wireless world

JULY 1981 60p

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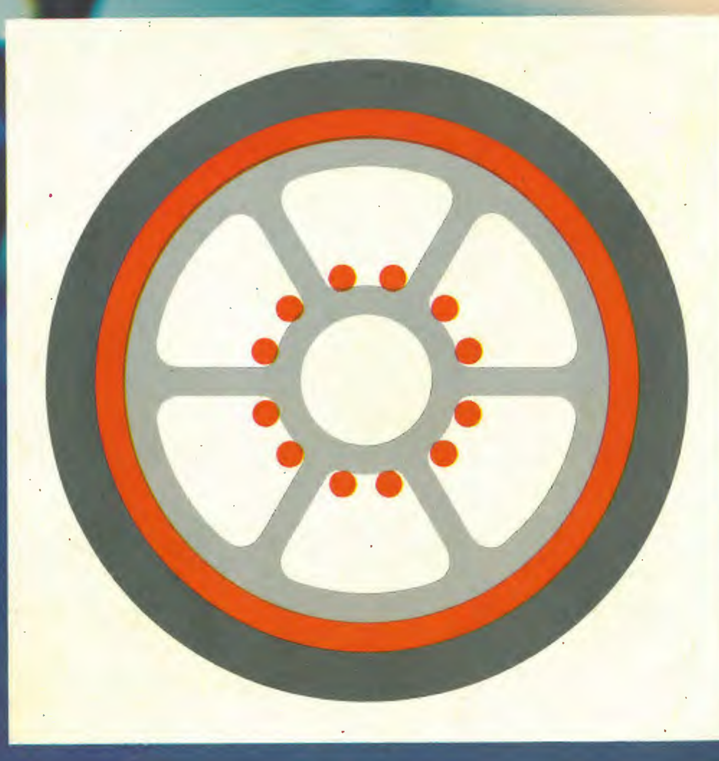
Uprated micro trainer

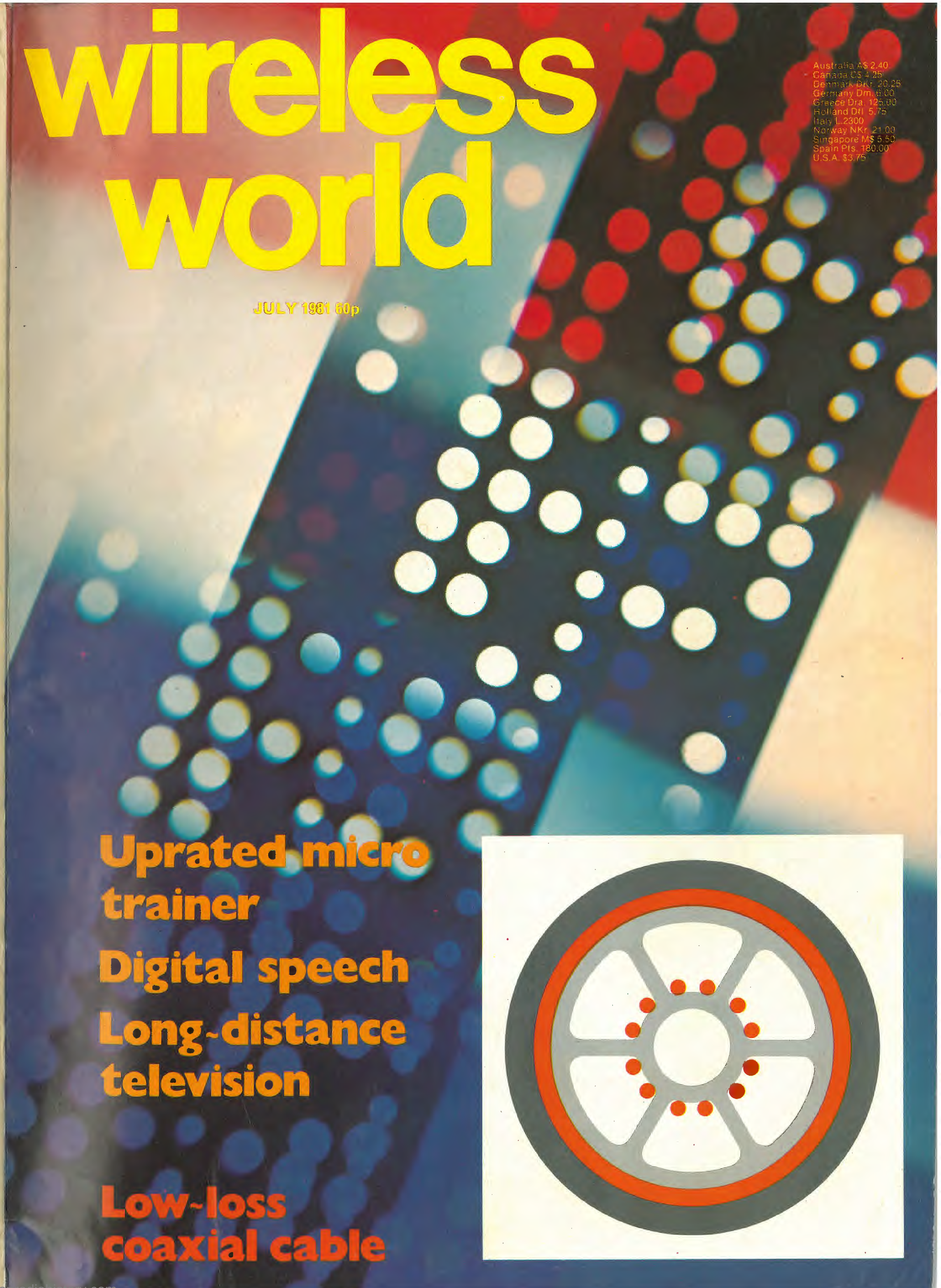
Digital speech

Long-distance television



Low-loss coaxial cable

WIRELESS WORLD JULY 1981 VOL 87 NO 1546



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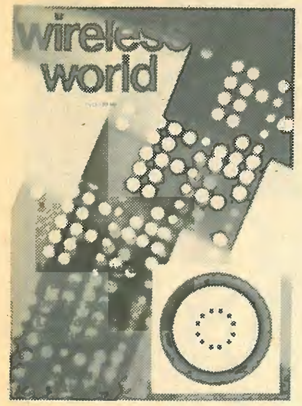

Front cover shows cross-section of the new type of coaxial cable described in this issue, superimposed on a photographic montage of punched tape symbolising the digital techniques in other articles. Photographer: Paul Brierley.

wireless world

ELECTRONICS/TELEVISION/RADIO/AUDIO

JULY 1981 Vol 87 No 1546

IN OUR NEXT ISSUE

Radio and the birth of the Universe. **A review of the significance of the 3K cosmic microwave background in the Big Bang cosmological theory.**

Electronics on the road. **Broadly surveys electronic ignition, anti-lock brakes, cruise control, active suspension and other electronic systems; also social influences on design.**

Correlator for angles. **Measuring technique suitable for testing timing scatter in automobile ignition systems and other rotary mechanisms.**

