, see flow diagram. If the next data byte is a letter and the teletypewriter is set for figures, the appropriate code is sent to convert to letters, and vice versa. Using a look-up table, data are converted to teletypewriter code and sent through 'drop' memory at address location 0008 to the teletypewriter interface using the transmit subroutine at 13AA. When the required section of memory has been printed, the program is terminated by a software interrupt instruction, SWI, which returns control to the monitor. List 2 is a memory map for those of you who want to make further use of the subroutines. If the teletypewriter races or prints rubbish try interchanging the selector magnet connections.

Bob Coates described the 6502 Nanocomp microprocessor trainer in the January 1981 issue, pp.32-36, and the 6809 version in July 1981, pp.33-37. An eprom programmer for both versions was described in the January 1982 issue, pp.30-33, and interfaces for expansion in November of the same year, pp. 32-34. A set of photocopies of these articles can be obtained by sending £2.55 and a large s.a.e. to Wireless World Trainer, Room L303, Quadrant House, The Quadrant, Sutton, Surrey SM2 5AS. WW



Interface details

The teletypewriter selector magnet can be in one of two states corresponding to logical one or zero. This magnet converts electrical impulses provided by two high-voltage output transistors, see Fig. 1, into mechanical movement which prints the appropriate character. Sections A and B of the i.c form a phase splitter which drives the output transistors in opposition, causing the magnet to shift from one state to another.

Teletypewriters use the CCITT No. 2 International 5 Unit Teleprinter Code in which five units, or bits, form the character to be printed. In addition, one start bit and one and a half stop bits are used, giving seven and a half bits in all. Each bit is 20ms long so each character including start and stop bits is 150ms long, fig. 2. The complete code is shown in Fig. 3.

Fig. 2. In teletypewriter code, five bits specify the character to be printed, one bit is the start bit and one and a half bits form the stop code. ▶

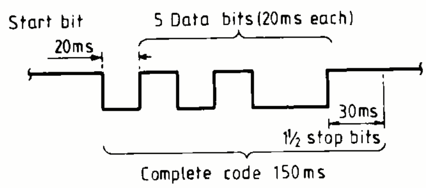
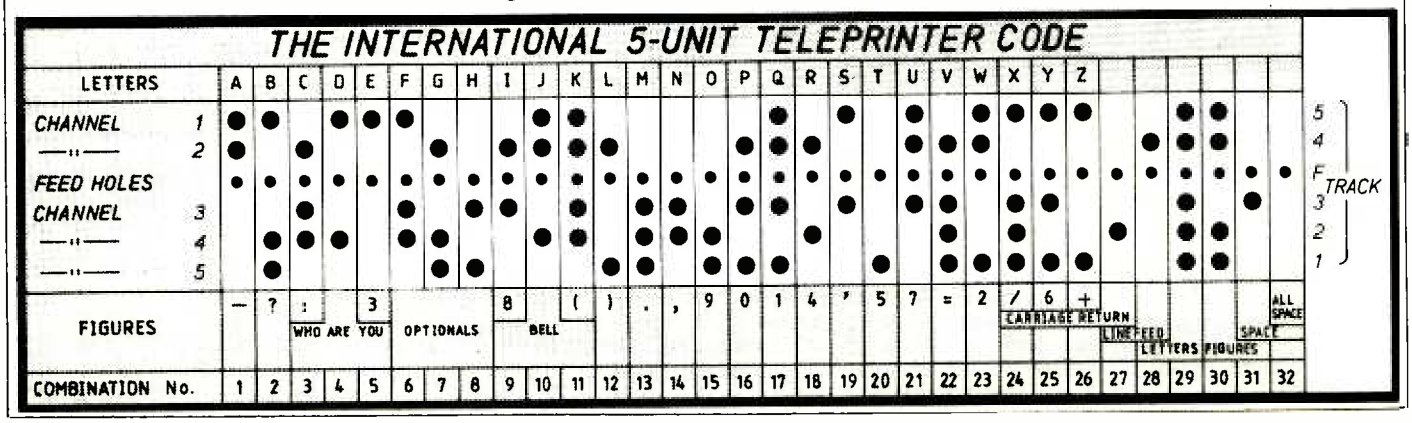


Fig. 3. International 5-unit teleprinter code. A letter code changes from figures to letters and vice versa for a figure code. Channel numbers are the equivalent of bit numbers and a punched hole represents a logical one. ▼



LETTERS

RECHARGEABLE H.T. BATTERY

May I comment on Mr Pash's letter concerning the Milnes rechargeable h.t. battery.

This was first produced in the late 1920s by the Milnes Radio Company of Yorkshire. The cells were nickel-cadmium type with alkaline potassium hydroxide electrolyte, producing a potential when charged of about 1¼V. All the cells were connected in series to give 120V for normal operation; but could be connected in a series-parallel arrangement with a built-in switch, so that the unit could be recharged from a normal 6V battery charger.

Unlike lead-acid accumulators, nickel-cadmium cells can survive to a ripe old age and it is very interesting to learn that the unit Mr Pash has found bears this out. The makers at the time claimed that they were 'virtually indestructible'.

D. P. Leggatt
Engineering
Information Department
BBC

'CURRENT DUMPERS'

To quote Michael McLoughlan (September, p.39), "it is therefore appropriate to call the output transistors in Fig. 1 the 'current dumpers'."

The Concise Oxford Dictionary, for example, explains that "to dump" means to deposit (rubbish, etc.), to abandon, to export at a low price goods unsaleable in the country of origin. I am unable to see the claimed appropriateness of the term in the context of the article.

Could this be one of the causes of the confusion which, as Mr McLoughlan mentions, has surrounded this subject?

M. G. Scroggie
Bexhill
Sussex

DESIGN COMPETITION

I was interested to read Mr Wattson's plea (September Letters) for a 'discriminating' hearing aid, as I did some research relevant to the problem some years ago.

I wanted to find out why two ears give a good idea of the direction of sounds, and therefore the ability to discriminate, when two microphones do not. The answer is simply that the ear lobes (and to some extent the sound 'shadow' cast by the head) modify the sound in a way that the brain can interpret as direction. If one 'blanks off' the cars with one's hands, then the ability to judge direction deteriorates and, for instance, conversation in a room sounds cavernous.

I experimented with ears modelled out of Plasticene and later papier maché, with small microphone inserts set in them. This gave quite spectacular results when listening over headphones – sounds being locatable through 360 degrees and also above the 'head'. I understand that this was first discovered by Bell Labs. in the 1930s, and is currently being re-discovered under the name of 'Holophony'.

A hearing aid shaped like a head would take a little social adjustment (which is why I did not pursue my recording idea!), but if a microphone could be placed inside the ear 'on top' of the earpiece, thus using the effect of the ear lobes, this would work. However, the problem of avoiding feedback would be formidable. Another possibility would be to put the microphone in one ear and the earpiece in the other. Information would be 'back to front' but if the aid was always worn I expect one would soon get used to it. The other possibility is that enough directional information could be generated electronically from a small array of microphones.

Developing the idea may be a good candidate for an undergraduate project?

Richard Buswell
Buswell Machine Electronics
Skelmersdale
Lancashire

★ ★ ★

Being deaf myself, I applaud Mr Wattson's plea for help with hearing, but I am not clear that he has properly stated the problem.

Inability to cut out or subdue unwanted sounds is a common complaint, not necessarily linked to deafness. ITV, when recently asked to cut down the background music and effects to their productions, replied that the output was in fact well-balanced, it was the listener who was at fault.

But the inability to hear clearly when wearing a hearing aid in conditions of high ambient noise is another problem.

Cosmetically tucked behind an ear it has the inherent disadvantage of responding mainly to sounds behind the wearer, both volume and frequency in front being much reduced.

Truly did Dunlop, in the Textbook of Medical Treatment, say "in older people, the old-fashioned ear trumpet may well be found more effective".

The problem is really serious. For instance, a conversation in a bar at opening time becomes more and more difficult as the arrival of more people increases the ambient noise, and after a time can become quite impossible. This also goes for cafés, wedding receptions; in fact, anything which generates ambient noise.

I think a solution could lie in the use of the 'T' switch, which enables direct pickup by induction without the mike, from a telephone coil, or a radiating cable in suitably equipped theatres.

If your young men could devise a modern equivalent of the ear trumpet – something that picks up sound from a forward direction, amplifies it and feeds it to a loop which could be 'heard' on the 'T' setting it would be a boon to everyone with a behind-the-ear aid.

G. Barnes
Market Harborough
Leicestershire

HERETICS GUIDE

One year and some twenty five printed pages have finally brought Dr Scott-Murray's 'Heretic's Guide to Modern Physics' to a close. Considering that he holds a Ph.D in a physics subject it is hard to believe that he could have expected to get away with some of the things asserted there. Thus almost everyone working with oscillating systems is aware that in them energy is continually changing to and fro between kinetic and potential forms, while the total energy remains nearly constant. According to quantum mechanics the total energy of an electron bound in a hydrogen atom is quantised and therefore constant, but its kinetic energy is not. In attempting to score a point against quantum theory Dr Murray in his very first article (*Wireless World*) June 1982, p81, col 1, question and answer session) glossed over, not only the distinction between the kinetic and the total energy of the electron, but also the distinction between its angular momentum, which is quantised, and its linear momentum, which for a hydrogen atom may take a range of values that according to the uncertainty principle is inversely proportional to the mean distance of the electron from the proton, a spread thoroughly checked experimentally. Anyone indulging in such antics can hardly complain if at this point the discussion takes on 'a testiness of tone'.

Dr Murray asserted time and time again that no experiments bearing on his 'heresies' have been performed, but when faced with the results of experiments made with gamma rays from radioactive sources adopted Nelson's tactics for dealing with information he didn't wish to know about. As an aerial designer he might at least be expected to take an interest in the polar diagrams for atomic and nuclear phenomena, but when discussing the Compton effect (December 1982) he ignored this aspect of the topic completely. Nowhere does he give even a hint that the quantized angular momentum of, say, a hydrogen atom, is closely associated with the complexity of the polar diagram of any photon emission from the atom about the direction of its axis of spin. This type of association has been confirmed by many measurements on radioactive nuclei aligned at low temperatures, and by angular correlation measurements, but on the evidence of his articles the nature, interpretation, and significance of such experiments appears to be a closed book to him.

LETTERS

In attempting to justify the notion that microphysics is determinate in retrospect (March 1983, p 45) Dr Murray selected his example with some care. If he had considered instead the two-slit interference experiment with electrons, then there are arguments which show that an experimental arrangement which defines the slit through which any particular electron passes destroys the interference pattern on the far side of the slits. Thus coupled observations of an electron as it leaves the source and as it subsequently passes some point in the shadow zone between the geometrical images of the two slits do not make it possible to say through which slit the electron passed. The Copenhagen doctrine to which he is so bitterly opposed asserts that if you can't tell which way the electron went with the baffle and slits present you are not logically entitled to conclude that it must have travelled by the direct path if similar observations are made with the baffle removed.

In the April 1983 issue Dr Murray questioned the existence of the neutrino and of discrete energy levels in nuclei. The existence of the latter is demonstrated by the spectra of the alpha particles emitted by many of the natural radioactive elements. The fact that some of them emit groups of alpha particles with several well-defined and distinct energies was known long before he took his degrees. As for the neutrino, measurements on nuclei recoiling after beta decay show that in general the nucleus does not recoil in the opposite direction to that in which the beta particle is ejected, so that from the conservation of linear momentum some other particle must be present. The energy of decay can then split between the electron and the neutrino in any way consistent with the conservation of total energy of linear momentum, since the linear momentum of a free particle is *not* quantized. Dr Murray's statement (p.61, col. 1) that 'according to the new ideas the mechanics of everything small is also quantized' is far too sweeping. There is no space here to go into the dramatic experimental consequences of the fact that the angular momenta of all the particles concerned in beta decay are quantized, and that in beta decay parity is not conserved. Incidentally parity was not invented by the nuclear theorists (p.62, col. 3), and in fact has well defined values for the electric and magnetic field distributions generated by dipole and by loop aerials, to come back to Dr Murray's own field.

On the same page he quoted a text book account of the use of virtual processes in calculations. These processes are used according to well defined rules, and always occur in cascaded pairs the overall effect of which is to satisfy the conservation laws. If permissible virtual processes are arbitrarily omitted from a calculation the results will not in general be in agreement with experiment, demonstrating in another way that the indeterminacies of quantum theory reflect the properties of the natural world, and do not simply arise from the limitations of experimental techniques.

Finally we come to Dr Murray's account of the experiments carried out by Dr Aspect and his colleagues in Paris in an attempt to resolve a clash between certain predictions of quantum mechanics and of Special Relativity. In the May letters I included a reference to their own account of their work given in Physical Review Letters[1], which includes a summary of the theoretical results, such as the Bell inequality, which their experiments were designed to test, and a very clear description of the experimental arrangements, which might almost be described as classical, give or take a couple of lasers and the use of photon counters. If Dr Scott-Murray had bothered to look up that reference instead of relying on second hand accounts he would have spared himself and *Wireless World* the dubious honour of having produced the most garbled discussion of a key scientific experiment that has been seen for many years. There are indeed none so blind as those who will not see.

References
(1) A. Aspect, P. Grangier, and C. Roger, *Phys. Rev. Lett.* 47(1981) 460.

C. F. Coleman,
Grove, Nr Wantage,
Oxfordshire.

The author replies:
Mr R. J. Lamb (*WW* letters, August) says that any attempt to prove the Causality law on the lines proposed in my March '83 article must involve a circular argument. He is right, of course; that is why I followed immediately with the reminder that one cannot prove that law, nor indeed any law in physics. What I sought to do was to transfer the burden of proof, so that I would no longer be required to prove that Causality held, but instead could challenge my opponents to prove – experimentally – that it did *not* hold. Was I successful?

I go along also with James A. MacHarg (Letters, July) when he says that my arguments are "so shallow and superficial that they merely invite argument from the specialists of this world". (However, I wouldn't agree that they are subjective arguments; I think they are as firmly based on experimental evidence as anything else in physics, and much more firmly based than, say, ψ-waves or quarks). The problem has been to state the case and précis enough material to support it within a limit of about 30,000 words. For every paragraph that reached print in *Wireless World* there is to hand about ten times as mcuh backing material, and if anyone wants to go deeper into specifics in a constructive spirit he will certainly be welcome.

On the other hand, Mr M. J. Niman (July) is annoyed with me for attempting to mislead your "gullible readers" by misquoting Dirac on the antimatter concept. Dirac went in for positive charge, he says, not negative matter. But did I misquote him? What Professor P. A. M. Dirac, F.R.S., actually wrote (in the second paragraph of Proc. Roy. Soc. *167*, p.148, 1938) was:

> "Secondly, we have the [Dirac] theory of the positron – a theory in agreement with experiment so far as is known – in which positive and negative values for the mass of an electron play symmetrical roles. This cannot be fitted in with the electromagnetic idea of mass, which insists on all mass being positive, even in abstract theory."

Not much doubt about that; also the term "abstract theory" is interesting. The whole paper is greatest fun and should be prescribed reading for heretics. Mr Niman seems to have been unaware of the fanciful nature of his high priest's real views.