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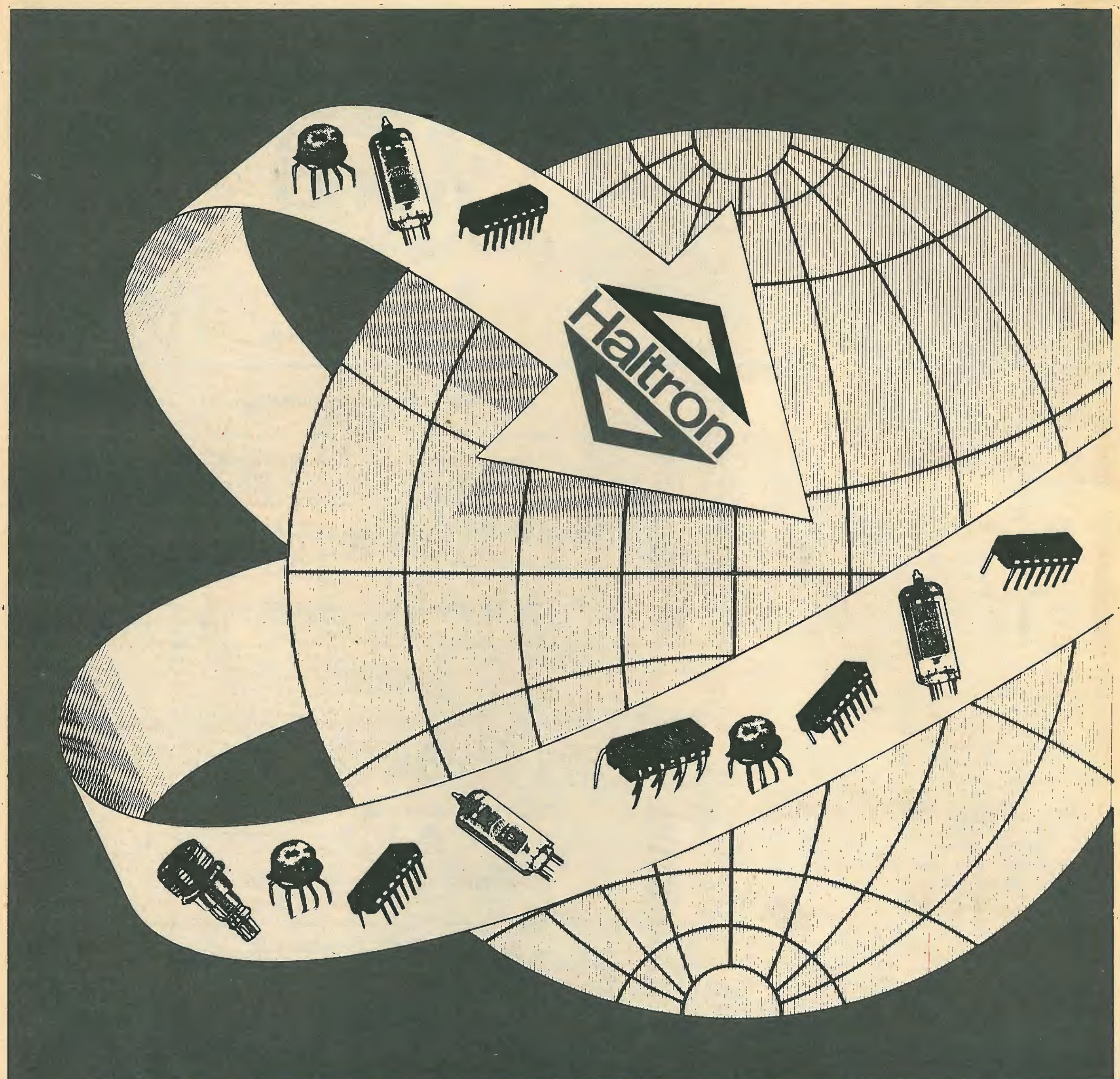

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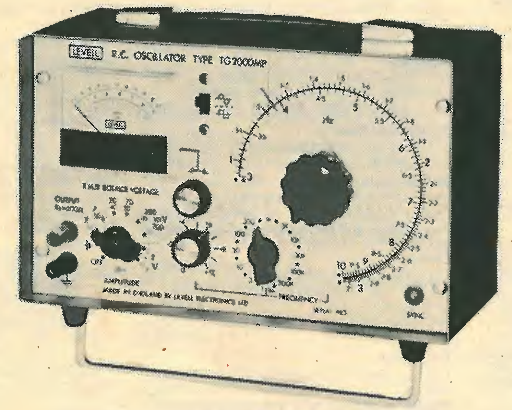
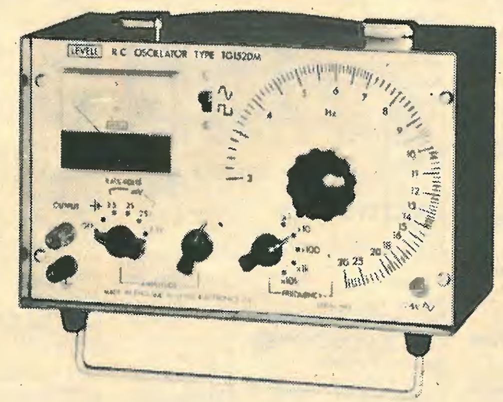


FREQUENCY	1Hz to 1MHz in 12 ranges. 0 to 1% fine control on TG200DMP.
ACCURACY	± 1.5% ± 0.01Hz up to 100kHz. ± 2% up to 1MHz.
SINE OUTPUT	7V r.m.s. down to < 200μV with Rs = 600Ω.
DISTORTION	< 0.05% from 50Hz to 15kHz, < 0.1% from 10Hz to 50kHz, < 0.2% from 5Hz to 150kHz, < 1% at 1Hz and 1MHz.
SQUARE OUTPUT	TG200D, DM & DMP only, 7V peak down to < 200μV. Rise time < 150nS.
SYNC OUTPUT	< 1V r.m.s. sine in phase with output
SYNC INPUT	± 1% freq. lock range per volt r.m.s.
METER SCALES	TG200M, DM & DMP only: 0/2V/ 0/7V & −14/+6dBm.
SIZE & WEIGHT	260 × 130 × 180mm. 4.3kg with batteries.

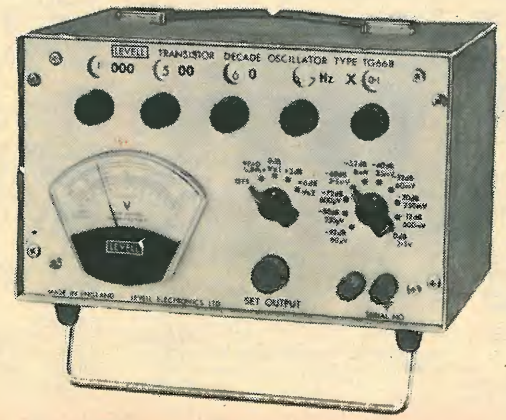
TG200	TG200D	TG200M	TG200DM	TG200DMP
£99	£108	£125	£130	£135



FREQUENCY	3Hz to 300kHz in 5 decade ranges.
ACCURACY	± 2% ± 0.1Hz to 100kHz. Increasing to ± 3% at 300kHz.
SINE OUTPUT	2.5V r.m.s. down to < 200μV
DISTORTION	< 0.2% from 50Hz to 50kHz. < 1% from 10Hz to 200kHz.
SQUARE OUTPUT	2.5V peak down to < 200μV.
SYNC. OUTPUT	2.5V r.m.s. sine.
METER SCALES	0/2.5V & −10/+10dB on TG152DM.
SIZE & WEIGHT	260 × 130 × 180mm. 3.4kg with batteries.

TG152D Without meter **£80**

TG152DM With meter **£99**



FREQUENCY	0.2Hz to 1.22MHz on four decade controls.
ACCURACY	± 0.02Hz below 6Hz. ± 0.3% from 6Hz to 100kHz. ± 1% from 100kHz to 300kHz. ± 3% above, 300kHz.
SINE OUTPUT	5V r.m.s. down to 30μV with Rs = 600Ω.
DISTORTION	< 0.15% from 15Hz to 15kHz. < 0.5% at 1.5Hz and 150kHz.
METER SCALES	2 Expanded voltage and −2/+4dBm
SIZE & WEIGHT	260 × 180 × 180mm. 5.4kg.

TG66B Battery model **£265**

TG66A Mains & battery model **£280**

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......July 1981...... Latest Test Equipment.....

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Boonton.
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Fluke.
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400E AC Millivoltmeter. 10Hz-10MHz. 1mV-300V DC o/p proportional to i/p £235.00
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7563A DC Log Voltmeter / Amplifier. Single i/p range 360µV-100V O/P 0-1.1V @ 10mV/dB £250.00
8405A Vector Voltmeter. 1-1000MHz. 0-360° in 4 ranges £1985.00

Marconi.
TF2604 Electronic Voltmeter. AC 20Hz-1.5GHz. 300mV-1KV. DC 10mV-1KV. 0.2Ω-500MΩ £350.00

Philips.
PM2454B AC Millivoltmeter. 10Hz-12MHz. 1mV-300V £195.00

ANALYSERS

Biomation.
1650D 16 Channel Logic Analyser. Displays Timing, Map, hex, octal. Clock rate upto 50MHz. Supplied with display formatter and a Hameg HM312-8 oscilloscope £2500.00

General Radio.
1911A Sound and Vibration Analyser. C/W Graphic leve recorder. 4.5Hz-25KHz. 1/3 or 1/10 octave £950.00
8407A/8412A Network Analyser. C/W 8600A/8601A sweeper. 0.1-110MHz £3500.00

Hewlett Packard.
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310A Wave Analyser 1.5KHz-1.5MHz 10µV-100V F.S. Dynamic range > 75dB £1050.00
3580A LF Spectrum Analyser 5Hz-50KHz. 30nV sensitivity £1950.00
3581A Wave Analyser with Internal Sweep. 15Hz-50KHz. 100nV-30V F.S. Dynamic range > 80dB. Frequency indicated by 5 digit LED readout £1500.00
8553L Spectrum Analyser RF Section. 1KHz-110MHz Sensitivity −120dBM. Scan width 200HZ-10MHz £1000.00

Tektronix.
7L18 Spectrum Analyser Module. 1.5-18GHz with Internal mixer. 18-60.5GHz with external mixer. Sensitivity −119dBM max reducing with frequency £6900.00
491 Spectrum Analyser. 10MHz-2GHz direct. Up to 40GHz with optional mixers £2700.00

Wayne Kerr.
RA200 Frequency Responce Analyser. Frequency range 20Hz-30KHz or 200Hz-200KHz. 11 in. crt display £850.00

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63H Inductance Bridge. 0-110mH. Bridge frequency 5-500kHz £1250.00

General Radio.
1608A LCR Bridge. Accuracy 0.05%. 0.05pF-1100µF. 0.05µH-1100H. 0.05mΩ-1.1MΩ £925.00

Marconi.
TF1245-TF1246-TF1247 'Q' Meter and Oscillators. Q 5 to 500. 40KHz-300MHz £950.00

Rohde & Schwarz.
LRT (BN6100) Inductance Meter. 1pH-100µH. 2.2-285KHz £395.00

Wayne Kerr
B642 0.1% LCR Autobalance Bridge 10µΩ-100GΩ, 1fF-10F, 1nH-10MH £750.00

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Fluke.
332A DC Voltage Calibrator. 0 to 1111.1110V. 0.1ppm resolution. 0.003% calibration accuracy £1495.00
760 Meter Calibrator. DC/AC Volts and current £2150.00

Tektronix.
191 Constant Amplitude Generator. 350KHz-100MHz £350.00

FREQUENCY COUNTERS

Advance.
TC15 & P1 Frequency Counter. DC — 500MHz, 9 digits £275.00

Fluke.
1900A-01 Frequency Counter. 5Hz-80MHz. 6 digits. Mains / battery operation £195.00
1925A Frequency Counter. 5Hz-125MHz, 9 digits, EMI proof case £375.00

Philips.
PM6664 Fully Auto Frequency Counter. 10Hz-520MHz, 8 digits £250.00

Racal.
9905 Timber Counter DC-200MHZ. 8 digits £235.00

MULTIMETERS

Avo.
Test Set Number 1. 20KΩ/volt, very robust £75.00
Full lead kit £6.25

S.E.I.
Super 50 Selectest. 20KΩ/volt £77.00

OSCILLOSCOPES

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1223A Dual Trace Variable Persistance Storage Oscilloscope. DC-15MHz. 2mV-10V/div. Max writing speed 1cm/µS £950.00

Philips.
PM3212 Dual Trade Portable Oscilloscope. DC — 25MHz. 2mV-10V/div £575.00

SE Labs.
SM121 6 Channel Monitor. 12" crt. Internal sweep £395.00

Tektronix.

432 Dual Trace Portable Oscilloscope. DC — 25MHz. 1mV sensitivity. 20nS-5S. Auto setting mains input 100-250V £510.00
454A Dual Trace Portable Oscilloscope DC — 150MHz. 2mV-5V/div. Full delayed sweep £1200.00
455 Dual Trace Portable Oscilloscope DC — 50MHz. 5mV-5V/div. Full delayed sweep. Super condition £925.00
464 Dual Trace Portable Storage Oscilloscope. DC — 100MHz. 5mV-5V/div. Full delayed sweep. Max writing speed 110 div/µS £2250.00
465 Dual Trace Portable Oscilloscope. DC — 100MHz. 5mV-5V/div. Full delayed sweep £1195.00
466 Dual Trace Portable Storage Oscilloscope Spec as per 464 but max writing speed 3000div/µS £2875.00
475 Oscilloscope DC-200MHz 2mV-5V/div. Delayed sweep £1495.00
485 Oscilloscope DC — 350MHz 5mV-5V/div. Delayed sweep £2350.00
521A PAL Vectorscope. Measures Luminance Amplitude, Chrominance Phase, Chrominance Amplitude, Differential Phase and Gain. As new condition £2650.00
T935A Oscilloscope DC — 35MHz 2mV-10V/div. Delayed sweep £595.00
7603 Oscilloscope C/W 2 off 7A26 and 7B53A, 4 Trace. DC — 100MHz £2295.00
7613 Storage Oscilloscope C/W 2 off 7A26 and 7653A. DC — 100 MHz 4 Trace, delayed sweep, max writing speed 4.9 cm/µs £3575.00

7633 Storage Main Frame c/w. 2 Off 7A26, 1 Off 7B53A. 4 Trace. DC-100MHz. Full delayed sweep. Max writing speed 1000cm/µS £4495.00
7704A Main Frame C/W 7A26, 7B80, 7B85. Dual Trace DC — 200MHz £3550.00

Telequipment.
D32 Dual Trace battery/mains Portable Oscilloscope. DC-10MHz. 10mV-5V/div £310.00
D34 Dual Trace Battery Portable Oscilloscope DC-15MHz. 2mV-5V/div. 24nS signal delay £445.00
D63 Dual Beam Oscilloscope c/w 2 Off V4 Modules. 4 Traces. DC-15MHz. 5mV-20V/div £725.00
D83 Oscilloscope Main Frame C/W V4 and 52A plug-in units. DC — 50MHz. 5mV-20V/div. Full delayed sweep. Very large CRT £725.00
DM64 Dual Trace Split Screen Bistable Storage Oscilloscope. DC-10MHz. 10mV-50V/div. Max writing speed 250 div/mS £715.00
1016 Dual Trace Portable Oscilloscope DC-15MHz. 5mV-20V/div. XY Mode. 1 only £310.00

OSCILLOSCOPE PROBES

EB90 X1 Probe. 1.2 mtr length DC — 20MHz £9.00
EB91 X10 Probe. 1-2 mtr length DC — 100MHz £11.00
EB95 X1, X10 Probe. 1.2 mtr length DC — 10MHz or DC — 100MHz £15.00

POWER SUPPLIES

Advance.
MG5-60 5V @ 60A switching £160.00
MG5-20 5V @ 20A switching £120.00
MG5-10 5V @ 10A switching £95.00
MG24-12 24V @ 12A switching £130.00

Weir.
762 Power Supply Unit 0-30V at 2A. Metered output £90.00

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Hewlett Packard
7045A XY Recorder. Sensitivity 250µV-5V/cm. Electrostatic paper grip. A3 size £950.00
7045A-001 XY Recorder. As 7045A but with int. time base £1025.00

Racal.
Store 7D Tape Recorder 7 channels FM electronics DC — 20KHz. $1^{5}/_{16}$-60ips £4500.00

S. E. Labs.
3006/12 12 Channel UV Recorder. Grid and timing lines. 6" paper £550.00
6012 50 Channel UV Recorder. Servo paper drive upto 5 metrs/sec. 12" paper £1100.00

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Watenabe.
MC641 6 Channel Chart Recorder. 1mV-100V. 250mm scan width £1495.00

Yokagawa.
3047 2 Channel Chart Recorder. 0.5mV-100V. 2cm/hr-60cm/min £435.00

SIGNAL SOURCES

Avo.
HF136 AM/FM Signal Generator. 4.0-120MHz. 0-100mV in 20dB steps plus fine control. O/P Z = 75Ω £410.00

Hewlett Packard.
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4204A Decade LF Oscillator. 10Hz-1MHz. 1mV-10V into 600Ω £695.00
606B AM Signal Generator. 50KHz-65MHz. AM 0-95% £850.00
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8616A UHF Signal Generator. 1800-4500 MHz. Max O/P +10dBM from 1800-3000 MHz, +3dBM 3000 MHz-4500 MHz. Mod as per 8614A £1950.00
8640B Phase Locked Signal Generator 0.5 to 520MHz £3200.00
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8690A/8699B RF Sweeper System. 0.1-4GHz in 2 ranges. Max O/P 10mW to 2GHz and 6mW to 4 GHz £2300.00

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TF995B/5 AM/FM Signal Generator. 200KHz-220MHz. 1µV-200mV. Narrow deriation for mobiles £695.00
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TF2100 AF Oscillator. 20Hz-20KHz. 0.05% distortion £150.00

Philips.
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Radiometer.
SMGiC Stereo Generator. Separate L and R Signals. Carrier frequency 100MHz. RF O/P 10µV-100mV into 75Ω £375.00

Tektronix.
148 PAL TV Insertion Generator. Provides all signals to test and measure on video TX systems. Immaculate £2500.00
1481C PAL Waveform monitor in as new condition £2275.00

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TF2332 AF Transmission Test Set. 20Hz-20KHz £425.00

Siemens.

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PSO-5 and PMO-5 Level Measuring Set. 10KHz-36MHz. −110 to +20dB. C/W AZD-1 Scale expander £2050.00
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Hewlett Packard.
3490A 5½ Digit DMM. AC/DC volts, resistance, 1µV resolution. 30 day warranty £375.00

Philips.
PM2527 4½ Digit DMM. AC/DC volts, current and resistance. 10µV resolution. True RMS £400.00

Solartron.
A243 5½ Digit DMM. AC/DC volts, resistance. 1µV resolution. 30 day warranty £375.00

7055 Microprocessor DMM. Scale Length 20,000. AC/DC volts, resistance. 1µV resolution £600.00
7055 plus processor control and RS232 interface £900.00
7065 Microprocessor DMM. Scale length 1,400,000. AC/DC volts, resistance £695.00
7065 plus processor control and RS232 interface £995.00

MISCELLANEOUS

Data Laboratories.