The purpose of my articles was not to review the sequence of argument and counter-argument that led to the establishment of the Copenhagen paradigm. That sequence is accessible in every textbook, where the student will find all the successes of current theory fulsomely recounted but only rarely, between the lines, any hint of the truth that all may not be well. He will find there no consideration of how big a photon might be, or of the structure of an electron, or of the nature of electric charge or electron spin, or of the mechanism of polarization. Adherents of the theory simply decline to discuss such matters, and seek to patronize or ridicule anyone who does. Very soon one comes to realise just how restricted the coverage of this theory is, and how little it has to say even within the field it claims to cover.

Thus Mr C. F. Coleman, who would seem to have assumed the mantle of Defender of the Faith in these columns (May, July, and now), has raised many points which show the superiority of quantum theory over the earlier, "classical" physics. Several of his points I have already dealt with, superficially I admit, in letters and in the text of the articles themselves. But I question the relevance of any of them to my heresy, since I am not advocating a return to Victorian ideas. I am merely suggesting that we should look now for a credible alternative to the quantum/wave theory, with the accent on the "credible". However, since Mr Coleman has twice provided literary reference to Dr Alain Aspect's 1981 paper (and has suggested that I did not even read it before misleading *Wireless World* readers), perhaps I had better analyse that most recent E-P-R experiment at the next level of detail as shortly as possible, from the heretical viewpoint. The following amplifies my June article.

Rather than use "annihilation" photons, which are high-energy gamma rays whose polarizations cannot be measured (why not, I wonder?), Aspect *et al* generated pairs of associated photons of visible light by means of a cascade process in the spectrum of calcium atoms. These photons travelled in opposite directions away from the point of generation, and their planes of polarization where measured (i.e., inferred statistically) by passing them through polarizers. The performance of each polarizer, filter and detector was measured separately, together with the losses inherent in the light-collection system; from these calibrations the statistical correlation to be expected between the photons' polarizations *as measured* could be calculated, on the assumption that the photons were polarized identically when radiated. This "prediction" is the sinusoidal curve in the second figure.

The experimental measurements fitted this "prediction" perfectly. The apparatus as a whole performed during the experiments exactly in accord with the calibrations of the two photons of any given cascade pair were closely correlated. That is what this experimental result says, and that is *all* it says. It doesn't seem to conflict with Special Relativity, or to depend upon ψ-waves, or to have to do with wave-mechanics at all. As Mr Coleman remarked, "the experimental arrangements might almost be described as classical".

Then why the fuss? I will tell you. It has got firmly into the heads of all these people that Bohr and Heisenberg were right, in that *the result of a measurement* performed on one photon of a pair must affect *the physical polarization* of its distant sibling. (A metaphysical quantity is misidentified with a physical quantity). Some weird "action", it is claimed, must pass from one detector to the other faster than the speed of light. In an attempt to rationalize this claim a number of "locally realistic theories" have been proposed, involving the assumed properties of a mythical sub-stratum of sub-physical "hidden variables". (I tell no lies: this is what our modern physics has come to). An extra-ordinarily complicated mathematical argument known as Bell's theorem, which I confess I have not bothered to understand, says that if these "hidden variables" or their equivalents existed, the result of Aspect's experiment would not be the result he actually obtained.

What Dr Aspect has reported in the paper referred to by Mr Coleman is the failure of Bell's theorem. Some people say this proves that the postulated "action" travelled through the apparatus faster than light. Dr Aspect himself did *not* say this, and neither do I. Perhaps Mr Coleman does?

Aspect's experimental result can be explained simply and naturally on classical or on slightly neo-classical reasoning. But now, *just watch* how fast a house of cards collapses! The experiment has disproved Bell's theorem, which was concerned with "locally realistic theories", which were based on "hidden variables", which were invented to support the argument of the "reduction of the wave-packet", which a specious take-it-or-leave-it consequence of the supposed existence of "ψ-waves", which in their turn were an elaboration into pseudo-scientific fantasy of an innocent speculation by a post-graduate student in 1925 . . .

Everybody nowadays should keep his Occam's razor handy. Using it, if one is not blinded by the conventional prejudice, one sees that Dr Aspect's experiment is just another nail in the coffin of the Copenhagen theory. It seemed to me that his contribution to the common weal was important enough to rate a mention, superficial though perforce it had to be, in the final article of the Heretic's Guide series. I am grateful to Mr Coleman for giving me this opportunity to explain why.

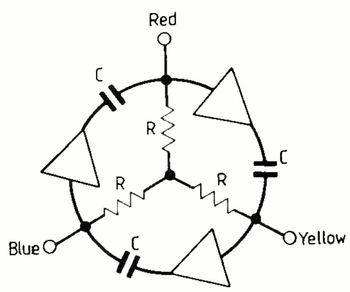
Scott Murray
Kippford
Galloway

ELECTRIC CHARGE FROM A RADIO WAVE

I am at a loss to know whether Professor Jennison was really serious in writing this article, for the conclusions he draws from his experiment seem somewhat extended.

The experimental apparatus he describes is an electronic polyphase generator, being 8-ph or 32-ph, according to how you count the nodes. As is well known in the art, polyphase machines are associated with rotating fields, and if what is normally the stator is driven backwards at synchronous speed, its field pattern will be stationary with respect to the laboratory floor. However, apart from that being an example of relative motion, what can be deduced from it? The complexity of Professor Jennison's apparatus goes some way to mask a well-known principle, the multistage phase-shift oscillator. With two stages we have the multivibrator, but with three or more a near sine-wave generator may result. The diagram shows a 3-stage RC oscillator, or should it be more properly a 3-ph generator? That depends on the purpose to which it is put. Clearly, if it is used in its 3-ph capacity, it will have when mechanically stationary, an associated rotating field. That field can be stopped by suitable mechanical rotation but can we draw any conclusions about field and charge from that?

If indeed we wish to freeze a travelling wave on a transmission line, then it is in



principle easier to adopt the proposal in the letter from R. J. Hodges, also in the August issue. Admittedly that pattern came from a pulse generator at the left hand end of the line, but it could just as easily have come from energy received by an aerial.

As for all that 3K stuff, that is just confusion worse confounded.

Chris Parton
Dept. of Electrical and Electronic Engineering
Bell College of Technology
Hamilton

TECHNOLOGY AND PEOPLE

Those who have read Prof. H. J. Campbell's most excellent book The Pleasure Areas (Eyre Methuen) will be fully aware that the analogy between electronics and the brain is very much stronger than a mere apparency: Campbell, a neurophysiologist of no mean standing, makes it clear that everything we do is done ultimately for stimulation of the pleasure areas which have evolved out of the "smell brain" of the fish.

Apparently there is stimulation from the peripheral receptors (broadly the senses): there is stimulation from the movement of muscles: and above all, there is stimulation from the thought processes at work in the vast neo-cortex that makes us different to the lesser beasts.

This latter point is where the importance comes in of the pyramid programme which I mentioned in my letter of February this year – it provides a very wide base of information wherefrom an entry into genuine abstraction becomes possible, whereas that entry is impossible from a narrow specialistic base simply because the subject does not have enough information to think about, i.e. to compare: indeed the "research" of a genuine specialist tends to be little more than a good old grope in the dark!

Obviously, the more information one has to think about the more interested one becomes in systems outside one's animalistic self: Adam was more like a wasp that will not be taught to keep out of the marmalade: Cain killed Abel to appease his own introvert jealousy: Lamech's ego caused him to think that he could dispose of whom he wished. On the other hand, Noah may be thought of as the first extrovert creative, not only saving the animals two by two, but planting the first vineyard and then, sadly, imitating a newt! Obviously he still had some interest in his own material pleasures.

To put it plainly, Noah was the first to get some way into the abstract with due stimulation of his frontal lobes. Campbell makes it clear that this stimulation is *electrical*, and electrical activity in the brain is the one sure sign of remaining life.

Action, the verb of the sentence, has

LETTERS

three dimensions: speed, priority, and direction. These three dimensions will qualify fully any action at all. What is interesting here is that any emergency (or any threat, real or imagined) brings about an increased sense of priority, and that priority is to the self in the sense of survival; I have long believed that the autist is in a mental state of high priority, a sort of absolute "converger".

As I see it, this priority may stem from two possible causes, the one being genetic, and the other perhaps from (shock) interaction with the environment, as it appears that it must be with all matters of intelligence. I remember seeing one autist on television many years ago who could do virtually nothing but play the flute: in this respect he could be considered not unlike what one imagines an absolute specialist would be like, and as far as communication goes, appeared to display the sort of symptoms which one might expect.

Your words about the blocking effect of too much information, and the removal of stress for communication, do suggest to me that the subject needs to be taught to use the function of "comparison" in a state of relaxation, because "comparison" is the thought process at work: it is also an electrical stimulation to the pleasure areas which might help to break down the unscalable vertices bounding the existing preferred pathways for electrical signals in the brain, and so assist the subject to "break the shell", and arouse natural curiosity over a wider spectrum.

The three basic functions of any computer (at abstract level) are perception (i.e. the intake of information), memory (the storage of the information) and comparison by which it is processed. If one thinks of a simple diode gate, the one that gets there first biases off the others: the action is one of comparison through time. Thinking inspection demonstrates that these three dimensions must have evolved in that order: it appears perhaps that the autist may have failed to evolve his function of comparison, or else have some kind of block against using it.

However, as Campbell mentions, the new-born babe is born with hardly any neo-cortex having developed – it is virtually an animal – and the cortex develops with the input of sensory information of one kind or another: might not the function of comparison be assisted to evolve with patience?

It is important to realise that an efficient function of comparison will actually call for information to process so that pleasure may be obtained from the electrical stimulation which ensues: it is my own belief that it is the frustration of this information-seeking in a society which pressurises "what" but seldom teaches "how" and "why" that causes creativity to twist into animal introversion such as hooliganism and crime, away from that understanding that brings care and responsibility in its wake from an interest in systems outside the self.

As to your use of the word "mind", may I suggest that "mind" is brain plus information taken in and processed? Thus "mind" would tend to be the overall integration of electrical activity within the brain, and demonstrable by the effects of that electrical activity in that it ultimately controls all our behaviour patterns.

For those interested in the subject of intelligence and creativity generally I unhesitatingly recommend Arthur Koestler's "Act of Creation" and "The Dragons of Eden" by Carl Sagan: but Campbell's "Pleasure Areas" is some kind of vital starting point.

Finally, I would like to congratulate Mr Young over his efforts within a specialistic society which itself seems to me to demonstrate at least mild symptoms of autism!

J. A. MacHarg
Wooler
Northumberland

THE NEW BUREAUCRACY

I note that I am not the only one to dispute Ivor Catt's various assertions. The small comfort afforded by such sentiment is, however, offset by the impertinence of the man in presuming to judge a stranger's qualifications and experience. His assumption that there is some link between von Neumann and large-scale integration is of some slight interest to the psychologists, but of no relevance to the rest of us.

His loyalty test – which I am quite prepared to do – confuses small-minded bureaucratic bungling with the job at hand, which is to rid us of the pernicious von Neumann arctitecture which he so despises. He – and MAPCON – still have not realised that machine architecture need have little to do with its technological implementation. To object to their insistence in the first place. Does this insistence block the development of parallel-array machines? Of his own wafer-scale integration techniques? (I do, incidentally, deny that any programmer was responsible for the statement he quotes – programmers think in terms of structure, not composition).

The von Neumann hand that feeds me is a difficult slave and worse master, the result of an unholy marriage of mathematical theorem-proving and "if it works, it's perfect" business approaches. I do not mind biting the hand of that bastard child, for I am not fed by it, but by those who ask me to tame it. I should regard its passing with equanimity if its successor is the sort of beast which allows dealing with sets of data, rather than bytes.

Let us sort out technology from architecture. Then we can start discussing the alleged antipathy between programmers and engineers – which starts with the architecture. Until then, the battle lies between him and his simple-minded bureaucrats.

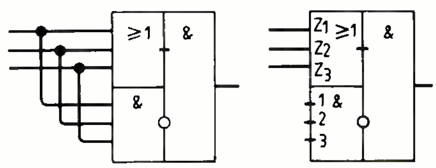
D. W. Scott
Challeston Ltd
Nettlestead Green
Kent

MIXED LOGIC

M. Butler's article on the use of mixed logic (*WW*, July 1983, pp.28 ff.) should be mandatory reading to anyone studying, or even teaching, digital techniques. He clearly emphasizes the often overlooked distinction between the actual working of circuit and its logical function(s).

M. Butler should, however, have made a passing reference to the IEC system of symbols for logical gates, that was started around 1970, and is now of standard use at such giants as the Philips and Texas Instruments. It became official norm in Germany in 1976, and also in The Netherlands. May I infer that BS followed suit? And when is *WW* to switch?

As to Mr Rudge's Letter (p.51), may I suggest the following alternatives. They are self-explanatory, I suppose.



J. Eyckmans
Sint-Truiden
Belgium

CALL SIGN

I was interested to read of the call sign 2MT on the Amateur Radio page of the August issue of *Wireless World*.

I have a copy of Harmsworth's Wireless Encyclopedia and, although it is undated, Sir Oliver Lodge writes in the introduction, ". . . to what is now in 1923 . . .".

The call sign 2MT is listed as belonging to 'Marconi Scientific Instrument Co., near Chelmsford Station, for specially authorised transmissions to amateurs.'

Another item is a 'Hanging Set': how to make a receiving set with simple controls suspended from the ceiling and giving light for the table as well as entertainment. The valves are the ordinary bright emitter type (Marconi-Osram R valves). Six valves are used – two stages of r.f. amplification, one detector valve and three stages of low frequency amplification.

Keith Ellis
Spondon
Derby

NEW PRODUCTS

HOSPITAL RADIO TRANSMITTER

With 'WW' emblazoned on the front of it, Wireless Workshop produce a medium wave transmitter for use in hospitals, universities and other private services. Using loop transmitting aerials throughout the buildings covered, the transmissions can be picked up on ordinary receivers. The four modules, all fitting together into a standard rack, are an audio processor, an m.f. exciter, a low-distortion v-mos linear amplifier in the cable distribution circuit, and a d.c. power unit. Each transmitting loop has its own, independently controllable, loop driver allowing the system to be accurately tailored to suit the reception area. The units may be purchased separately, so the audio unit could be used with other transmitters, while the wide bandwidth and low distortion (according to 'WW') of the m.f. exciter makes it useful for testing a.m. receivers. Wireless Workshop, 25 Ditchling Rise, Brighton, E. Sussex BN1 4QL.
WW 301

WW 301

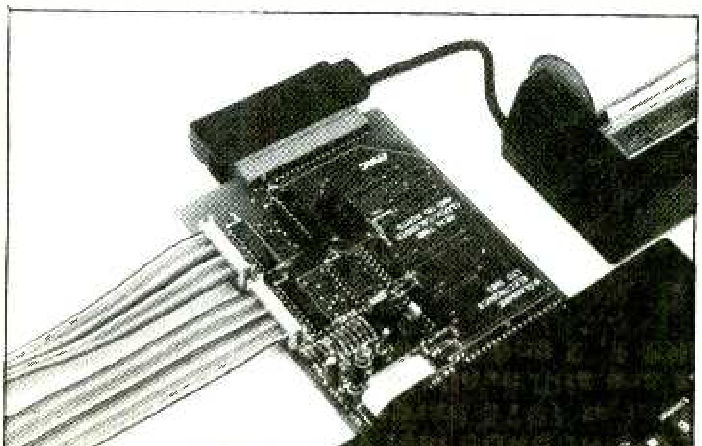
MACHINE-CODE MONITORS

Basic in personal computers has its limitations and much more computer commands at a higher speed are obtainable if the user is prepared to the computers own operating language or 'machine-code'. To make this easier software programs allow the display of a computer's memory and allow programs to be entered and displayed in their machine code format and sometimes in the mnemonics used to make this numerical language more intelligible. One such program is the N-Bug, written by Kuma for the Newbrain computer. With it, a single display shows a complete memory dump which may be scrolled through, the display also shows the state of each register, and a screen editor allows programs to be entered easily, altered and corrected. Other features include hexadecimal/decimal interconversion, relative jump calculations and the setting of breakpoints. Another display screenful offers menu selection of printer and tape input/output and allows the saving, verifying and loading of machine-code programs. N-Bug is complemented by Zen an assembly language editor/assembler; both are available from Kuma Computers Ltd, 11 York Road, Maidenhead, Berks SL6 1SQ.

A very similar program, written this time for the Oric-1 computer, is the Extension Monitor by Kenema Associates. There are some useful additional facilities; the ability to step through a program, to search for byte or character strings, to set or eliminate breakpoints. Other commands may be defined by the user. Hexadecimal display also 'translates' any character codes embedded in it and displays these in a separate column. A disassembled mnemonic display is included. Kenema Associates Ltd, 1 Marlborough Drive, Worle, Avon BS22 0DQ.
Kuma WW 302
Kenema WW 303

REAL-TIME CLOCK FOR SINCLAIRS

A time controller for the ZX81 and Spectrum computers has been developed in Ireland. The battery-backed circuit can control eight inputs and eight outputs and also provides the computer with date and time, including seconds. The controller has its own rom program and only a single instruction is needed from the computer to give the date and time. The circuit plugs directly into the computer's expansion port and provides another port for the addition of a ram pack, printer or other peripheral. It may be used as an electronic diary, with an alarm for important appointments; as a controller for household appliances or intruder alarms; to time sound effects or games and in process control, laboratory experiments etc. The version for the ZX81 costs £34.50 and for the Spectrum, £38.50. Glanmire Electronics Ltd, Westley House, Trinity Avenue, Bush Hill Park, Enfield, Middlesex EN1 1PH.
WW 304



WW 304

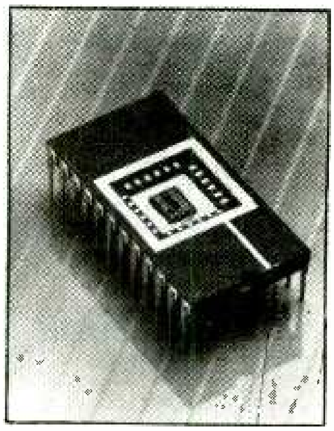
MASS MEMORY IN SOLID STATE

Plugging into the disc drive port of many popular computers, the MegaRAM storage unit offers memory capacity of between 1 and 32M-bytes. The advantages of using solid state memory, according to the distributors, is that it operates much faster than magnetic discs; and this is particularly noticeable when running programs with a lot of input/output activity, such as data base management, file sorting and merging and similar tasks. Another advantage is the lack of any moving parts, hence better reliability and no noise. At the end of a computing session, the memory can be copied onto a disc for long-term storage.

The MegaRAM circuitry includes automatic error checking and correction for any single-bit errors. An optional power supply includes battery back-up giving time to transfer the contents to back-up storage in the event of a mains failure. Compass Peripheral Systems, 67 Milford Road, Reading, Berks RG1 8NA.
WW 305

D-TO-A CONVERTER RUNS COOL

Monolithic construction and low power dissipation make the DAC80 run a lower operating temperatures and allow the use of low-cost plastic packaging, claim Analog Devices.



The 12-bit converter with selectable voltage output has also claimed for it a higher reliability, a wider temperature range, and more accuracy than those of competing models. Analog Devices Ltd, Central Avenue, East Molesley, Surrey KT8 0SN.
WW 306

FSK MODEM ON A CHIP

To construct a low speed modem (300 or 600bit/s) all that is needed is the XR-14412 integrated circuit and a few external components. The crystal-controlled circuit can operate simplex, half or full-duplex modes with self-test and echo facilities. It needs a single supply rail and inputs and outputs are t.t.l. or c-mos compatible. Using a suitable transformer, the modem can connect directly to a telephone line or may be used with an acoustic coupler. For phase-shift key (p.s.k.) modems a self-contained bandpass filter is available, the XR 2120. Full details of both from Rastra Electronics Ltd, 275 King Street, London W6 9NF.
WW 307

TOROIDAL TRANSFORMERS

Fully encased in an ABS plastic shell, the ILP range of lower power toroidal transformers have been produced in answer to public demand. Starting at 15VA, available now, the range is to be extended to provide transformers up to 120VA. ILP Electronics Ltd, Graham Bell House, Roper Close, Canterbury, Kent CT2 7EP.
WW 308

BENCH POWER

A series regulated power pack can give a constantly variable output between 0 and 18V, and 0 to 5A. Coarse and fine manual controls are provided or the output may be controlled by an external potentiometer. The Trio PR 655 is provided with two large meters to indicate current and voltage. A fixed current protection circuit may be switched in; as can regulated current or voltage operation. Remote sensing is possible and the supply may be configured in a series or parallel, master or slave mode. House of Instruments, Clifton Chambers, 62 High Street, Saffron Walden, Essex CB10 1EE.
WW 309

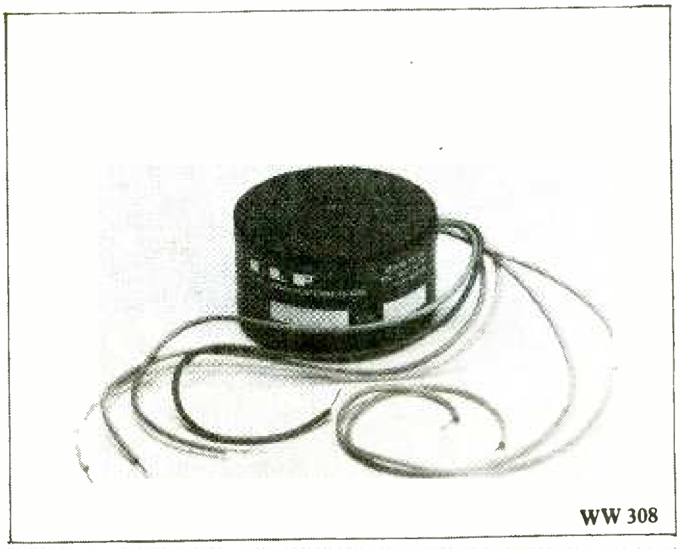
LOW POWER SOLID-STATE LASER

A series of monolithic GaAs GaAlAs pulsed lasers has been extended to include the LA5-02, with an output of 6W peak at a wavelength of 905nm. The emitted beam width of 150μm makes it suitable for proximity detection, ranging and security systems. STC Components, Laser Unit, Brixham Road, Paignton, Devon TQ4 7BE.
WW 310

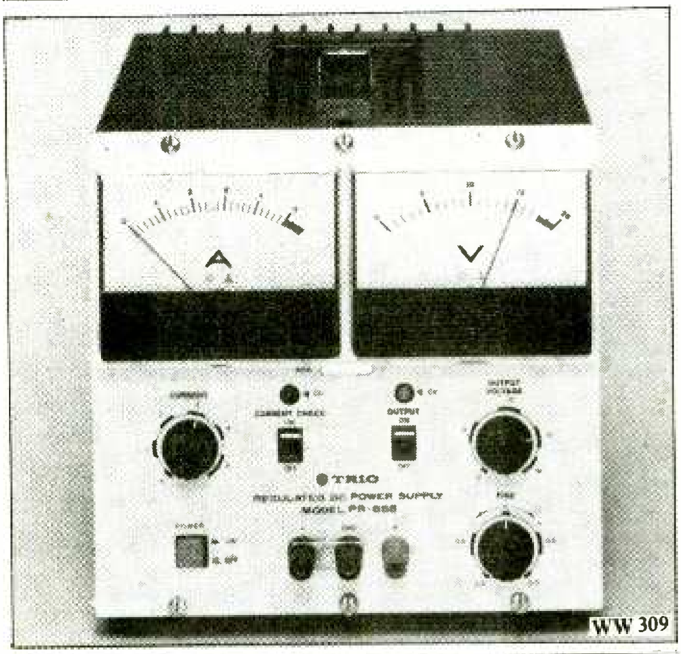
COMPUTER CONNECTOR KIT

Suitable for RS232 and V24 computer interfaces, a kit of housings, contacts, cable clamps and extraction and crimping tools can be used for rapid repair or replacement and in experimental use. It will help to overcome those frustrating moments when the plug on a cable doesn't fit the socket on the peripheral. Ampliversal, Terminal House, Stanmore, Middlesex HA7 4RS.
WW 311

If you would like more information on any of the items featured here, enter the appropriate WW reference number(s) on the mauve reply-paid card bound in this issue. Overseas cards require a stamp.



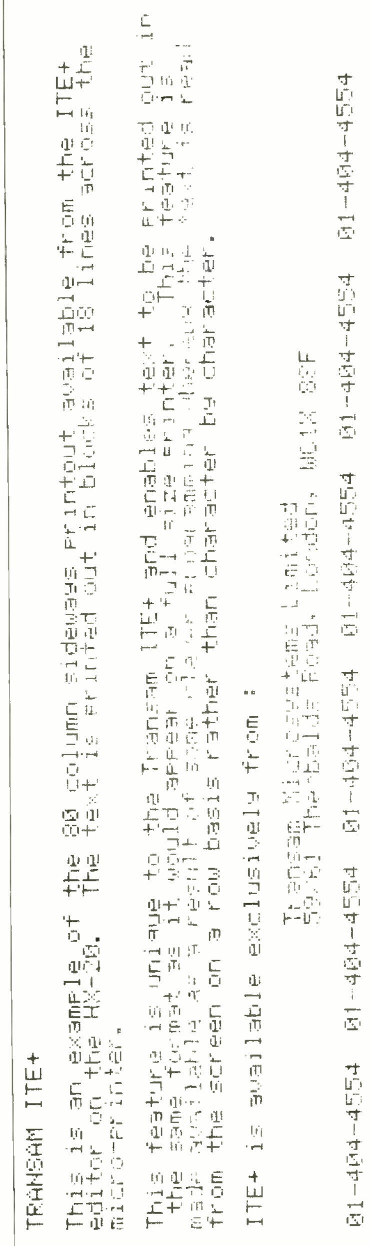
WW 308



WW 309

WW 311

SIDEWAYS PRINT ON EPSON MICRO


TRANSAM ITE+

This is an example of the 80 column sideways printout available from the ITE+ editor on the HX-20. The text is printed out in blocks of 18 lines across the micro-printer.

This feature is unique to the Transam ITE+ and enables text to be printed out in the same format as it would appear on a full size printer. This feature is made available as a result of [illegible] the text is read from the screen on a row basis rather than character by character.

ITE+ is available exclusively from :

Transam Microsystems Limited
59/61 Theobalds Road, London, WC1X 8SF

01-404-4554 01-404-4554 01-404-4554 01-404-4554 01-404-4554 01-404-4554 01-404-4554

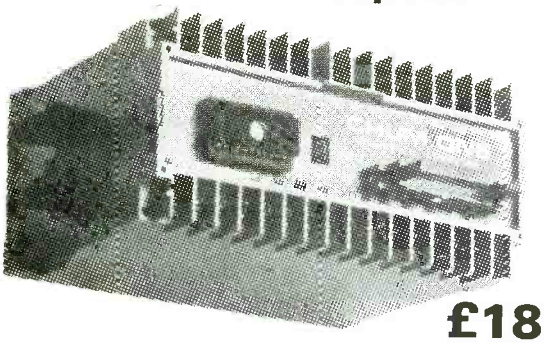
WW 312

NON-VOLATILE RAM

A 16K static ram that has a miniature lithium back-up battery is claimed to last for more than five years. The battery is contained within the ram package and the device fits a standard 24 pin socket and can replace any existing 16K ram or 2716-type eproms, at a similar price. The MK48Z02 comes from Mostek UK Ltd, 1 Valley Drive, Kingsbury Road, London NW9.
WW 313

CHUM ONE

Industrial Computer



£189

- ★ Basic and Z80 Assembly Language
- ★ Detachable Hand-Held Keyboard
- ★ 8K Bytes of Non-Volatile Memory
- ★ 8 Analogue Inputs
- ★ 1 Analogue Output
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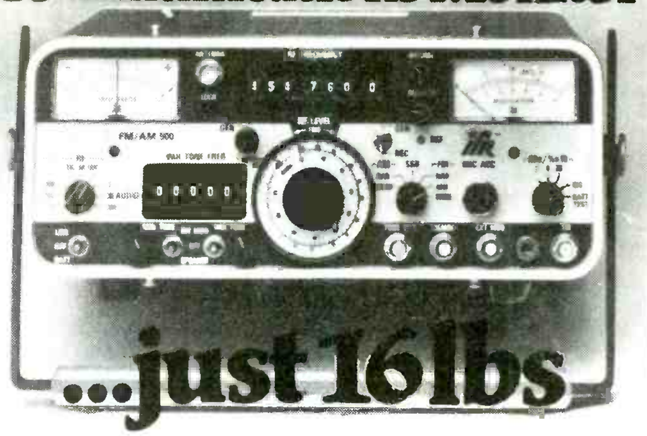
- ★ 32-Character by 2-line Display
- ★ Software:
  Machine Control — Data Log
  Thermocouple — Weighing machine

WARWICK DESIGN GROUP, 12 ST. GEORGE'S ROAD LEAMINGTON SPA CV31 3AY (0926) 34311

WW – 037 FOR FURTHER DETAILS

Your own customised Communications Monitor



The vast range of available options allows you to customise the FM/AM 500 Micro-Monitor to suit your specific needs, and weighing in at just 16 lbs your 'field-tests' can now be precisely that!

For a practical demonstration to prove our point contact:-

Mike Dawson on 01-897 6446.

Hunting — Fieldtech Heathrow

Fieldtech Heathrow Limited
Huntavia House 420 Bath Road
Longford Middlesex UB7 0LL
Telex: 23734 FLDTEC G

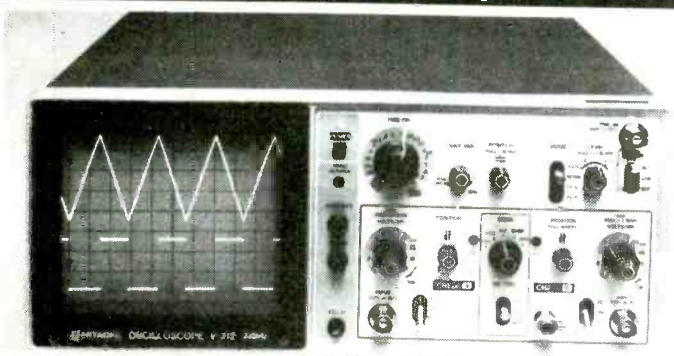
WW – 029 FOR FURTHER DETAILS

Hitachi Oscilloscopes

performance, reliability, value

New Models!

immediate delivery!



New from Hitachi are three low-cost bench 'scopes with bigger screens and extra features in a new slimline ultra-lightweight format.
The range now extends to 13 models:—

4 dual trace single timebase models 20MHz to 40MHz
2 dual trace sweep delay models 20MHz and 35MHz
2 dual timebase multi-trace models 60MHz and 100MHz
2 miniature field portable models, 20MHz and 50MHz
3 storage models, one tube storage, two digital storage

Prices start at £295 plus vat (model illustrated) including 2 probes and a 2-year warranty. We hold the range in stock for immediate delivery.