DL905 Transient Recorder with Pre-Trigger facility. Ideal for viewing single shot voltage transients 1 only £990.00

Dranetz.
606-3 Power Line Disturbance Monitor. Ideal unit for computer maintenance and installation engineers £2600.00

Ferrograph.
RTS2 Recorder Test Set Measures Wow & Flutter, Distortion, Gain £345.00
RTS2 + ATU-1 Recorder Test Set and auxiliary test set £375.00

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334A Auto Nulling Distortion meter. 5Hz-600KHz. 0.1%-100% FS. AM detector i/p £800.00
432A Power Meter with 478A Thermistor Head. 10MHz-10GHz. 100µW-10mW £450.00
4329A Insulation Resistance Meter. Range 500KΩ to $2 \times 10^{16}\Omega$ £500.00
8745A S Parameter Test Set. Fitted with 11604A Universal Arms 0.1-2GHz £2750.00

Marconi.
TF791D Deviation Meter. 4-1024MHz £195.00
TF2162 MF Attenuator DC — 1MHz 0-111dB Impedance 75Ω £135.00
TF2331 AF Distortion Meter 20Hz-20KHz. 0.1%-100% 1mV-30V voltage range £395.00

Rohde and Schwarz.
MSC Stereo Coder. 30Hz-15KHz £500.00

Tektronix.

TM515 Main Frame £150.00
TM504 Main Frame £100.00
DC503 100MHz Counter £195.00
DM502 3½ Digit DMM £150.00
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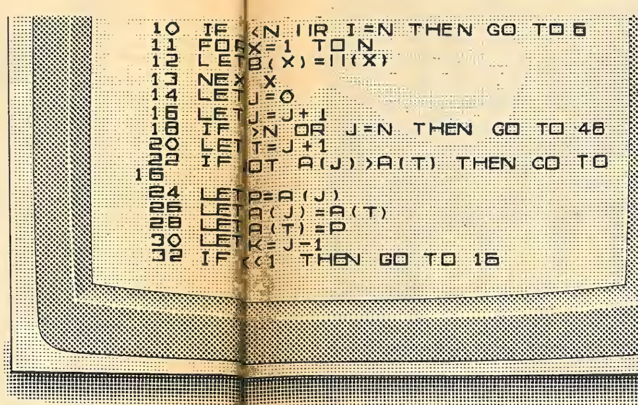
Kit: £49.95 complete



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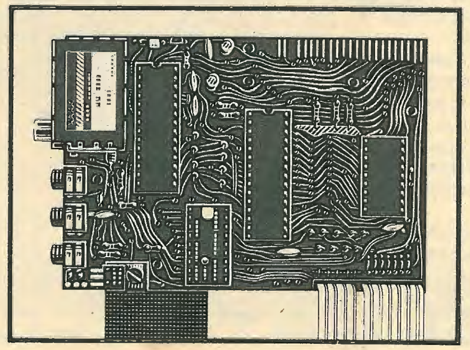

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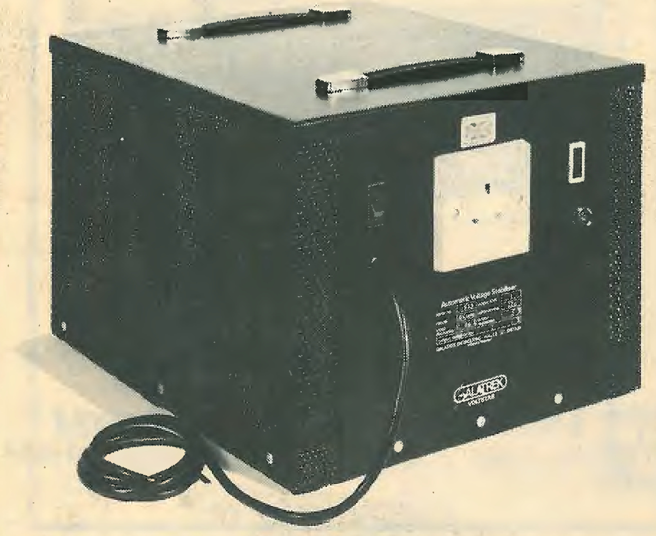

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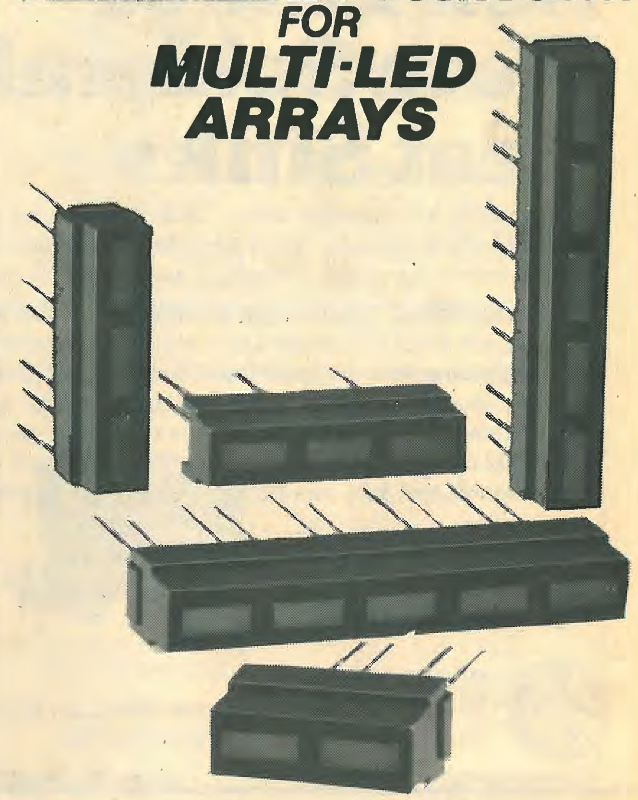

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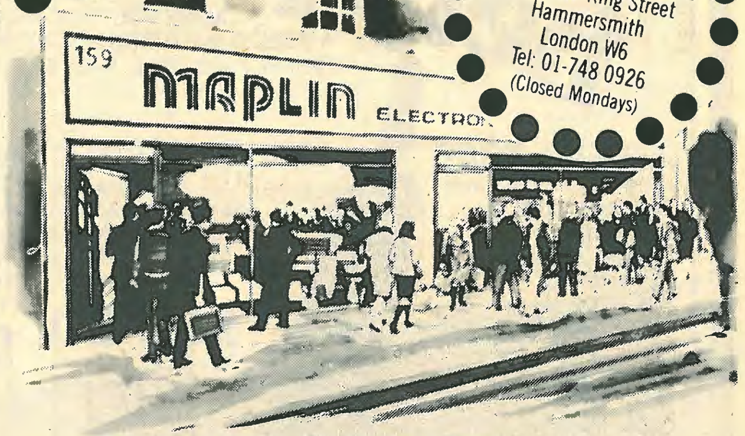

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wireless world

Decline of the philosophical spirit

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Ampère's *Théorie mathématique des phénomènes électro-dynamiques* (1826) is still worth reading. It is known as the principal founding source of electrodynamics, but other features are just as instructive. It begins with an extensive homage to 'Newtonian philosophy', and continues with a long mixture of physical theory, mathematical analyses and reports of experimental procedures. Ampère sought not merely methods of explaining and calculating effects; he wanted to find out how the phenomena actually occurred. Indeed, in the naive tradition sometimes followed at the time, he thought of his theory as a truth, 'uniquement déduite de l'expérience', to complete the title of his book.

Ampère is remembered now only for this work, but in fact it was a small part of his output. He was a polymath, whose activities were unified by his philosophical spirit. This spirit informed all his writings and came to its zenith in his *Essai sur la philosophie des sciences* (1834). But he was an outsider in philosophical thought, for the 1830s also saw the rise of positivism in the hands of some of his former students at the Ecole Polytechnique: Auguste Comte, and engineer-scientists such as Dupin and Poncelet. Associated closely at that time with educational and social causes, positivism became one of the dominant philosophies of the 19th century and has maintained its influence, directly and indirectly, until today. Knowledge without metaphysics; rejection of abstract intellectual objects; even a lack of attention to the way in which mathematics is used in physics. It is a strange contrast to read Ampère's *Essai*, with its Kantian concern with phenomena and their causes, with man's knowledge and his cognitive power to know.

It was through movements such as positivism that philosophy and science became separated. Positivism and its cousins (mechanism, materialism, instrumentalism, behaviourism, and so on) do not solve philosophical problems so much as ignore them. Yet scientists accept positivist tenets without much thought: facts are facts are facts; theories are useful *only* for predicting new facts; mathematics is just a fiction which *in principle* has nothing to do with physical reality; the aim of science is consensus (as a noted FRS contentedly put it on television recently); the history of science is bunk – and, above all, philosophising about science is time-wasting nonsense. At the same time philosophy itself has become an enclosed profession, largely concerned with footling 'puzzles' in ordinary language; its practitioners rarely know anything beyond the writings of their professional colleagues. There are exceptional figures in the communities of both science and philosophy; but they stand out as such, often nervously.