For colour brochure giving specifications and prices ring **(0480) 63570.**

Reltech Instruments, 46 High Street, Solihull, W. Midlands, B91 3TB

WW – 046 FOR FURTHER DETAILS

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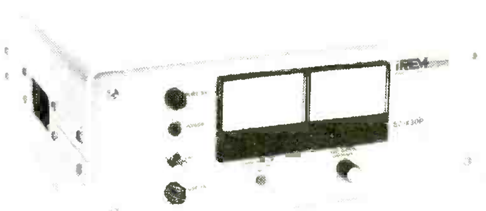

IREM

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P.O. Box 936, London, W4 4NW Telephone: 01-994 7155. Telex: 28604

WW – 048 FOR FURTHER DETAILS

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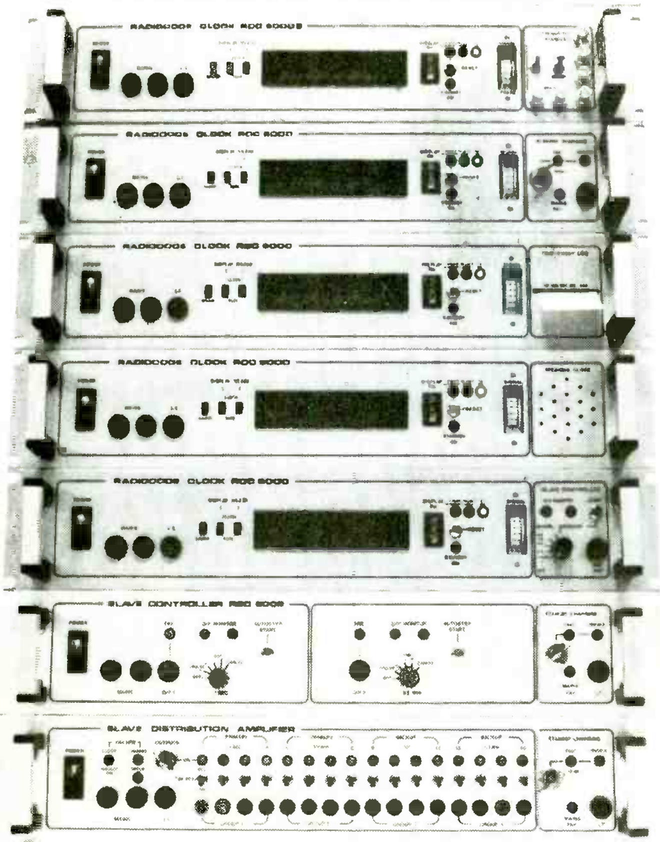
WW – 050 FOR FURTHER DETAILS

RADIOCODE CLOCKS SOLVE PROBLEMS

ATOMIC TIME, FREQUENCY AND SYNCHRONISATION EQUIPMENT



NEW PHASE-MODULATION SYSTEMS

Until recently, atomic time and date information was only available on v.l.f. transmissions using amplitude modulation. The RCC 8000AM series of equipment uses these transmissions to offer high noise immunity and high accuracy, particularly at very long range.

The new RCC 8000PM series of equipment uses, for the first time, phase modulated tranmissions with massive radiated powers of up to 2 Mega-Watts to offer long range, excellent noise immunity and no scheduled maintenance periods.

NEW PRODUCTS

The AM and PM series of Radiocode Clock equipment has been further expanded to include seven new models (from top) **8000S** – combined clock, frequency standard and optional stopclock. **Internal standby power supply** – with dual rate constant current charger. **Time-event log** – prints hours, minutes, seconds, milliseconds and day of year, on receipt of a log pulse. **Speaking clock** – time announcement or audio recording. **Slave controller** – total control of single-standard master/slave systems ie one pulse/sec. **Dual standard slave controller** – total control of two different and independent slave systems, ie. one pulse/sec and one pulse/half min. **Slave distribution amplifier** – maximum flexibility for the largest master/slave installations requiring dual standard operation, multiple circuits and complete master/slave backup.

NEW OPTIONS

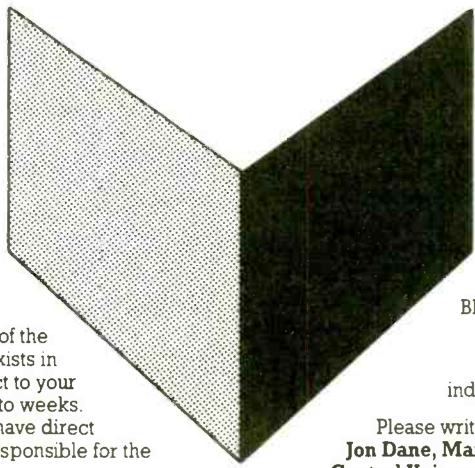
A continuously expanding range of fully integrated software and hardware is available for both series of Radiocode Clock equipment. Standard options now include:

- IRIG B precision serial o/p
- RS232/V24 1mS resolution
- General purpose parallel o/p
- FSK record/replay system
- Keypad entry of alarm times
- Keypad entry of time/date
- Time code generators
- Intelligent slave systems
- Standard frequency outputs
- Stopclock operation
- Calibrated systems for increased accuracy

Radiocode Clocks Ltd*
Unit 19, Parkengue, Kernick Road Industrial Estate
Penryn, Falmouth, Cornwall. Tel: Falmouth (0326) 76007
(*A Circuit Services Associate Co.)

WW – 025 FOR FURTHER DETAILS

CUBE Your partner in electronic enterprise



Share in the Success Story of *Industrial* Microcomputing.
The spectacular growth in the use of microcomputers in the home, in education and in the office is merely the overture to the real revolution – the micro-computerisation of industry.

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If you are planning a product which includes microprocessor control, then CUBE modules can both perform the development task *and* be economically configured as part of the end product. Development time and costs will be radically reduced because of the high level of performance that already exists in CUBE. Delivery time of a finished product to your customers can be reduced from months to weeks. Technical support? Your engineers will have direct access to our Cambridge design team responsible for the entire CUBE range.

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Control Universal Limited is a company with a solid reputation for designing and manufacturing computers in Cambridge. An impressive record of growth both in sales and in the range of products offered allows us to offer a solution to nearly every machine and process control application. Full details of the CUBE range, and how they are now fully supported by software tools (such as BBC BASIC and FLEX cross-compilers) are in our catalogue, free on request.

Let's work together and aim for electronic industrial control for a more prosperous world!

Please write to me directly:
Jon Dane, Managing Director
Control Universal Ltd., Unit 2, Andersons Court
Newnham Road, Cambridge CB3 9EZ
telephone: 0223–358757 telex: 995801–G, GLOTX

Control Universal Ltd
The Hardware House

WW – 044 FOR FURTHER DETAILS

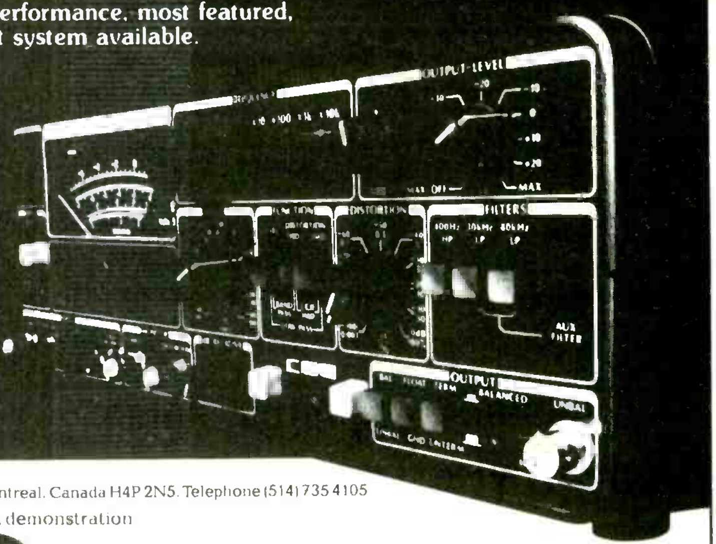
Looking for a Distortion Measurement System?

The Amber model 3501 is quite simply the highest performance, most featured, yet lowest cost audio distortion and noise measurement system available.

It offers state-of-the-art performance with THD measurements to below 0.0008% (−102dB), maximum output level to +30dBm and noise measurements to below −120dBm.

It has features like automatic operation, optional balanced input/output and powerful IMD measurement capability. It includes comprehensive noise weighting with four user changeable filters. Unique features like manual spectrum analysis and selectable bandwidth signal-to-noise measurements.

The 3501 is fast, easy to use and its light weight and small size make it very portable. It can even be battery powered.



amber Amber Electro Design Inc. 4810 Jean Talon West, Montreal, Canada H4P 2N5. Telephone (514) 735 4105

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Worldwide Export: Gotham Export Corporation, 741 Washington Street New York NY10014

WW – 033 FOR FURTHER DETAILS

The Wings Appeal Fund helps to maintain the RAF Association Home for Disabled and Chronic Sick. Care is essential for those who have served their country and who are in need. So please help by giving all you can for an emblem in WINGS WEEK in September or send a donation to show that you care.

Give as they Gave

To: Royal Air Forces Association, Appeals Dept., (DS) Portland Rd., Malvern, Worcs. WR14 2TA.

I enclose a donation of________ for the Wings Appeal Fund.

Name________

Address________

Please tick if receipt required ☐ or information on RAFA Membership ☐

Space donated by Wireless World

MANUFACTURERS & DISTRIBUTORS

"LESLIE" TREMELO SPEAKER SYSTEM

A two-speed rotating baffle system which when used as part of an **Organ**, Hi-Fi or Disco System produces the famous **LESLIE** effect. The unit comes complete with a 50watt 8 ohms speaker at peak output, two 220/240v 50 Hz motors with central drive to rotating Horn/Baffle, this gives a three-way sound effect i.e. normal tremelo sound when stationary, wraparound sound when revolving at 1 rev per sec and supersound at 7 revs per sec. Baffle size 485mm x 395mm. Overall depth from speaker magnet to central boss of rotating horn/baffle 300mm approx. £200 for 5, £360 for 10, £825 for 25, £1,500 for 50, £2,700 for 100. Sample sent for £45 + £5 P&P (£57.50 inc. VAT).

ORGAN KEYBOARDS

High Quality 54-note keyboard manufactured by **FATAR** in Italy. Keys are mounted on a pressed steel frame with steel springs on each key. Note Range "C" to "C" £100 for 5, £180 for 10, £410 for 25, £775 for 50. Sample keyboard sent for £25 + £3 P&P (£32.20 inc. VAT).

TWIN KEYBOARD AND FRAME

Two 37-note "C" to "C".
Keyboards mounted on a plastic frame. Keyboards are offset by one octave and are hinged for easy adjustment. Manufactured by **FATAR**. £175 for 5, £315 for 10, £710 for 25, £1,275 for 50. Sample sent for £40 + £4 P&P (£50.60 inc. VAT).

STEREO CASSETTE FRONT LOADING REPLAY MECHANISM for in-car entertainment, complete with motor and preamplifier. Manufactured in UK under Licence of Staar, S.A. £45 for 10 + VAT, £205 for 50 + VAT, £375 for 100 + VAT. Sample for £5 + £1.50 P&P (£7.48 inc. VAT).

MONO DYNAMIC MICROPHONE AND STAND, 3.5mm J plug fitted to approx. 1m lead £7 for 10 + VAT, £32 for 50 + VAT, £60 for 100 + VAT, £270 for 500 + VAT, £500 for 1,000 + VAT. Sample sent for £1 + 50p P&P (£1.38 inc. VAT).

REVERSIBLE GEARED MOTOR, manf. by CROUZET, 8 rpm 240 volt 50 Hz with universal T drive. £35 for 10 + VAT, £162 for 50 + VAT, £300 for 100 + VAT, £1,250 for 500 + VAT. Sample sent for £3.75 + 75 P&P (£5.17 inc. VAT).

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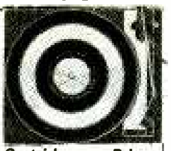
240 volt AC. Post £2



Make	Model	Drive	Cartridge	Price
BSR	P170	Rim	Ceramic	£20
GARRARD	6200	Rim	Ceramic	£22
GARRARD	Delux	Belt	Magnetic	£40
GOLDRING	G102	Belt	Magnetic	£30
BSR	P232	12 volt	Magnetic	£24

AUTOCHANGERS 240 VOLT

BSR	Budget	Rim	Ceramic	£16
BSR	Delux	Rim	Ceramic	£18
BSR	Delux	Rim	Magnetic	£26

MAINS PRE-AMP FOR MAGNETIC CARTRIDGES to low gain amplifier 10mv to ½ volt, mono **£5**, stereo **£7**. P&P £1

HEAVY METAL PLINTHS
Post £1
Cut out for most Garrard decks. Black or silver grey finish. Size 16×13¾in. **£4**

DECCA TEAK VENEERED PLINTH. Post £1 **£5**
Superior finish with space and panel for small amplifier. Board is cut for B.S.R. 18¾in.×14¼in×4in. Black/chrome facia trim. Also with boards cut out for Garrard £3. **Tinted plastic cover £5**

TINTED PLASTIC COVERS Post £1

17⅞×13⅛×3¼in	£5	18¼×12½×3in	£5
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16½×15×4½in	£5	16⅝×13×4in	£5
17×12⅞×3½in	£5	14½×13⅛×2¾in	£5
22⅝×13⅞×3in	£5	17¼×13¾×4⅛in	£5
21½×14¼×2½in	£5	21×13⅞×4⅛in	£5
23¾×14×3⅞in	£5	30¾×13⅜×3¼in	£5

THE "INSTANT" BULK TAPE ERASER £10.50 Post 95p
Suitable for cassettes and all sizes of tape reels. AC mains 200/250V. Hand held size with switch and lead (120 volt to order). Will also demagnetise small tools and computer tapes.
Tape Head Demagnetiser only £5.

BATTERY ELIMINATOR MAINS to 9 VOLT D.C.
Stabilised output, 9 volt 400 m.a. U.K. made in plastic case with screw terminals. Safety overload cut out. Size 5×3¼×2½in. Transformer Rectifier Unit. Suitable Radios, Cassettes, models, **£5.** Post £1

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R.C.S. LOW VOLTAGE STABILISED POWER PACK KITS **£3.95.** Post 65p
All parts and instructions with Zener diode printed circuit, mains transformer 240V a.c. Output 6 or 7½ or 9 or 12V d.c. up to 100mA. Please state voltage required.

RELAYS. 6V DC **95p.** 12V DC **£1.25.** 18V **£1.25.** 24V **£1.30**
ALUMINIUM CHASSIS. 2½in deep 6×4–**£1.75**; 8×6–**£2.20**; 10×7–**£2.75**; 12×8–**£3.20**; 14×9–**£3.60**; 16×6–**£3**; 16×10–**£3.80**; 12×3 **£2.20**; 14×3 **£2.50**; 13×9 **£2.80**.
ALUMINIUM PANELS. 6×4–**55p**; 8×6–**90p**; 14×3–**90p**; 10×7–**£1.15**; 12×8–**£1.30**; 12×5–**90p**; 16×6–**£1.30**; 14×9–**£1.75**; 12×12–**£1.80**; 16×10–**£2.10**.
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ALI ANGLE BRACKET 6×¾×¾in. **30p.**
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TOGGLE SWITCHES SP **40p.** DPST **50p.** DPDT **60p.**
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RESISTORS. 10Ω to 10M. ¼W, ½W, 1W, **2p**; 2W **10p.**
Low ohm 1 watt 0.47 to 3.9 ohm **10p.**
HIGH STABILITY. ½w 2% 10 ohms to 1 meg. **10p.**
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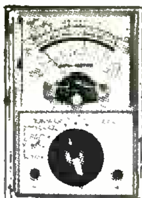
PICK-UP CARTRIDGES SONOTONE 9TAHC **£3.80.**
BSR Stereo Ceramic SC7 Medium Output **£2.** SC12 **£3.50.**
PHILIPS PLUG-IN HEAD. Stereo Ceramic. AU1020 (G306 -GP310 -GP233-AG3306, **£2. A.D.C., QLM 30/3 Magnetic £6.50.**
STYLUS most Ceramic Acos, Sonotone, BSR, Garrard Philips,**£1.50** ea. Send old one for quote.
MAGNETIC STYLUS, Sony, JVC, Sanyo, Goldring, etc. **£4.**
LOCKTITE SEALING KIT DECCA 118 . Complete **£1.**
VALVE OUTPUT Transformers push/pull 15 watt **£14**; 30W **£18**;50W **£20**; 100W **£24.** Post £2. 100V/Line 20W **£3.75.**
SPEAKER MATCHING TX 4 to 8 or 8 to 4 ohm 15 watt **£3.**
MICROSWITCH, 50p, Miniature **65p.** SPDT.
ANTEX SOLDERING IRON 'C' 15W **£5.25.** 25W 'X25' **£5.50.**
WAFER SWITCHES. 1¼" dia. Long Spindle **60p ea.**
1P 12W; 2P 2W; 2P 6W; 3P 4W; 4P 2W; 4P 3W.
FERRITE ROD. 6"×½", 6"×⅜", 8×5/16" **50p**
XLR Lead Plug **£2.40.** Lead socket **£2.75**
XLR Chassis Plug **£2.20.** Chassis Socket **£2.55.**
BANANA 4mm Plugs/Sockets, red/black **20p**
JACK PLUGS Mono Plastic **25p**; Metal **30p.** Sockets **25p.**
JACK PLUGS Stereo Plastic **30p**; Metal **35p.** Sockets **30p.**
FREE SOCKETS – Cable end **30p.** Metal **45p.**
2.5mm and 3.5mm **JACK SOCKETS 25p. Plugs 25p.**
DIN TYPE CONNECTORS
Sockets 3-pin, 5-pin **15p.** Free Sockets 3-pin, 5-pin **25p.**
Plugs 3-pin **20p**; 5-pin **25p**; Speaker plugs **25p**; Sockets **15p.**
PHONO PLUGS and SOCKETS ea. **20p**; Double sockets **30p.**
Free Socket for cable end **20p.** Screened Phono Plugs **25p.**
B.N.C. PLUGS £1. Sockets **£1.** Free Sockets **£1.10.**
U.H.F. PLUG 50p. Socket **50p.** Reducer **20p.** Coupler **50p.**
300 ohm TWIN RIBBON FEEDER 10p yd.
300 ohm to 75 ohm AERIAL MATCHING TRANSFORMER £1.
U.H.F. COAXIAL CABLE SUPER LOW LOSS, 75 ohm 25p yd.
COAX PLUGS 30p. COAX SOCKETS 20p. Lead Sockets 65p.
NEON INDICATORS 250V, round **40p.** Rectangular **45p.**
MORSE CODE TAPPER AND BUZZER SET £3.
CAR CASSETTE MECHANISM. 12V Motor Stereo Head **£5**

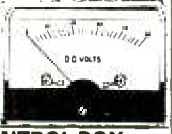
POTENTIOMETERS Carbon Track
5kΩ to 2MΩ. LOG or LIN. L/S **50p.** DP **90p.** Stereo L/S **£1.10.** DP **£1.30.** Edge Pot 5K. SP **45p.**



MINI-MULTI TESTER NEW
De luxe pocket size precision moving coil instrument. Impedance + Capacity – 4000 o.p.v. Battery included.
11 instant ranges measure:
DC volts 5.25, 250, 500.
AC volts 10, 50, 500, 1000.
DC amps 0-250μA, 0-250mA.
Resistance 0 to 600K ohms.
£7.50 Post 65p

De Luxe Range Doubler Model **£19.50**
50,000 o.p.v. 7×5×2in. Post £1
43 Ranges, 1,000V, AC-DC, 20 meg, etc.

PANEL METERS
50μa, 10Cμa, 500μa, 1ma, 5ma, 50ma, 100ma, 500ma, 1 amp, 2 amp, 25 volt, VU 2¼×2×1¼. Stereo VU 3¼×1⅝×1in. **£4.50** Post 50p



RCS SOUND TO LIGHT CONTROL BOX
Complete ready to use with cabinet size 9×3×5in. 3 channel, 1000 watt each. For home or disco **£27** Post £1
OR KIT OF PARTS £19.50

LIGHT BOXES, 20x9x9in, red, yellow, blue, green, **£16.**
DISCO BULBS 100 watt, blue, green, yellow, red, amber, screw or bayonet **£2** each. Post £1.50 per six.
"FUZZ" lights, red, blue, green, amber, 240V. **£28.** Post £1.
200 Watt Rear Reflecting White Light Bulbs. Ideal for Disco Lights, Edison Screw. 6 for **£4**, or 12 for **£7.50.** Post £1.50. Suitable panel mounting holders **85p.**

RCS "MINOR" 10 watt AMPLIFIER KIT £14
This kit is suitable for record players, guitars, tape playback, electronic instruments or small PA systems. Two versions available: Mono, **£14**; Stereo, **£20.** Post £1 10W per channel; size 9½×3×2in. SAE details. Full instructions supplied. 240V AC mains.

RCS STEREO PRE-AMP KIT. All parts to build this pre-amp. Inputs for high, medium or low imp per channel, with volume control and PC Board **£3.50**
Can be ganged to make multi-way stereo mixers Post 65p

MAINS TRANSFORMERS

	Price	Post
250-0-250V 30mA, 6.3V 3.5A, 6.3V 1A	£6.00	£2
350-0-350V 250mA, 6.3V 6A CT	£12.00	£2
220V 25ma 6V lamp £3.00 / 220V 45ma 6V 2 Amp	£4.00	£1
250V 60mA, 6V 2A	£4.75	£1
Step-Down 115V to 240V 150W **£9.** 250W **£10.** 500W	£12.00	£2

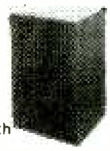
GENERAL PURPOSE LOW VOLTAGE
Tapped outputs available

	Price	Post
2 amp. 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 25 and 30V	£6.00	£2
1 amp. 6, 8, 10, 12, 16, 18, 20, 24. 30. 36, 40. 48. 60	£6.00	£2
2 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£10.50	£2
3 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£12.50	£2
5 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60	£16.00	£2

5-8-10-16V. ½ amp.	£2.50	£1	15-0-15V. 1 amp	£4.00	£1
6V. ½ amp.	£2.00	£1	15-0-15V. 2 amps	£4.50	£1
6-0-6V. 1½ amp.	£3.50	£1	20V 1 amp	£4.00	£1
9V. 400ma.	£1.50	£1	20-0-20V 1 amp	£4.50	£1
9V. 3 amp	£4.50	£1	20-40-60V 1 amp	£4.50	£2
9-0-9V. 50ma	£1.50	£1	25-0-25V 2 amps	£5.50	£2
9-0-9V. 1 amp	£3.50	£1	28V 1 amp Twice	£6.00	£2
10-0-10V. 2 amps	£4.00	£1	30V 1½ amp	£4.50	£1
10-30-40V. 2 amps	£4.50	£1	30V 5 amp and 17-0-17 2a	£5.50	£2
12V. 100ma	£1.50	£1	35V 2 amps	£4.50	£1
12V. 750 ma	£2.50	£1	TOROIDAL 30-0-30V 4a and 20-0 20V ½a	£8.50	£2
12V 3 amps	£4.50	£1			
12-0-12V. 2 amps	£4.50	£1			

CHARGER TRANS	Post	RECTIFIERS	Post
6-12 volt 3a	£4.50+£2	6-12 volt 2a	£1.10+80p
6-12 volt 4a	£6.50+£2	6-12 volt 4a	£2.00+80p

OPUS COMPACT SPEAKERS £18 pair Post £2
TEAK VENEERED CABINET
11×8½×7in, 15 watts. 4, 8 or 16 ohm
OPUS TWO 15×10½×7¾in 25 watt 2-way system **£39 pair.** Post £3
GOODMANS Q70 8 ohms 70 watt 3 way with Mid & Treble controls, **£70.** PP £4



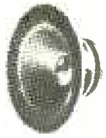
LOW VOLTAGE ELECTROLYTICS Wire ends All 10p ea
1 mf, 2 mf, 4 mf, 8 mf, 10 mf, 16 mf, 25 mf, 30 mf, 50 mf, 100 mf, 250 mf. All 15 volts. 22 mf/6v/10v; 25 mf/6v/10v; 47 mf/10v; 50 mf/6v; 68 mf/6v/10v/16v/25v; 100 mf/10v; 150 mf/6v/10v; 200 mf/10v/16v; 220mf/4v/10v/16v; 330 mf/4v/10v; 500 mf/6v; 680 mf/6v/10v; 1000 mf/2.5v/4v/10v; 1500 mf/10v; 2200 mf/6v/10v; 3300 mf/6v; 4700 mf/4v.
500mF 12V **15p**; 25V **20p**; 50V **30p.** 1200mF 76V **80p.**
1000mF 12V **20p**; 25V **35p**; 50V **50p**; 100V **£1.20p.**
2000mF 30V **42p**; 40V **60p**; 100V **£1.40**; 1500mF 100V **£1.20.**
2200mF 63V **90p.** 2500mF 50V **70p**; 3000mF 50V **65p**;
4700mF 30v **75p**; 40v **£1**; 63v **£1.80.**
NON POLARISED CAPACITORS – REVERSIBLE
1mF 250V **25p**; 1.5mF 100V **25p**; 2.2mF 250V **30p**; 3.3mF 100V **40p**; 4.7mF 100V **40p**; 10mF 63V **40p**; 32mF 50V **25p.**
HIGH VOLTAGE ELECTROLYTICS

2/500V	45p	32+32+16/350V	90p	8+16/450V	75p
8/450V	45p	100+100/275V	50p	16+16/350V	80p
16/350V	45p	150+200/275V	50p	32+32/350V	85p
32/500V	95p	32+32+32/325V	50p	32+32/500V	£2
32/350V	50p	50+50+50/350V	95p	50+50/300V	50p
50/450V	95p	8+8/500V	£1	50+50/350V	80p

CAPACITORS WIRE END High Voltage
.001, .002, .003, .005, .01, .02, .03, .05 mfd 400V **10p.**
.1MF 400V **14p.** 600V **15p.** 1000V **25p.**
.22MF 350V **12p.** 600V **20p.** 1000V **30p.** 1750V **60p.**
.47MF 150V **10p.** 400V **25p.** 630V **30p.** 1000V **60p.**
TRIMMERS 30pF, 50pF, **10p.** 100pF, 150pF **20p.** 500pF **30p.**
MICROSWITCH SINGLE POLE CHANGEOVER 40p.
GEARED TWIN GANGS 365+365+25+25pF **£2.**
BRASS SPINDLE EXTENDERS 85p. Couplers **65p.**
VERNIER DRIVE DIALS, 36mm **£2.50,** 50mm **£3.**
SLOW MOTION DRIVE 6:1 £1.50. Reverse Vernier drive **90p.**
TWIN GANG 25+25pF or 120+120pF **£1**

HEATING ELEMENTS, WAFER THIN (Semi Flexible)
Size 11×9×⅛in. Operating voltage 240V, 250W approx. Suitable for Heating Pads, Food Warmers, Convector Heaters, for Propagation, etc. Must be clamped between two sheets of metal or ceramic, etc.
ONLY **60p** EACH (FOUR FOR **£2**) POST 50p.

NEW baker Star sound
High power full range quality loudspeakers. British made. Ideal for Hi-Fi, music P.A. or discotheques. These loudspeakers are recommended for high power quality.



MODEL	INCHES	OHMS	WATTS	TYPE	PRICE	POST
MAJOR	12	4-8-16	30	HI-FI	£16	£2
SUPERB	12	8-16	30	HI-FI	£26	£2
AUDITORIUM	12	8-16	45	HI-FI	£24	£2
AUDITORIUM	15	8-16	60	HI-FI	£37	£2
GROUP 45	12	4-8-16	45	PA	£16	£2
DG 75	12	4-8-16	75	PA	£20	£2
GROUP 100	12	8-16	100	PA	£26	£2
DISCO 100	12	8-16	100	Disco	£26	£2
GROUP 100	15	8-16	100	PA	£35	£2
DISCO 100	15	8-16	100	Disco	£35	£2

BAKER AMPLIFIERS BRITISH MADE

NEW PA150 MICROPHONE PA AMPLIFIER £129
4 channel 8 inputs, dual impedance, 50K-600 ohm 4 channel mixing, volume, treble, bass. Presence controls, Master volume control, echo send return socket. Slave sockets. Post £3.

BAKER 150 Watt AMPLIFIER 4 Inputs £99
For Discotheque, Vocal, Public Address. Three speaker outlets for 4, 8 or 16 ohms. Four high gain inputs, 20 mv, 50K ohm. Individual volume controls "Four channel" mixing. 150 watts 8 ohms R.M.S. Music Power. Slave output 500 M.V 25Kohm. Response 25 Hz – 20kHz ± 3dB. Integral Hi-Fi preamp separate Bass & Treble. Size – 16"×8"×5½". Wt – 14lb: Master volume control. British made. 12 months' guarantee. 240v A.C. mains or 120V to order. All transistor and solid state. Post £2.
100 Volt Line Model £114. MONO SLAVE 150 watt £80.
New Stereo Slave 150 + 150 watt 300 watt Mono £125. Post £4.

BAKER MOBILE PA AMPLIFIER. All transistor, 60 watt RMS, 12v DC & 240v AC, 4 inputs 50k. Aux + 2 mics + 1 phono. Outputs 4-8-16 ohm + 100 volt line, **£89** p.p. £2

BAKER PORTABLE DISCO 150w. Twin console + amplifier + mike and headphones + twin speakers **£300.** 300 watt version Complete **£399.** Carriage £30. Console with pre-amp only **£107**

ELECTRONIC ECHO CHAMBER £85. Post £2
BBD Delay System 30 m/sec to 200 m/sec. Variable echo and direct sounds. Maintenance free. 240V AC.

DISCO GRAPHIC MIXER EQUALISER £108. Post £2
4 Channel stereo, 5 band graphic, red + green LED, VU display, headphone monitor, or Deluxe Model **£119.**

PA CABINET SPEAKERS, Complete. 8 ohm 60 watt 17×15×9in. **£25.** Post £4. 4 or 8 or 16 ohm 75 watt 23×15×11in, **£50.** 90 watt 32×15×11in. **£63.** 120 watt **£77.** Carr. £10. Black vinyl covered with handles.
WATERPROOF HORNS 8 ohms. 25 watt **£20.** 30 watt **£23.** 40 watt **£26.** 40W plus 100 volt line **£32.** Post £2.