Meanwhile the real world seems to have remained the same as it was in Ampère's day, especially with regard to the phenomena studied in physics. Thus the objects of scientific study remain basically unchanged, and so does the need for philosophical as well as technical skill. We now know far more about the technicalities of electricity and magnetism than did Ampère and his contemporaries; but we no longer bring to our theoretical studies the sensitivity to philosophical questions which Ampère, and others of his time, could show. He and his contemporaries were not really scientists in the way that we understand the term; they often called themselves 'natural philosophers', enquirers into the nature around them and into the powers of man to think up theories about it. They may have fallen into optimistic naiveties such as the allegedly immediate deduction of theories from facts; but they did not succumb to our reflex dismissals of the non-experimental and our inattention to the place of mathematics in scientific knowledge. The imperatives which informed not only Ampère but also his contemporaries such as Faraday and Ohm, and successors like Kelvin and Maxwell, have faded; the traditions of natural philosophy have long been broken; reflection has given way to 'research'.

New development in h.f. coaxial cable

Structure offers lower losses and improved power handling

by **S. G. Carter,** M.Sc., Cable and Wireless and **H. M. Barlow,** F.R.S., University College, London

Recently it has become possible to make a high-frequency cable which is a cross between the conventional coaxial design and waveguides, a type of structure that exhibits much lower losses than is usual when based on attenuation per unit of cross-sectional area. This cable transmits in the dipole mode, well known for its application in optical fibres, and consists of an outer screen, as in the ordinary coaxial cable, with a group of parallel wires forming a concentric cylindrical structure for the inner in place of the more usual solid metal wire or tube.

At very low frequencies the guided transmission of telecommunication signals over long distances can be carried out by a single wire, using an earth return, or by pairs of parallel wires in space. However, as the frequency is increased the lack of electrical balance of the wires and the unrestricted spread of the field from them begins to present interference problems and a change has to be made to a screened transmission system. Up to the present, this has almost invariably taken the form of either TEM transmission in a coaxial cable or propagation in a hollow metal waveguide. Both of these arrangements have their own advantages and disadvantages but, as expected, signal attenuation has always been a major factor influencing system design. Any reduction of attenuation can lead to lower transmitted powers, small cables, an improved system noise performance and increased repeater spacing, either separately or in combination, according to design.

In the structure shown in Fig. 1, the currents set up the inner multi-wire structure are such as to provide for electric field across a diameter as well as a circumferential field: thus the arrangement supports a wave in the dipole mode. As a rule, a large part of the transmitted power is located within the wire-grid structure while, outside the grid, the field decays rapidly. In these circumstances the outer metal tube functions primarily as a screen and normally only produces a small perturbation of the field, even when its radius is reduced to about double that of the inner wire grid. Consideration of the operating conditions show that the inner multi-wire structure at u.h.f. behaves very much like the optical fibre at infra-red frequencies, where transmission is in the same HE_{11} mode with the power largely confined to the core and a rapid decay of field in the cladding. Further, like the large core-diameter optical fibre, the dipole mode cable can in principle support many different modes of propagation (as many as there are separate conductors) but, in practice, provision is made to ensure that only the lowest order dipole mode is carried. There is, however, one significant distinction between the behaviour of multi-conductor coaxial cable and optical fibre. Any attempt to screen a dielectric rod transmitting in the dipole mode in the u.h.f. region results in destruction of the field and inhibition of propagation in that mode. This is because the boundary conditions on the inside of the screen cannot be satisfied at such frequencies. The wire-grid coaxial cable suffers no such limitation. As with ordinary TEM transmission in conventional coaxial cables (and unlike tubular metal waveguides), the dipole-mode cable does not exhibit frequency cut-off and, in principle, can therefore be operated at any part of the spectrum down to d.c. However, it is in the high u.h.f. and s.h.f. regions that the losses are so much lower than those obtainable with current-day coaxial cables.

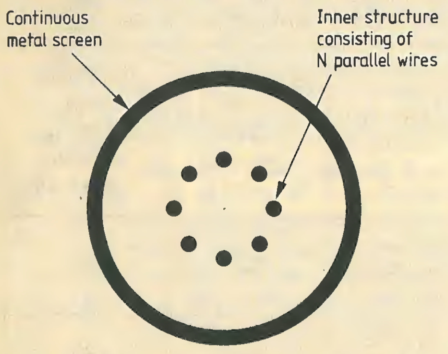

Fig. 1. Cross-sectional view of basic form of dipole-mode cable.

Cable structure

While Fig. 1 shows the basic structure of the dipole-mode cable, comprising a number of parallel wires to form a cylindrical grid, coaxial with an outer metal screen, it is of course necessary to support the inner conductors and separate them from the outer. Although regularly spaced disc insulators or beads may, when the cable is straight, keep the wires of the inner in position and also help to reduce the amount of dielectric employed, the need for a flexible cable tends to demand a continuous dielectric tube to support the wires. So far two different types of cable structure have been developed experimentally and these are illustrated in Fig. 2. The polythene tube is extruded to include the group of parallel wires attached either to the outside or the inside of the tube and this inner structure is then, as a whole, located within the outer screen by one of the methods employed in the construction of ordinary low-loss coaxial cables; for example, a dielectric membrane helixed around the inner or, alternatively, a cartwheel-type dielectric spacer. For experimental purposes the method chosen was to support the inner structure by thin p.t.f.e. discs with a hole in the centre through which the inner cable structure was inserted. These supports were spaced approximately every 8 cm.

The cable attenuation is dependent not only on the number of wires included in the inner structure but also on their diameter. In general, the loss decreases as the number of wires increases and as more of the circumference of the inner is covered by metal. However, capacitive circumferencial current is necessary for HE_{11} mode propagation and consequently the wires must always be spaced far enough apart to maintain this dipole mode at an adequate power level. Clearly, there are practical problems in fabricating a cable with a large number of very thin wires or strips of metal and therefore the experimental work was limited to structures having not more than 16 wires.

Cable terminations

Instruments and components available today for measurements all employ conventional, coaxial connectors and cables, so that the introduction of this new form of multi-conductor, dipole-mode cable requires special arrangements. Not only is a connector required to maintain the continuity of the multi-wire system, but transducers are necessary to convert the TEM waves of the supply to dipole-mode configuration prior to launching the wave on the cable. This operation has to be carried out with minimum loss and over as wide a band of frequencies as possible.

One method of launching into a dipole mode cable is to take the output from a conventional coaxial supply and, using a power divider, split it into as many parts as there are separate wires in the inner

structure of the dipole-mode cable. At the same time the amplitude and phase of each input is adjusted so that when superimposed they comprise the required dipole mode field distribution. This has been tried experimentally but it was found to be difficult to establish and maintain the precise amplitudes and phases required.

A more practical method of launching the required dipole mode from a TEM source is to use either electric or magnetic coupling into the multi-conductor cable. In general, transverse electric field coupling as shown in Fig. 3 gives more effective transfer of power but this tends to be at the expense of bandwidth when compared with the corresponding magnetic coupling shown in Fig. 4. In the electric field coupler (Fig. 3) a transverse wire fed from the coaxial input is located at approximately a quarter of the signal wavelength from a short-circuit termination formed by connecting together all the inner wires and the outer screen. Matching from the characteristic impedance of the coaxial feed to the dipole mode cable is obtained by suitably adjusting the series and shunt pistons shown in the diagram. The magnetic launcher (Fig. 4) is typified by a small loop of wire inserted into the end of the dipole mode cable and extending a short distance from the short-circuited end. A three-section matching unit is used to transform the impedance of the coaxial input down to the very low impedance of the loop. Table 1 shows the loss and bandwidths achieved in practice with these two different types of launcher.

Cable attenuation

Particular interest in dipole mode cables centres on the fact that their attenuation has been shown to be considerably lower than that of an equivalent, conventional coaxial cable. furthermore, the dipole-mode cable has no cut-off frequency and, unlike a hollow metal waveguide, can be used satisfactorily at quite low frequencies.

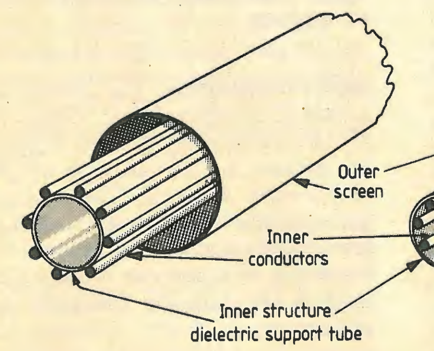

Fig. 2. Two different forms of dipole-mode cable.