R.C.S. 100 watt R.M.S. VALVE AMPLIFIER
4 Channel mixing. Master treble, bass and volume controls. 5 Speaker outlets, suits 4, 8, 16 ohm. Disco group. **£125.** Carr. & ins. £15.

60 WATT VALVE AMPLIFIER,
3 mixer inputs, 4-8-16 ohm, 100 volt line. 5 controls, 2 mic inputs plus 1 input switchable for mic, phono, aux. Treble and bass and 3 volume controls, 7 valves. **£69.** Post £3.

FAMOUS LOUDSPEAKERS "SPECIAL PRICES"

MAKE	MODEL	SIZE	WATTS	OHMS	PRICE	POST
WHARFEDALE	TWEETER	4in	30	8	£7.50	£1
PEERLESS	TWEETER	3¾in	60	8	£6.50	£1
AUDAX	TWEETER	4in	30	8	£6.50	£1
AUDAX	MID-RANGE	4in	50	8	£7.50	£1
SEAS	MID-RANGE	4½in	100	8	£14.50	£1
AUDAX	WOOFER	5½	25	8	£10	£1
GOODMANS	HIFAX	7½×4¼	100	4/8/16	£30	£2
GOODMANS	WOOFER	8in	25	4/8	£7.50	£1
GOODMANS	HB WOOFER	8in	60	8	£12.50	£1
WHARFEDALE	WOOFER	8in	30	8	£9.50	£2
CELESTION	DISCO/GROUP	10in	50	8/16	£19	£2
GOODMANS	HPG/GROUP	12in	120	8/15	£29.50	£2
GOODMANS	GR12/GROUP	12in	90	8/15	£27.50	£2
GOODMANS	HPD/DISCO	12in	120	8/15	£29.50	£2
GOODMANS	HP/BASS	15in	250	8	£72	£3
GOODMANS	HPD/BASS	18in	230	8	£84	£4

SPEAKER COVERING MATERIALS. Samples Large S.A.E.
B.A.F. LOUDSPEAKER CABINET WADDING 18in wide **35p** ft.

MOTOROLA PIEZO ELECTRIC HORN TWEETER, 3⅜in. square **£5**
100 watts. No crossover required. 4-8-16 ohm, 7⅜×3⅛in. **£10**

CROSSOVERS. TWO-WAY 3000 c/s 30 watt **£3.** 100W **£4.**
3-way 950 cps/3000 cps. 40 watt rating. **£4.** 60 watt **£6.** 100W **£8.**
LOUDSPEAKER BARGAINS. Please enquire, many others in stock.
4 ohm, 5in, 7×4in, **£2.50**; 6½in, 8×5in, **£3**; 8in, **£3.50.** 6½in 20W,**£7.50.**
8 ohm, 2⅝in, 3in, **£2**; 5×3in, 6×4in, 7×4in, 5in, **£2.50**; 6½in, 20W **£7.50** 8×5in, **£3**; 8in, **£4.50**; 10in, **£5**; 12in, **£6.** 8in 25W **£6.50**
15 ohm, 2¼in, 3½in, 5×3in, 6×4in, **£2.50.**6½in 10W **£5.** 8in **£4.** 10in **£7.**
25 ohm, 3in, **£2**; 5×3in, 6×4in, 7×4in, **£2.50.** 120 ohm. 3¼in dia. **£1.**

EMI 13½x8in. SPEAKERS
Model 450A, 10 watts R.M.S. with moving coil tweeter and two-way crossover, 3 ohm or 8 ohm. "Final Clearance" **£8** Post £1.50
SUITABLE BOOKSHELF CABINET
~~Teak Veneers £6.50.~~ Size 18×11×6in. Post £1.50

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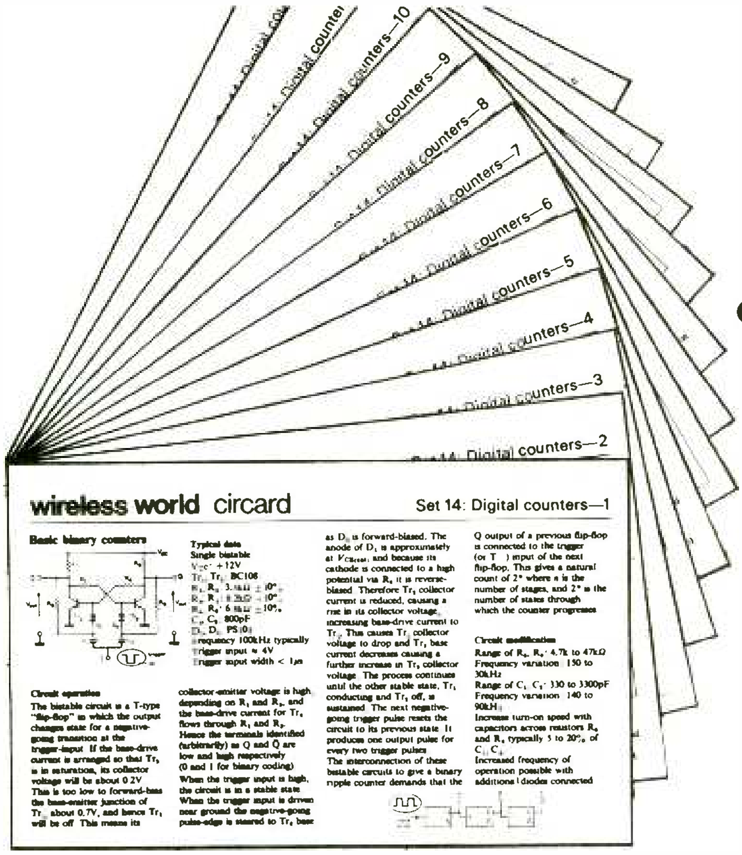
WW-7

MARK 1983 WITH GAPS IN CIRCUIT FILES WELL-PLUGGED

WIRELESS WORLD CIRCARDS last year benefited many 'new generation' readers who bought at 1976 bargain prices + 10% discount for 10 sets! Most sets are still available although companion volumes CIRCUIT DESIGNS 1, 2 and 3 are out of print (CIRCARDS sets 1 to 30).



The Offer stands, so order now your sets of 127 × 204mm cards in plastic wallets. These unique circuit cards normally contain descriptions and performance data of 10 tested circuits, together with ideas for modifying them to suit special needs.

1 Basic Active filters 2 Switching Circuits, comparators and Schmitts (But these gaps cannot be filled) * 6 Constant current circuits 7 Power amplifiers 8 Astable circuits 9 Optoelectronics 10 Micro power circuits 11 Basic logic gates 12 Wideband amplifiers 13 Alarm circuits 14 Digital Counters 15 Pulse modulators 16 Current differencing amplifiers – signal processing 17 Current differencing amplifiers – signal generation 18 Current differencing amplifiers – measurement and detection 19 Monostable circuits 20 Transistor pairs 21 Voltage-to-frequency converters 22 Amplitude modulation and detection 23 Reference circuits 24 Voltage regulators 25 RC oscillators – 1 26 RC oscillators – 2 27 Linear cmos – 1 28 Linear cmos – 2 29 Analogue multipliers 30 Rms/log/power laws 31 Digital multipliers 32 Transistor arrays 33 Differential and bridge amplifiers 34 Analogue gate applications – 1 35 Analogue gate applications – 2.

*Photocopies only: 3 Waveform generators 4A.C. measurement 5 Audio circuits @ £3.20 each set.

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7423	22p
7425	25p
7426	24p
7427	22p
7428	22p
7430	18p
7432	22p
7433	22p
7437	22p
7438	60p
7439	36p
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7454	20p
7460	30p
7470	30p
7472	25p
7473	25p
7474	27p
7475	32p
7476	25p
7480	48p
7481	120p
7482	90p
7483A	48p
7484A	90p
7485	90p
7486	30p
7489	170p
7490A	32p
7491	48p
7492A	36p
7493A	32p
7494	75p
7495A	38p
7496	50p
7497	120p
74100	120p
74104	50p
74105	55p
74107	27p
74109	27p
74110	45p
74111	55p
74112	170p
74116	90p
74118	90p
74119	75p
74120	75p
74121	32p
74122	36p
74123	45p
74125	34p
74126	36p
74128	45p
74132	43p
74136	38p
74141	55p
74142	175p
74143	200p
74144	200p
74145	75p
74147	90p
74148	75p
74150	120p
74151A	40p
74153	40p
74154	120p
74155	45p
74156	48p
74157	45p
74159	150p
74160	55p
74161	55p
74162	55p
74163	55p
74164	60p
74165	75p
74166	90p
74167	200p
74170	150p
74172	250p
74173	65p
74174	55p
74175	50p
74176	55p
74177	50p
74178	90p
74179	90p
74180	55p
74181	140p
74182	50p
74184	120p
74185A	120p
74190	60p
74191	60p
74192	60p
74193	60p
74194	50p
74195	50p
74196	48p
74197	48p
74198	120p
74199	120p
74221	80p
74251	60p
74259	100p
74265	55p
74273	120p
74276	120p
74278	100p
74279	55p
74283	50p
74285	160p
74286	160p
74290	75p
74293	90p
74298	120p
74351	150p
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74LS11	20p
74LS12	20p
74LS13	25p
74LS14	36p
74LS15	20p
74LS20	20p
74LS21	20p
74LS22	20p
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74LS28	20p
74LS30	20p
74LS32	25p
74LS33	20p
74LS37	20p
74LS38	20p
74LS40	20p
74LS42	36p
74LS47	60p
74LS48	60p
74LS51	20p
74LS54	20p
74LS55	20p
74LS73A	20p
74LS74A	30p
74LS75	30p
74LS76A	27p
74LS83A	46p
74LS85	60p
74LS86	25p
74LS90	32p
74LS91	60p
74LS92	40p
74LS93	32p
74LS95B	50p
74LS96	90p
74LS107	33p
74LS109	33p
74LS112	33p
74LS113	30p
74LS114	32p
74LS122	60p
74LS123	60p
74LS124/629	150p
74LS125	36p
74LS126	36p
74LS132	42p
74LS133	30p
74LS136	30p
74LS138	42p
74LS139	42p
74LS145	75p
74LS147	120p
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74LS151	50p
74LS153	50p
74LS154	150p
74LS155	40p
74LS156	40p
74LS157	40p
74LS158	35p
74LS160A	50p
74LS161A	50p
74LS162A	45p
74LS163A	45p
74LS164	48p
74LS165A	60p
74LS166A	90p
74LS168	140p
74LS169	110p
74LS170	100p
74LS173A	90p
74LS174	45p
74LS175	45p
74LS181	120p
74LS183	120p
74LS190	60p
74LS191	60p
74LS192	60p
74LS193	60p
74LS194A	50p
74LS195A	50p
74LS196	60p
74LS197	54p
74LS221	80p
74LS240	70p
74LS241	70p
74LS242	60p
74LS243	60p
74LS244	70p
74LS245	140p
74LS247	70p
74LS248	70p
74LS249	70p
74LS251	45p
74LS253	45p
74LS256	200p
74LS257A	45p
74LS258A	45p
74LS259	80p
74LS260	35p
74LS261	80p
74LS266	25p
74LS273	75p
74LS275	175p
74LS279	35p
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74LS348	140p
74LS352	70p
74LS353	70p
74LS356	175p
74LS363	180p
74LS364	180p
74LS365A	36p
74LS366A	36p
74LS367A	36p
74LS368A	36p
74LS373	75p
74LS374	75p
74LS375	60p
74LS377	90p
74LS378	85p
74LS379	92p
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74LS669	70p
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74S132	110p
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74S138	110p
74S139	120p
74S140	60p
74S151	180p
74S153	180p
74S157	250p
74S158	195p
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74S195	300p
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74S200	450p
74S201	320p
74S225	650p
74S240	250p
74S241	300p
74S244	300p
74S251	250p
74S257	250p
74S258	250p
74S260	70p
74S261	300p
74S262	850p
74S283	300p
74S287	225p
74S288	150p
74S299	550p
74S373	400p
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74C192	100p
74C193	115p
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74C221	150p
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4019	25p
4020	48p
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4022	45p
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4027	20p
4028	40p
4029	45p
4030	15p
4031	125p
4032	80p
4033	125p
4034	140p
4035	45p
4036	275p
4037	110p
4038	110p
4039	290p
4040	40p
4041	40p
4042	40p
4043	40p
4044	40p
4045	105p
4046	50p
4047	45p
4048	50p
4049	24p
4050	24p
4051	45p
4052	60p
4053	50p
4054	90p
4055	90p
4046	90p
4059	450p
4060	55p
4063	90p
4066	27p
4067	225p
4068	14p
4069	14p
4070	14p
4071	14p
4072	14p
4073	14p
4075	14p
4076	48p
4077	16p
4078	16p
4081	14p
4082	15p
4086	55p
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4094	90p
4095	75p
4096	70p
4097	290p
4098	90p
4099	100p
4500	575p
4502	60p
4503	45p
4504	75p
4505	400p
4506	35p
4507	35p
4508	130p
4510	45p
4511	45p
4512	48p
4514	120p
4515	110p
4516	55p
4518	40p
4520	50p
4521	90p
4522	120p
4526	60p
4527	60p
4528	50p
4532	70p
4534	400p
4536	270p
4538	90p
4539	70p
4543	75p
4553	245p
4555	35p
4556	35p
4557	300p
4560	120p
4566	160p
4568	250p
4569	170p
4572	30p
4583	90p
4584	40p
4585	75p
40014	40p
40085	90p
40097	45p
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40103	170p
40105	110p
40106	40p
40109	100p
40110	275p
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40174	50p
40175	75p
40193	75p
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40245	180p
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NE555	16p
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TIP32C	40p
TIP33A	70p
TIP33C	80p
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TIP34C	120p
TIP35A	120p
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2N3055	35p
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2N5191	90p
2N5245	40p
2N5401	60p
2N5459	30p
2N5460	60p
2N5485	36p
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8205	225p
8212	110p
8216	100p
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8250	850p
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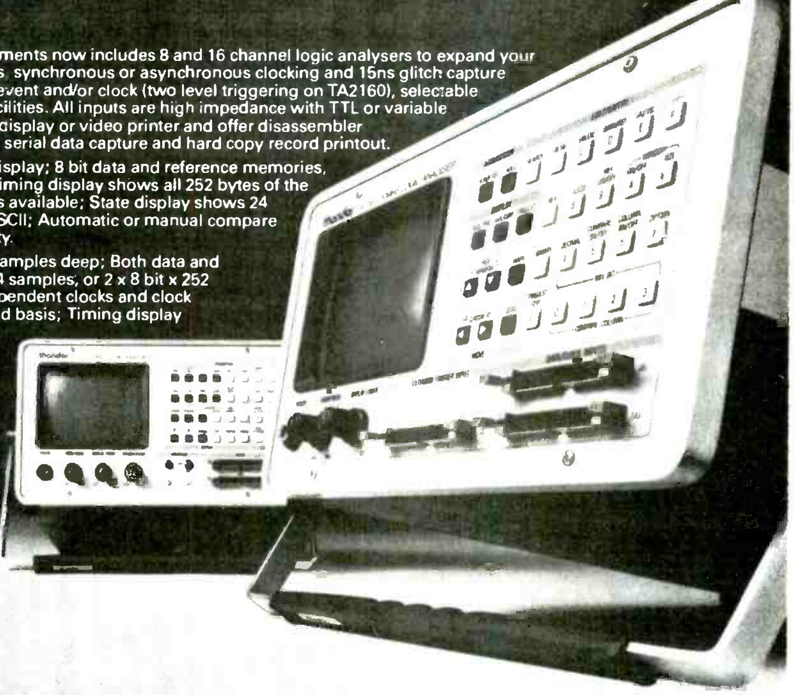

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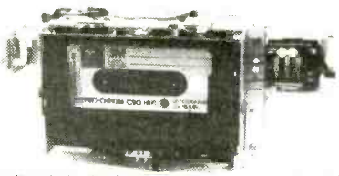

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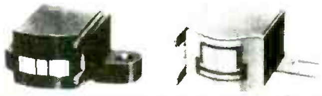

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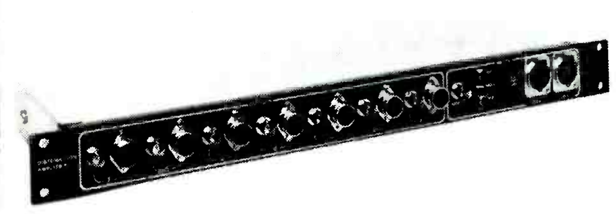

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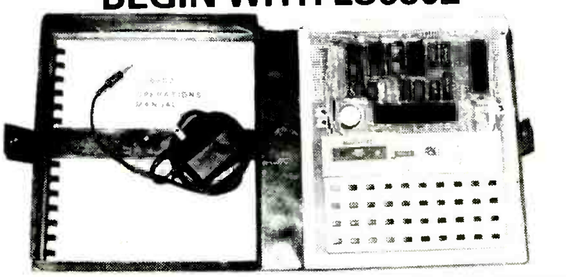

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BF200 0.40
BF241 0.15
BF245 0.30
BF246 0.28
BF256/LC 0.28
BF257 0.28
BF258 0.28
BF259 0.28
BF271 0.26
BF273 0.13
BF336 0.34
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BF394 0.19
BF422 0.32
BF457 0.32
BF458 0.36
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BF595 0.23
BF597 0.25
BFR39 0.23
BFR40 0.23
BFR41 0.28
BFR81 0.25
BFR88 0.30
BFR90 1.50
BFR91 1.75
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BFT43 0.28
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2N3702 0.12
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2N3704 0.12
2N3705 0.12
2N3706 0.12
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2N3773 1.95
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2N4444 1.15
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2N5496 0.65
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BB105B 0.30
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BY127 0.11
BY133 0.15
BY164 0.45
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BY179 0.63
BY182 0.55
BY184 0.35

BY199 0.40
BY206 0.14
BY208-800 0.33
BY210-800 0.33
BY223 0.90
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BY299-800 0.22
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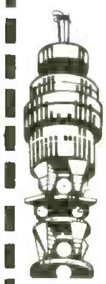
Applications are invited for the above post. The successful applicant will take charge of all engineering aspects of the Centre's work, including planning and development, studio and mobile operations and supervision of the technical staff. Applicants should preferably be graduates or have comparable qualifications in electronic engineering and wide experience in broadcasting, industrial or educational television. Initial salary on Grade II for Other Related Staff £11,160-£14,125 a year according to qualifications and experience. Tenable for two years in the first instance. Particulars from the Registrar and Secretary (Staffing), the University, Sheffield S10 2TN to whom applications (5 copies), including the names of three referees, should be sent by 30 September 1983. Quote ref. R898/BH.

(2266)



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(291)

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Location: West London

An appointment exists within a long established electronic data capture company for a senior development engineer.

The main duties associated with this appointment are:

★ Development of microprocessor based data capture equipment.
★ Development of customised interfaces.
★ Customer liaison.

The successful applicant would probably be qualified to HNC level, and have at least three years' experience in the electronic industry, preferably in data processor type equipment, and have experience of microprocessors and data communications interfaces.

Normal large company benefits + company car.

Salary commensurate with experience.

Apply to Box No. 2282

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Qualifications to tec (HC) or equivalent. Some experience in a related area preferred. Some UK and European travel expected

Salary £6,000+ (negotiable). Car provided

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Electra Med
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Cambridge CB3 0QB

(2269)

SURREY COUNTY COUNCIL
Guildford County College of Technology
invite applications for the following vacancy:
Department of Science and Electrotechnology

SENIOR TECHNICIAN in COMPUTER TECHNOLOGY

£6,264-£7,005/£7,191-£7,896
plus £270 Surrey Allowance

Suitably qualified person required to service computer equipment, with an emphasis on microprocessor development.

Application forms and further details from the Committee Clerk, Guildford County College of Technology, Stoke Park, Guildford, Surrey GU1 1EZ, on receipt of SAE. (Tel: Guildford 31251)

Closing date: Friday 14th October 1983
(Re-advertisement)

(2268)

PHOTOSTAFF

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1935

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The successful applicant should be fully conversant with BS-415 safety standards, applicable to domestic electrical equipment, and should have had at least two years' experience in this field.
He/she should be qualified to H.N.C. or equivalent standard in electronics and preferably with at least three years' experience in domestic HiFi and/or Video equipment. Some experience in technical writing is also essential.
Benefits include competitive salary, four weeks' holiday, subsidised restaurant, contributory pension scheme and private health cover.

For further information or an application form, please contact:
Mrs C. A. Burridge, Pioneer High Fidelity (GB) Limited Field Way, Greenford, Middx. UB6 8UZ. Tel: 01-575 5757

(2196)

LABORATORY TECHNICIANS

We have vacancies for Laboratory Technicians at senior and junior level at our Equipment Department, based at Chiswick. Duties include the testing of newly manufactured broadcast equipment and involve work on sound, television, radio-frequency and digital equipment.

Technicians should possess, or be studying for a TEC or HTEC certificate in electronics, and have at least one year's relevant experience. Salary is in the range £6346 to £7615.

Applicants with less experience may be considered for junior posts at a lower salary.

Requests for application forms to **Engineering Recruitment, BBC, P.O. Box No. 2BL, London W1A 2BL. Quote reference 83.E.4099/WW.**

BBC

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PLYMOUTH HEALTH AUTHORITY

Department of Medical Physics and Biomedical Engineering

ELECTRONICS TECHNICIAN

required for interesting post in medical electronics. The person appointed will be a member of a team of nine in a well-equipped and expanding Department. He/she will be responsible to a graduate electronics engineer for maintenance and development of a wide range of patient-orientated equipment situated in Hospitals and Health Centres throughout the Plymouth Health District.

Hospital experience is not essential, as further training will be given. HNC, ONC, City and Guilds Final Certificate or equivalent qualification is required. The work involves occasional travel and necessitates a current driving licence. There is a requirement to participate in a scheme to provide out of hours emergency cover. The current salary scale is £5,171 rising to £6,798.

Further information is available from Mr A. C. Dawson, Chief Technician, telephone Plymouth (0752) 834276.

Application forms are available from the Personnel Officer, Unit Personnel Dept. PGH No. 1, Belvedere, Greenbank Road, Plymouth PL4 7JN. Please enclose a stanped addressed envelope.

Closing date for return of application forms: 21st October, 1983.

(2260)

Proposal Support Manager

£10,000 + generous bonus Surrey

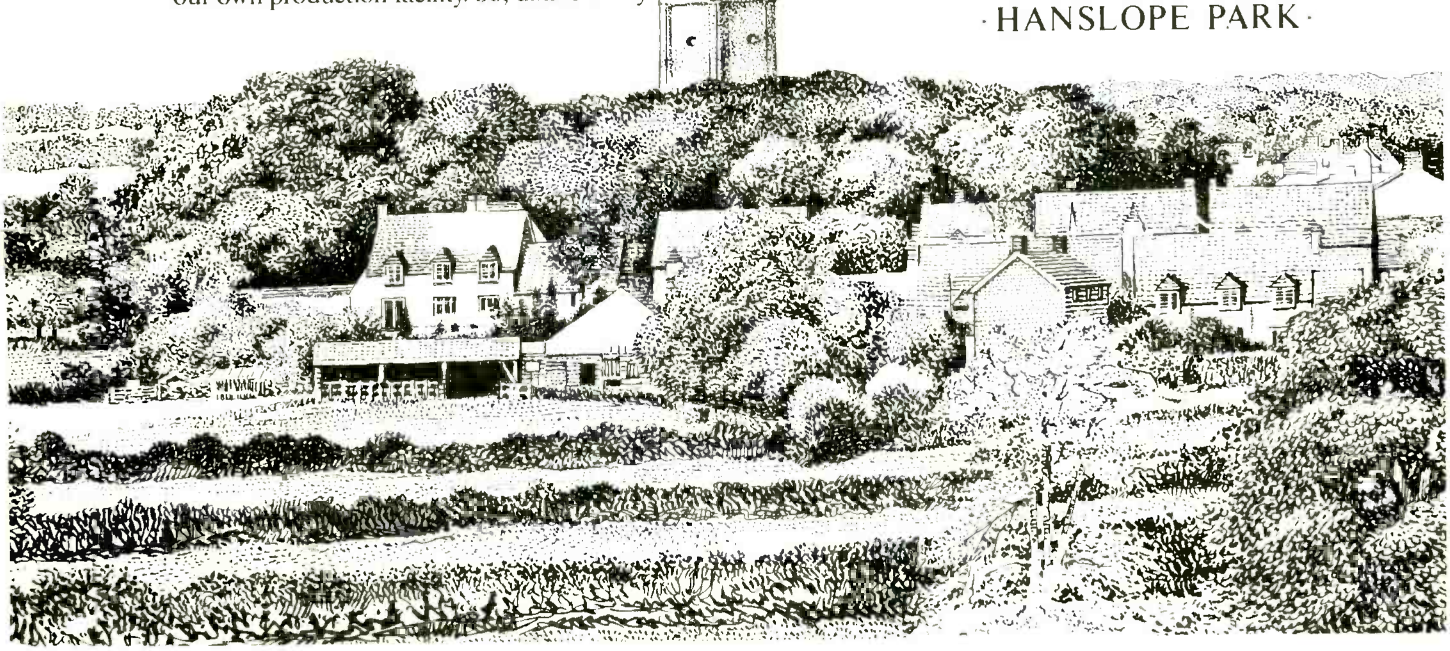
Granger Associates are a leading company in the design, manufacture and marketing of communications equipment for overseas markets. Our products are marketed extensively to both major industrial nations and to developing countries and we are now looking to strengthen further our commercial expertise by appointing a Proposal Support Manager.

Based at our Sales Headquarters in Weybridge, Surrey, you'll provide vital support to the international sales team in the preparation of systems and proposal documentation for all our communications products marketed to Europe, Africa and the Middle East, with particular emphasis being placed upon HF systems.

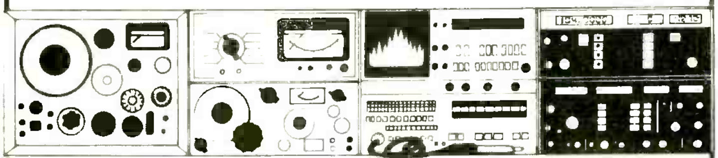
In addition to sound relevant experience gained within an electronics engineering environment, you will need to be a good communicator at all levels with the ability to interpret Government, Military and commercial specifications, and work effectively under pressure. Knowledge of a foreign language would be a distinct advantage.

Please write in the first instance with full c.v. to Mrs L. Tabb, Granger Associates Ltd., 1 Brooklands Road, Weybridge, Surrey KT13 0SD.

Granger Associates Ltd.



Test & Calibration Engineers



Having introduced an extended new product range, many of which are microprocessor based, Marconi Instruments has once again confirmed itself as Europe's leading manufacturer of sophisticated test and measurement systems. Our products are selling throughout the world and we are naturally developing further new and innovative designs.

A key role in our organisation is that of our Luton based Service Division, where a group of Technicians satisfy a very wide range of customer needs in the repair and calibration of test equipment.

When you join our team you will quickly become individually responsible for work assignments involving many different kinds of propriety products.

Prospects are excellent. The Division is part of a large company with its main Instrument Design/Manufacturing Base at St. Albans, a Microwave Plant at Stevenage and a further substantial Design Manufacturing Group at Donibristle in Scotland. The Company is proud of its policy of promoting men and women from within, as future Salesmen, Managers and Engineers.

Salaries, which are dependent upon experience and ability are excellent and regular overtime is normally available. Progress for competent engineers and technicians can be rapid. Relocation assistance is available in approved cases. Special consideration is given to 'ex-forces' personnel.

Whatever your level of experience we would like to hear from you. Cut out the coupon and send it to John Prodger, Recruitment Manager, Marconi Instruments Limited, FREEPOST, St. Albans AL4 0BR. Tel: (0727) 59292.

Name Age

Address

Tel. No.

Years Experience

Present Salary:	£6,000 – £7,000	£7,000 – £8,000	£8,000 – £9,000	Over £9,000
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Qualifications

Present Job

(2143)

marconi instruments

Marconi

ELECTRONIC MAINTENANCE ENGINEER

Yorkshire Television, one of the five major Independent Television Companies, has established a worldwide reputation for producing quality award-winning programmes. Each week, over 100 hours of programmes are transmitted to 6 million viewers in Yorkshire, Lincolnshire and Derbyshire.

The Industry Code of Practice sets exacting quality standards for broadcast television. To meet these stringent performance parameters, the Electronic Maintenance team follows a comprehensive policy of routine maintenance, inspection, examination and measurement of the complex electronic systems in the Leeds studio facility.

Through internal promotion, an opportunity has arisen to join the Electronic Maintenance team. Applicants should be qualified to a minimum of HNC level or equivalent in Electronic Engineering. Experience of working, using advanced test equipment, on broadcast electronic systems, either with a television company or an equipment manufacturer is essential.

Starting salary will be in a range up to £12,500 depending on qualifications and experience, plus overtime payments.

Applications in writing to:
The Personnel Officer (Recruitment)
Yorkshire Television Limited
The Television Centre, Leeds LS3 1JS

YORKSHIRE TELEVISION

ELECTRONIC INSTRUMENT SYSTEMS TECHNICIANS

Sartorius Instruments is a world leader in electronic weighing in the analytical, research, quality assurance and allied industries. The product range is expanding further into the industrial system's market and personnel are required to supplement our already established Field Service team.

Successful applications will service and install our computerised systems nationwide. Primary responsibilities will be problem solving of Sartorius equipment and liaison production and the customer.

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On appointment you will spend three weeks training in our workshop in Belmont followed by suitable training at our parent company factory in West Germany, when available. Initially the job will require a large proportion of time to be spent at our in-house service centre at Belmont, Surrey.

Candidates must be in possession of a current driving licence and be prepared for nationwide travel. A company car is provided.

In addition to the above vacancies technicians are required for certain areas on general electronic and mechanical balance maintenance.

If you would like to receive more information or apply for a position, please write giving brief career details to the Service Co-ordinator, Sartorius Instruments Limited, 18 Avenue Road, Belmont, Surrey.

(2267)

Television Recording requires Electronics Engineers to train in Broadcast Engineering, to support an expanding Video Tape and Telecine Operation, which includes complex digital and analogue equipment.

Applicants need not initially possess an in-depth knowledge of Television Engineering, as full training will be given, but previous academic training must be supported by enthusiasm for practical engineering.

After training, applicants will progress to work involving all aspects of Television Recording, including in-depth servicing, acceptance of equipment, design of modifications, and technical investigations.