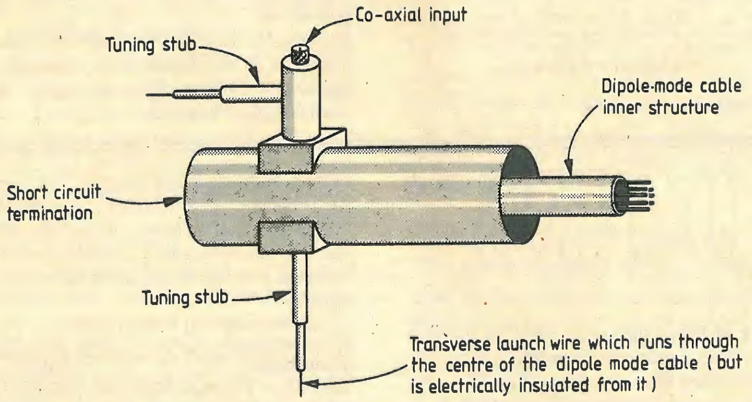

Fig. 3. TEM-to-dipole-mode transducer, using transverse-electric field coupling.

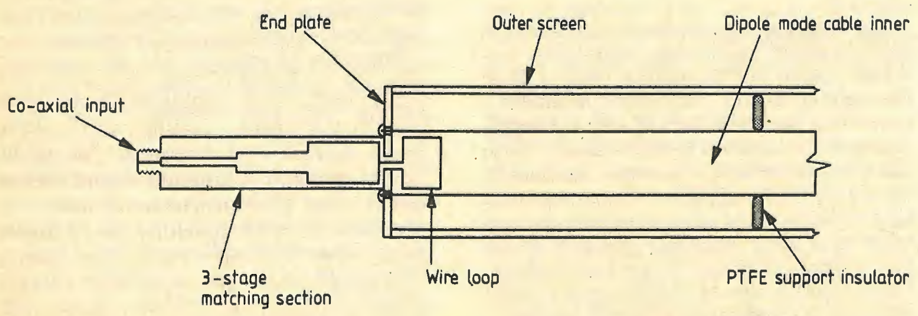

Fig. 4. Cross-section of dipole-mode launcher using magnetic coupling.

Attenuation measurements having been made at various frequencies on two different dipole mode cable structures, both mounted inside a 2.22 cm-diameter copper tube. A simple substitution method was employed, consisting of a direct comparison between the loss of a known length of the cable with that of a back-to-back connexion between two dipole-mode launchers. Joints were made in the cable by employing short, thin, brass tubes to interconnect the individual wires and a sleeve was placed over the break in the outer.

The measured losses are shown in Fig. 5 and, while these display the very low attenuation obtainable, a more interesting result is a direct comparison between dipole mode and TEM losses in the same cable. The dipole-mode cable can be made to operate in the TEM mode, simply by joining them together, at each end, all the inner structure wires and then feeding between them jointly and the outer, as in a conventional coaxial cable. The use in TEM transmission of an inner structure, comprising parallel wires rather than a solid metal conductor, only causes between 7% and 10% increase in attenuation. The results of such a comparison made at a

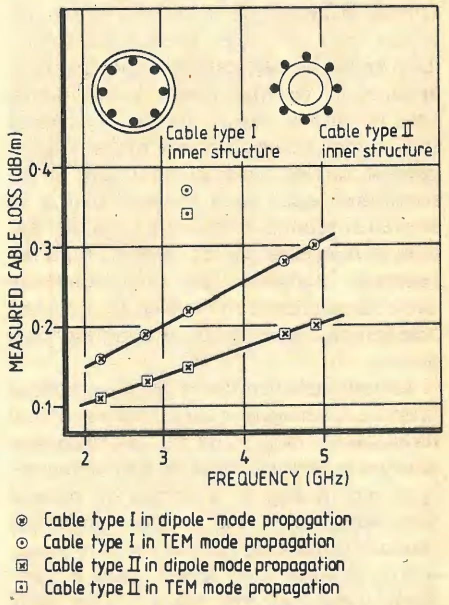

Fig. 5. Measured losses of multi-conductor cable in dipole-mode and TEM-mode transmission.

Table 1. Comparison of available bandwidth and losses for dipole-mode launchers shown in Figs. 3 and 4.

Launcher type	Bandwidth (between 3dB points) MHz	Nominal loss (TEM to dipole mode) dB
Magnetic coupling (see Fig. 4)	500	3.5
Electric coupling (see Fig. 3)	150	0.26

frequency of 3.3GHz on five different forms of cable are shown in Table 2. From these results it is clearly seen that when using an inner structure with a radius of about half that of the outer the losses are reduced to about 50% of those of the same cable operated in the TEM mode.

Practical applications

Optical-fibre transmission seems destined to take a large share of long-distance telecommunications and in due course to displace many of the coaxial line systems. However, there will always be a large number of circumstances in which conventional coaxial cable remains applicable and it is in these areas that the dipole-mode cable could find a useful place. The reduced attentuation characteristics of this cable reflects the more uniform energy-density distribution over the cross-section and the effective use made of the area occupied by the inner structure. Since the breakdown voltage of a cable is directly related to the uniformity of energy-density distribution within the cable, the expectation is that the power-handling capacity of dipole-mode cable will prove superior to that of the corresponding ordinary coaxial cable.

A typical example where this factor, together with the lower attenuation behaviour, could be particularly important is in application to high-power u.h.f. aerial feeders, such as those carrying the output from a television transmitter to the point of radiation. Here the size and weight of the transmitter equipment requires that it be located at ground level while the aerial has to be as high as possible consistent with the coverage required. The interconnecting cable has therefore to be both of considerable length and capable of handling high power.

Various structures have been considered over the development period for a practical dipole-mode cable, and the one that now emerges as likely to be of particular success is shown in Fig. 6. This has 12 parallel wires spiralled around an inner polythene tube and supported centrally within a concentric flexible outer screen using a 'cartwheel' type dielectric spacer. This cable can be expected to exhibit the required low-loss characteristics while remaining flexible enough for all normal purposes. Jointing the cable can be performed in a number of ways, ranging from the simple technique of soldering the individual wires together with small metal sleeves to the construction of a connector arrangement similar to that employed in conventional coaxial cables but with plug-in joints for each of the inner wires. An alternative jointing technique has been used in which the separate wires are laid in metallized grooves cut longitudinally in a small length of dielectric tube.

In this new form of coaxial cable, transmitting in a wave mode not previously applied to such a purpose, an important development is foreseen, offering much lower losses, coupled with high-power operation at frequencies up to and including the bottom end of the microwave band. The opportunities for future application are considered to be clearly distinguishable from optical-fibre competition.

Table 2. Comparison of dipole-mode and TEM losses for five different types of cable contained within 2.22cm diameter outer screen.

Cable type number	Wire size (swg)	Cross sectional view of inner structure	Measured losses at 3·3GHz (in dB/m)	
			Dipole mode	TEM mode
I	18		0·22	0·37
II	18		0·15	0·34
III	22		0·27	0·45
IV	18		0·29	0·39
V	22		0·20	0·36

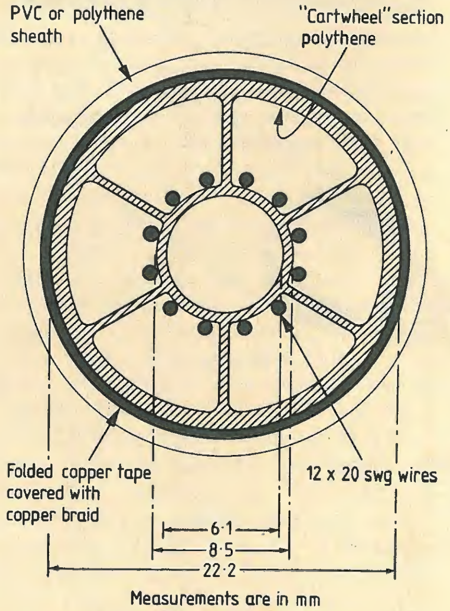

Fig. 6. Dipole-mode cable.

Acknowledgements. The authors are indebted to Professors A. L. Cullen and E. A. Ash of University College, London, for the facilities made available in the pursuit of this work. They also acknowledge with gratitude the most valuable collaboration provided by Cable & Wireless Ltd., in seconding for a year one of us (S.G.C.) to work full-time in the University on the project.

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BOOKS

Handbook of Fiber Optics, Edited by Helmut T. Wolf. 558pp, hardback. Granada, £25.00. Ten authors from Germany, Japan and America collaborated to produce this book, which is on the use of optical fibres in communications: applications for fibres conducting unmodulated light are largely ignored, except in the case of endoscopy.

The book is a concentration of a large body of widely scattered information, and is thus a convenient survey of the subject, with a large number of references. Each author undertakes a review of a particular facet of optical communications (the book was first published in 1979) and there are reviews of research activities in Europe, the USA and Japan. The writing is at a level which would be suitable for engineers and scientists in other disciplines who need to use optical fibres, and could be used by students. For the worker already involved, it is a useful reference source and guide to further reading.

After a long introduction to the subject by the editor, four chapters describe the components of a system —waveguides, sources, detectors, connectors and switches. These are followed by sections on economics, applications in communication systems and a piece on medical endoscopes.

Ferromagnetic Core Design and Application Handbook, by M. F. DeMaw. 256pp., hardback. Prentice-Hall International, £12.95. The emphasis in the title of this book ought, perhaps, to have been on the applications of cores rather than on their design, since the majority of the text is devoted to very practical information on the specification and use of inductors which employ iron or ferrite cores.

Properties of materials and the physics of cores are covered in the first chapter, the succeeding three being concerned with the use of cores in the forms of rods and bars, toroids, beads, sleeves and pots. Chapter 5 deals with permanent magnetic materials. A good bibliography, a list of references and a number of appendices complete a most helpful book. The circuit diagrams used throughout the book to illustrate the use of cores, and reference to commercial cores by type number are especially useful, though the references are to American components.

6809 evaluation system for £100

Uprated Nanocomp and cassette interface

by R. Coates

The 6809 is a recent 8-bit microprocessor which uses a 16-bit architecture to considerably improve the performance available from an 8-bit device. Because development of conventional 16-bit processors is accelerating, many designers think that the 6809 represents the practical limit for an 8-bit device. Unfortunately, few potential users have been able to evaluate this processor because there is very little hardware available at present and information is still scarce. This design is based on the well-tried and tested Nanocomp (Jan. 81) and provides a useful low-cost evaluation system for the 6809.

The 6809 is the most recent addition to the M6800 family of microprocessors, and provides a much more advanced architecture than the 6802. Internally the device is a 16-bit processor, which can perform 16-bit operations, with several extra registers and other improvements. However, because the device retains an 8-bit external data bus, the hardware is very similar to the 6802 and can therefore be used with a slightly modified Nanocomp.

The improved performance of the 6809 is attributable to several factors besides the potential of 16-bit operations. An important advantage is the addition of extra and more powerful addressing modes which enable the processor to recognize 1464 different variations of instructions and addressing modes from a basic instruction set of 59. Despite this large number of instructions, the improved architecture makes the device easier to program.

To preserve software compatibility with earlier Motorola microprocessors, the 6809 is compatible at source-code level with the 6800 so all but a few of the existing mnemonics are included. Exceptions such as INX have been excluded to maintain as rigidly as possible the regularity of the architecture. Extra addressing modes have been provided for the existing instructions and new instructions, unique to the 6809, have been added. Therefore, source programs written for the 6800 can be reassembled using the 6809 op-codes, (not all are the same as the 6800) and existing software can be transferred. All mnemonics excluded from the 6809 can be performed by new instructions. Although it may seem pointless to transfer existing software to a more powerful processor, it allows users to upgrade their systems without having to re-learn completely.

Table 1. Revised memory map

		7FFF
eprom	monitor	
	- - - - - - - -	7C00
	user eprom	7800
		7400
		7000
		4003
	pia	
		4000
2114 rams		13FF
	display buffer	
	- - - - - - - -	13FA
	monitor workspace	
	- - - - - - - -	13E0
	- - - - - - - -	13D0
	monitor stack	
	- - - - - - - -	13B0
	user stack	
	- - - - - - - -	
	program ram	
		1000

pia
4000 output/data direction register A
4001 output/data direction register B
4002 control register A
4003 control register B

Branch instructions have been improved by adding 16-bit 2's complement offsets as well as 8-bit. This permits a branch to be made from anywhere to anywhere in the full 64K address range, which makes the writing of position independent programs much easier.

Circuit modifications

The block diagram of this design is identical to the original version except that the 6809 does not have an on-chip r.a.m. and the 128 bytes at address 0000 to 007F are not available. The circuit diagram in Fig. 1 is almost identical to the original and, apart from the obvious change of c.p.u. chip, the main difference is that the 74LS00, which generated the VMA.E signal, is omitted. This i.c. is not required because there is no valid memory address signal on the 6809, and invalid memory addresses are forced to FFFF. The E output can be used directly in place of VMA.E. Another alteration is the provision of an extra interrupt input, the fast interrupt request FIRQ. This input is not used in the present design, but is brought out to a pin for possible future use. Reset on the 6809 has a Schmitt-trigger input which, with capacitor C_9, provides automatic power-on reset. Because the c.p.u. on-chip r.a.m. is not available, the memory map has been revised and is shown in Table 1. The monitor workspace is now positioned at the top of the 1K memory and therefore about 40 bytes are lost for user programs. All other aspects of the circuit and testing are as described for the 6802 version.

Operation

Operation is more or less the same as the 6802 version. As the monitor software listing now includes cassette-tape handling routines, the full 1K allocated to the monitor program, 7C00-7FFF, is now used. These routines use the L and P keys and are described later. The main alteration to the monitor is the register display command R which has been revised to take account of the increased number of c.p.u. registers. This command is automatically entered after a SWI, but may be re-entered with the R key. The condition-code register contents are first displayed with the right-hand digit denoting the register being displayed as shown,

C = condition-code register
A = acc A
b = acc B
d = direct page register
H = X register (index)
y = Y register
U = user stack pointer
P = program counter
S = hardware stack pointer

The I key will increment through the various registers, and their contents will be shown on the left four digits. After displaying S, the unit automatically returns to the monitor start. The two new software interrupt instructions, SW12 and SW13, are not used by the monitor but, with the hardware interrupts, the program can jump to and continue from a specified address in certain memory locations. These are listed in Table 2.

When an interrupt occurs, the continuation address is fetched, which is usually the interrupt service routine, and proces-

Table 2. Interrupt jump locations

When an interrupt occurs, an address is fetched from the memory shown and processing continues from that address.

Interrupt	Address
SW13	13E5/6
SW12	13E7/8
FIRQ	13E9/A
NMI	13F2/3
IRQ	13F4/5

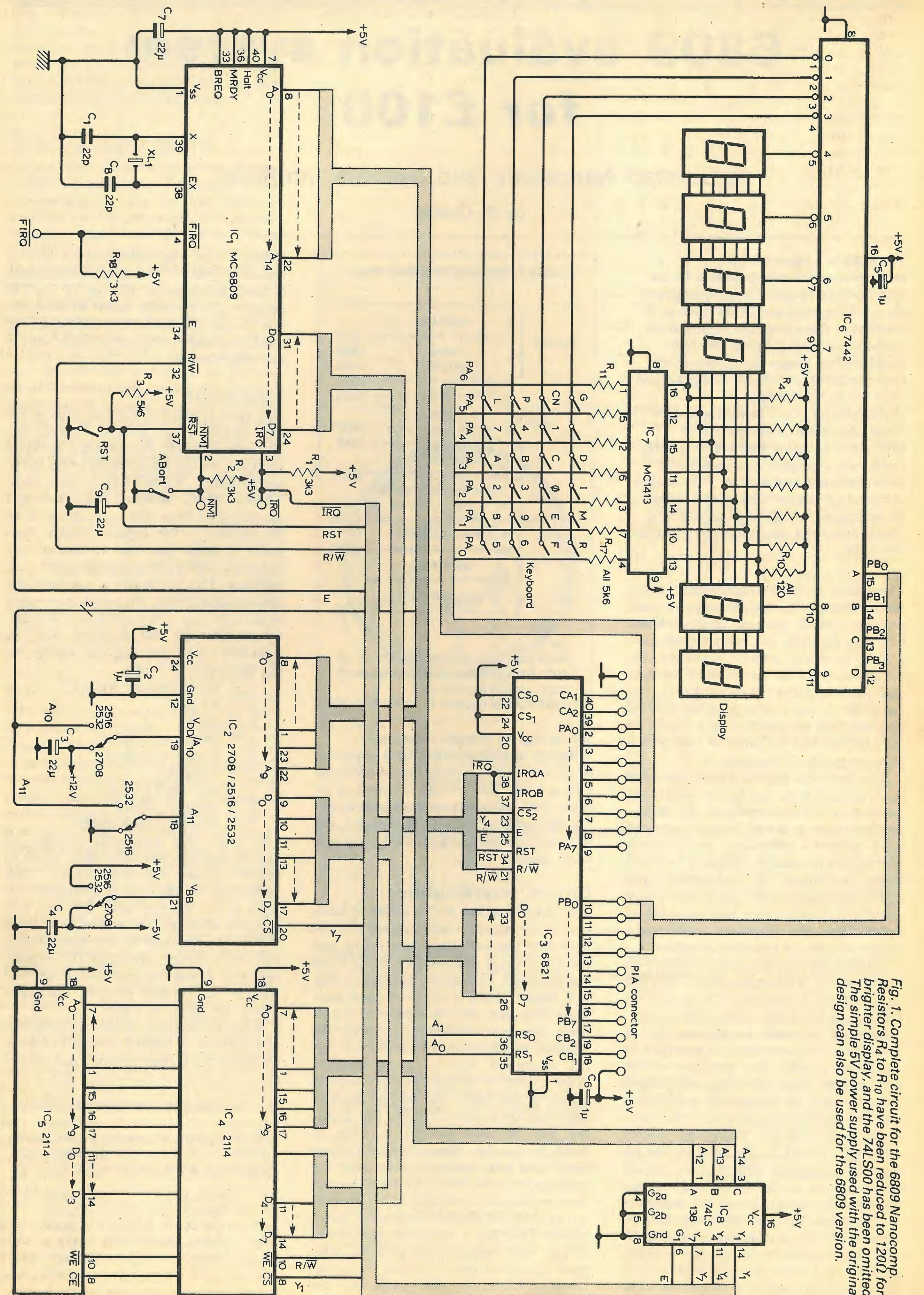


Fig. 1. Complete circuit for the 6809 Nanocomp. Resistors R_4 to R_{10} have been reduced to 120Ω for a brighter display, and the 74LS00 has been omitted. The simple 5V power supply used with the original design can also be used for the 6809 version.