These challenging posts offer excellent promotional prospects for the self-motivated and committed engineer capable of working at the forefront of today's technology.

Salaries range from £8,129 to £9,200–this includes an allowance for shift working. A higher salary will be considered in exceptional circumstances.

Qualifications required are, a Degree in Engineering, HND, HNC, Full C & G.

For further information please write, with details of your academic and work experience, to **Bob Neal, BBC, P.O. Box 2 BL, London W1A 2BL.**
Please quote ref: 83.E.4055.
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BBC
television recording

WW/219

Head of Antennae Design Group

In "Survivability" technology MEL, the Electronic Systems Development Division of the Philips U.K. Group of Companies, have been pioneers for over 30 years. Since the earliest days of Electronic Warfare, we have been applying our technical expertise and in-depth understanding of military and naval needs to the development of systems which detect, analyse and counter enemy threats. Systems which include ESM, ECM and ECCM that are more than a match for the growing sophistication of land-based, airborne or shipborne radar and air or surface launched homing missiles.

A key in-house consultancy and design service is that of the Antennae Design Group who ensure the application of the most advanced technology in the design, production and utilisation of antennae systems for many of our projects.

Applicants for the position of Head of this key activity must offer an appropriate professional engineering background and proven ability in technical leadership at least to the level of 2 i/c within a similar activity. The successful candidate will report directly to the Technical Manager and will carry "bottom line" responsibility for the performance of the Group.

Salary and other conditions will be attractive. Assistance with relocation is available, if required. Please write, in full confidence, quoting reference WW9 to:
Mr. L. B. Staunton, Personnel Manager, MEL, Manor Royal, Crawley, Sussex.

MEL

(2285)

Electronic Engineers – What you want, where you want!

TJB Electrotechnical Personnel Services is a specialised appointments service for electrical and electronic engineers. We have clients throughout the UK who urgently need technical staff at all levels from Junior Technician to Senior Management. Vacancies exist in all branches of electronics and allied disciplines - right through from design to marketing - at salary levels from around £5000-£15000.

If you wish to make the most of your qualifications and experience and move another rung or two up the ladder we will be pleased to help you.

All applications are treated in strict confidence and there is no danger of your present employer (or other companies you specify) being made aware of your application.

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Tunbridge Wells,
Kent. TN4 8AS.

Tel: 0892 39388

TJB

Please send me a TJB Appointments Registration form:

Name ....

Address ....

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(861)

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1) Video/TV Equipment
Field Service Engineers required with experience of analogue/digital/computer based equipment. £9-£10,000 – Hants.

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Commissioning/Servicing Engineers required. To £8,500 – Sussex.

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Service Engineers to repair complex PCBs for terminals, printers, disc drives, etc. C. £8,000 – Surrev

4) Video/CC TV/Audio Equipment
Installation/Service Engineers needed with experience of audio/video systems. C. £9,000 – Surrey

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(RAF, RN, Army)
We have many clients interested in employing ex-service fitters and technicians at sites throughout the UK. Phone for details.

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We are paying very high rates for contract design and test engineers who have a background in RF, MICROWAVE, DIGITAL, ANALOGUE or SOFTWARE, at sites throughout the UK.

Hundreds of other Electronic and Computer Vacancies to £12,500

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Roger Howard, C.Eng., M.I.E.E., M.I.E.R.E.

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(1640)

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Specialists in Field & Customer Engineering appointments, all locations and disciplines

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(24 hours)

CUSTOMER ENGINEER

North London-based
to £9,100 + car + extensive benefits

Do you have at least a couple of years' electronics field service experience backed by a relevant HNC (or equivalent)? If so, you could be just the person we seek to service our sophisticated range of medical electronic equipment in the North London area.

As the dominant leader in the UK instrumentation market, we can offer you a comprehensive programme of induction and on-going training. There are outstanding career development prospects in this very successful high-technology company. An attractive salary is backed by profit-sharing and a share-purchase scheme among the wide range of company benefits.

Aged at least in your mid-20s, and preferably living on or within reach of the territory, you must have the strong personal presence to succeed in a demanding customer-contact environment in addition to a high level of technical capability. Previous experience of hospital markets and equipment, whilst an advantage, is not essential.

Move up to a more satisfying – and more rewarding – field service challenge with the top name in electronic measurement systems. Call Andrew Webb for more information and an application form on 0344 773100. Or write to him enclosing your full personal and career details at Hewlett-Packard Limited, Nine Mile Ride, Easthampstead, Wokingham, Berkshire RG11 3LL.

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The ideal candidates will be:-

- qualified to degree or equivalent in electronics or telecommunications
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- currently employed within radio or communications related industries

The responsibilities range from involvement in the initial design of specifications, through all the trouble-shooting and problem solving aspects of the concept to prototype building and successful quantity production.

These opportunities offer a dedicated professional environment with an unrivalled range of support resources throughout the group. Career development is excellent within one of the Company's most successful and fastest expanding departments. The complete package, which will include relocation expenses where appropriate, is highly attractive to the successful candidate.

For an initial and confidential discussion please call Bob Archibold on Newbury (0635) 33445 quoting reference D/111 or write in strict confidence to: –

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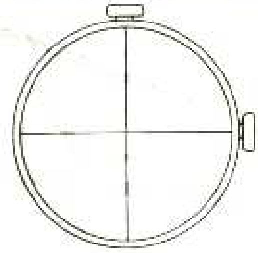
(High Technology Search & Selection),
7, London Road, Newbury, Berkshire RG13 1JL.
Tel: Newbury (0635) 33445.

ARC

(2255)

Appointments

THE HUNT IS ON–FOR ELECTRONICS ENGINEERS WHO HAVE SET THEIR SIGHTS HIGH



The current Jaguar cars represent the epitome of mechanical engineering excellence, but to maintain this lead through the remainder of this century will require a complementary standard in vehicle electronics. We are therefore seeking to recruit a specialist electronics team whose brief will be to identify and solve problems in the application of microprocessors and computers to cars from system design through to manufacture and service.

The formal qualifications sought will be a degree in electronics or related subject, with both hardware and software experience. Applications from multi-disciplinary engineers who have experience in other relevant areas such as engines, instrumentation, transducers, CAD, reliability engineering or computer modelling will be viewed with particular favour.

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To put your career on target write in confidence giving full career details and current salary to:

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Manager, Organisation & Personnel Planning
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(2256)

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Studios/HF/MF/VHF/TV. Knowledge of a foreign language would be an advantage.

An attractive salary and benefits package will be offered to the successful applicant.

Please send c.v. or résumé to:
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INCOMTEL LTD, 225 Goldhawk Road London W12 8SB. Tel: 01-743 5511

(2258)

UNIVERSITY OF LONDON
Institute of Education

TECHNICIAN

required to organise and run new Advisory and Service Unit containing BBC, 380Z, 480Z, Spectrum and Apple microcomputers. Duties include hardware maintenance, assisting users and designing interfaces between microcomputers and other equipment. Experience in practical applications of digital and analogue electronics to microcomputers and peripheral equipment; knowledge of BASIC, 6502 and Z80 assembler and programming of VIAs also required.

Salary within range £8,422-£9,822 inclusive. Appointment for three years initially.

Please contact Mary Griffin, on 636 1500 Extension 254 or at University of London Institute of Education, 20 Bedford Way, London WC1H 0AL for further details and an application form. Closing date 5 October.

(2262)

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(2172)

The Polytechnic of North London

Department of Electronic and Communications Engineering

LABORATORY TECHNICIAN Grade III (Electronics)

Applications are invited for the above post, to assist senior staff in the day-to-day running of the Department's busy laboratories.

The duties involve the construction, modification and repair of experimental chassis working from precise instructions, together with the preparation and setting-up of equipment for class practicals. Some experience with the use and maintenance of oscilloscopes, signal generators and power supplies would also be an advantage.

Qualifications:
OND, ONC, two A levels or Ordinary City and Guilds or equivalent, with three to five years' relevant experience (including training period).

Salary scale:
£5,151-£6,036 plus £1,220 London Weighting.

Application forms and further details from Mr. E. W. Bowman, Departmental Superintendent, Department of Electronic and Communications Engineering, The Polytechnic of North London, Holloway Road N7 8DB.

Closing date for receipt of applications: October 7, 1983.

(2280)

INSTALLATION ENGINEER

Electronics engineer required to pre-assemble and install complex sound and lighting systems worldwide. Good electronics knowledge and common sense vital. Applicants should be single, in twenties, and be prepared to travel extensively. Salary up to £10,000 depending on experience.

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Bacchus International Discotheque Services
64/66 Glentham Road
London SW13 9JJ

(2243)

GRAND OPPORTUNITY FOR LIGHTING BOFFIN

A neat, company-minded, self-motivated individual interested in working with a team of people shaping the future.

Duties will include Q.A. of Lighting and Audio Musical Products for the music, theatre and rock 'n' roll industry, with some opportunities for design and update work.

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(2251)

ELECTRONICS TECHNICIAN (Grade V)

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Application form from Personnel Officer (Technical Staff FC7), University College London, Gower Street, London WC1E 6BT.

(2259)

INDUSTRIAL VIDEO ENGINEER

With experience in high quality black and white video needed.

Telephone 01-900 0497

(2246)

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Recently awarded contracts have created a need for immediate expansion of on-site facilities and the design team. Some senior appointments have been filled from within, but there are still opportunities for Engineering Managers and Group Leaders to head up additional teams now being formed.
At Senior Engineer/Engineer levels there are several vacancies in each of the above work areas.
Qualifications required are Degree/HND/HNC in a relevant discipline, plus experience.
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Design Engineers

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Address ____________
____
Age ______ Telephone (Home) ____________ (Work) ____________
Qualifications ____________

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Marconi
Space & Defence Systems

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Have you thought of teaching your skill? We have a vacancy for a Radio and TV Electronic Servicing Instructor at Deptford Skillcentre.

To apply you should have a full trade training, be at least 25 years of age, and have five years' practical experience behind you.

The promotion opportunities, pensionable security and self-respect are what only a leading training organisation like ours can offer.

There is a starting salary of £7,062 rising by two annual increments to £8,510 plus £500 Outer London Weighting.

If you think you've got what it takes telephone **Thirza Mathieson on 01-836 1213, ext. 443. Manpower Services Commission, Selkirk House, 166 High Holborn, London WC1V 6PF.**

(2290)

ELECTRONICS ENGINEER

committed to Third World Development

to develop simple solar voltaic products and assist in establishing small scale manufacturing units in **Botswana.**
Practical experience of design and construction of electronic devices essential.
2 year contracts including modest living allowance and flights. Regret no funding for dependants.

Write for details including short c.v. and s.a.e. to: International Voluntary Service, EW2, 53 Regent Road, Leicester LE1 6YL.

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Further details and application forms are available from the Personnel Officer, Brighton Polytechnic, Moulsecoomb, Brighton BN2 4AT. Tel: Brighton 693655, Ext. 2536. Closing date: September 30, 1983. (2290)

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BBC MICROCOMPUTER "GENLOCK" BOARD

This card enables the video outputs of the computer to be synchronised to an external video or sync. signal. The board is supplied ready to fit inside the computer. Send s.a.e. to

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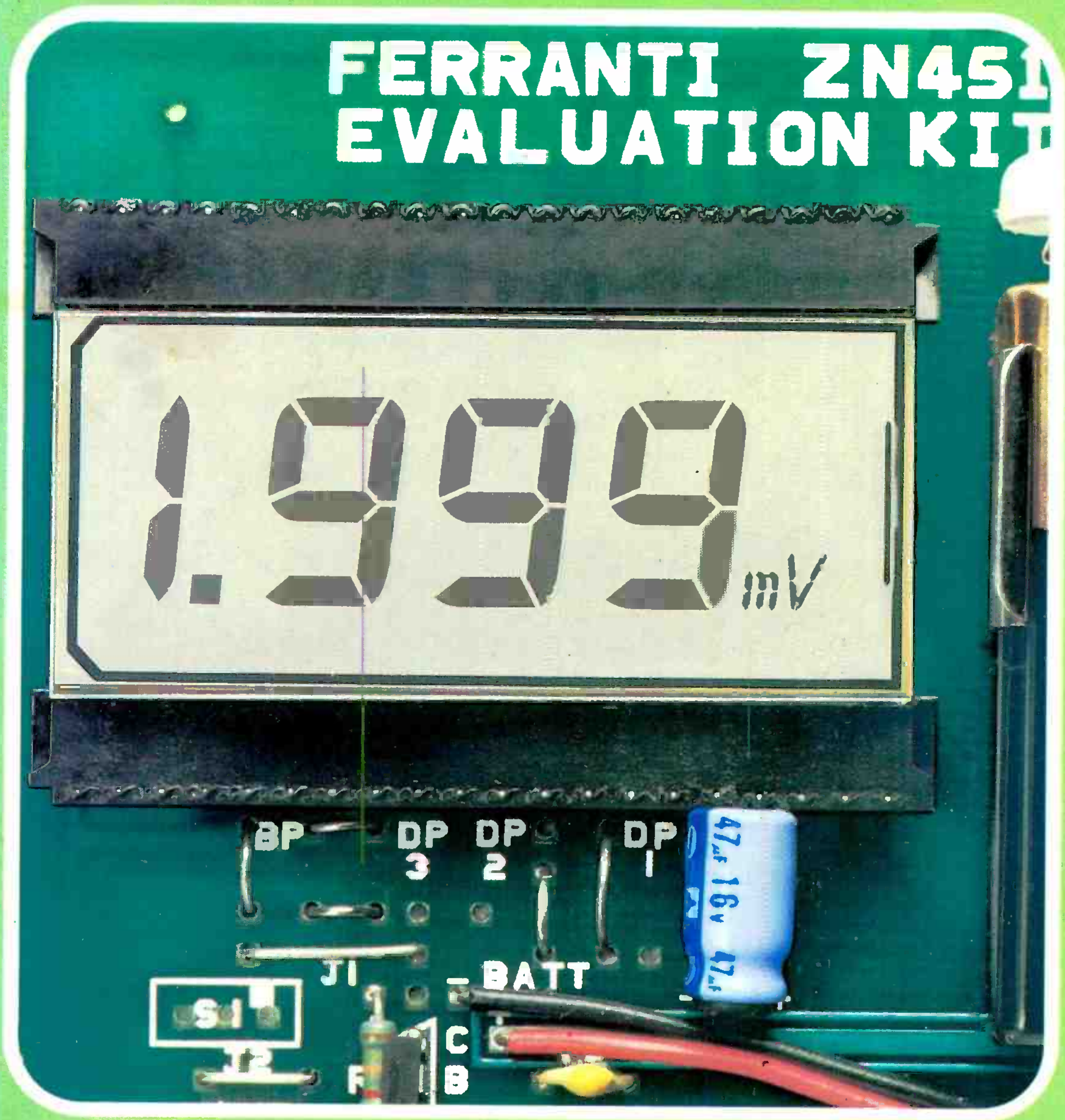

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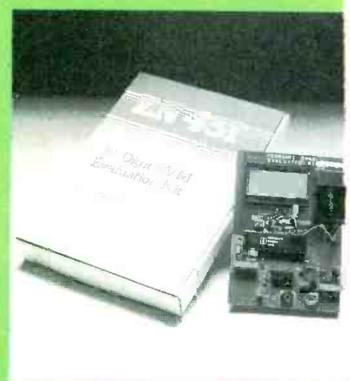

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