sing continues from that point. The NMI input, however, is used for the abort key and its jump address is set automatically when a reset occurs, but it may be modified for other purposes by a users program. The monitor has been written to ensure that the useful monitor subroutines, listed in Table 2 of the original article, function identically and have the same entry address points. The re-entry point to the monitor from a user program is 7D97, which also applies to the 6802 version.

The four original programs can be included if a 2 or 4K e.p.r.o.m. is used. The start address for hex-decimal/decimal-hex converter is 7800, duckshoot – 7940, branch calculator – 7A00 and mastermind –7A80. For duckshoot, the speed is set at location 1000 and 1 because there is no memory at 0000 in the 6809 version. Two's complement offsets used by the branch instructions of the 6802 are limited to 8 bits but the 6809 also uses 16-bit offsets, with the PC relative addressing mode, therefore the branch calculator program now caters for these. In addition to requesting the start and destination addresses, the program requests the number of bytes in the instruction, b in the right-hand display, which must be entered. If an instruction has only two bytes, it must be an 8-bit offset so an 8-bit value is given or two dashes if it is out of range.

An instruction which requires a 16-bit offset must be three bytes or more, so a 16-bit answer is displayed if a byte value of three or greater is given.

Programming

Because programming information for the 6809 is not widely available yet, a brief description of the architecture is given together with the instruction set and programming details. However, for serious programming, Motorola's MC6809 Preliminary Programming Manual is essential.

A programming model of the 6809 is shown in Table 3, and details of the registers are given below.

Accumulators (A, B, D)
The A and B registers are general purpose 8-bit accumulators for arithmetic calculations and data manipulation. Some instructions link the registers to form a single 16-bit accumulator (D) with A as the most significant byte.

Direct page register
The direct addressing mode in the 6800 allows a shorter form of instruction to be used for accessing the bottom 256 bytes of memory. This facility has been enhanced in the 6809 so that the 8-bit direct page register is used as the most significant byte for direct addressing. This allows the direct mode to be used under program control at any place in memory.

Index registers (X, Y)
These are the same as the single 6800 register. The 16-bit address in the registers take part in the calculation of effective addresses and can be used to point to data directly. The address can also be modified by an optional constant or register offset. The 8-bit constant offsets are supplemented with 5 and 16-bit offsets. All four pointer registers (X, Y, U, S) can be used as index registers.

Stack pointers (U, S)
The hardware stack pointer, S, is used by the processor during subroutine calls and interrupts, and points to the top of the stack instead of the next free location as in the 6800.

The user stack pointer, U, allows arguments to be passed to and from subroutines. Both stack pointers can also be used as index registers, and have additional Push and Pull instructions which can operate on any or all of the registers (except themselves).

Program counter
Used by the processor to point to the address of the next instruction to be executed.

Condition code register
This register, also known as the flag register, defines the state of the processor at any time. The register comprises
C (bit 0) CARRY. Indicates that a carry occurred on the last ALU operation, or a borrow from subtraction instructions.
V (bit 1) OVERFLOW. Set by an operation which causes a two's complement arithmetic overflow.
Z (bit 2) ZERO. Set if the result of the previous operation was zero.
N (bit 3) NEGATIVE. Contains the m.s.b. from the result of the preceeding operation. Therefore, a negative two's complement will leave N set.
I (bit 4) IRQ mask bit. Interrupts on this line will not be recognised if I is set. NMI, FIRQ, IRQ, RESET and SWI all set the I bit, but SW12 and SW13 do not affect it.
H (bit 5) HALF CARRY. Indicates a carry from bit 3 in the ALU after an 8-bit addition. Used by the decimal adjust instruction to perform the b.c.d. decimal add adjust operation.
F (bit 6) FIRQ mask bit. Interrupts on this line will not be recognised if I bit is set. NMI, FIRQ, SWI and RESET set the F bit. IRQ, SWI and SW13 do not affect it.
E (bit 7) ENTIRE FLAG. Used to indicate whether all the registers were stacked or a subset (PC and CC) performed by a FIRQ. The E bit of the stacked condition code register is used on return from interrupt (RTI) to determine the extent of unstacking.

The main improvement offered by the 6809 is the proliferation of addressing modes which are summerised below.

INHERENT. In this mode the opcode contains all necessary address information (single byte instruction).

IMMEDIATE. The data to be used by the instruction immediately follows the opcode in memory. Can be an 8-bit or 16-bit value depending on the instruction.

EXTENDED. The contents of the two bytes following the opcode specify the 16-bit effective address used by the instruction.

EXTENDED INDIRECT. A special case of indexed addressing where one level of indirection is added to extended addressing, ie, the two bytes following the postbyte of an indexed instruction contain the address of the address of the data.

DIRECT. Similar to extended but only the lower 8 bits of the effective address are specified in the byte following the opcode. The upper 8 bits of the effective address are supplied by the direct page register. Therefore, programs using this mode rather than extended will use less memory.

INDEXED. The most complex addressing mode. In all indexed addressing, one of the pointer registers (X, Y, U, S and sometimes PC) is used in a calculation of the instruction. The postbyte of an indexed instruction specifies the basic type and variation of addressing mode, and the pointer register to be used. Table 4 gives the details necessary for calculating the postbyte opcode for all forms of indexed addressing. The five basic types of indexing are

Zero Offset. The selected pointer register contains the effective address of the data to be used by the instruction.

Constant Offset. A two's complement offset and the contents of one of the pointer registers are added to produce the effective address of the operand. The pointer register's initial content is unchanged by the addition.

Three sizes of offset are available, ± 4-bit (−16 to +15), ± 7-bit (−128 to +127) and ± 15-bit (−32768 to +32767). The 5-bit offset is included in the postbyte, whereas 8-bit and 16-bit offsets require 1

Table 3. Programming model of the 6809

15 … 0		
X – Index register		Pointer registers
Y – Index register		Pointer registers
U – User stack pointer		Pointer registers
S – Hardware stack pointer		Pointer registers
PC		Program counter
A	B	Accumulators
D		

7 … 0	
DP	Direct page register
E F H I N Z V C	CC – Condition code register

Table 4. Indexed addressing modes

Type	Forms	Non indirect: Assembler form	Postbyte op-code	+	+#	Indirect: Assembler form	Postbyte op-code	+	+#
Constant offset from R (signed offsets)	no offset	R	1RR00100	0	0	[R]	1RR10100	3	0
	5-bit offset	n, R	0RRnnnnn	1	0	defaults to 8-bit			
	8-bit offset	n, R	1RR01000	1	1	[n, R]	1RR11000	4	1
	16-bit offset	n, R	1RR01001	4	2	[n, R]	1RR11001	7	2
Accumulator offset from R (signed offsets)	A – register offset	A, R	1RR00110	1	0	[A, R]	1RR10110	4	0
	B – register offset	B, R	1RR00101	1	0	[B, R]	1RR10101	4	0
	D – register offset	D, R	1RR01011	4	0	[D, R]	1RR11011	7	0
Auto increment decrement R	increment by 1	,R+	1RR00000	2	0	not allowed			
	increment by 2	,R++	1RR00001	3	0	[,R++]	1RR10001	6	0
	decrement by 1	,–R	1RR00010	2	0	not allowed			
	decrement by 2	,––R	1RR00011	3	0	[,––R]	1RR10011	6	0
Constant offset from PC	8-bit offset	n, PCR	1XX01100	1	1	[n, PCR]	1XX11100	4	1
	16-bit offset	n, PCR	1XX01101	5	2	[n, PCR]	1XX11101	8	2
Extended indirect	16-bit address	–	–	–	–	[n]	10011111	5	2

R = X, Y, U or S X = 00 Y = 01 X = don't care U = 10 S = 11

+ and +# indicate the number of additional cycles and bytes for the particular variation

or 2 bytes respectively after the postbyte for the offset.

Accumulator Offset. Similar to constant offset indexed except that the two's complement value in one of the accumulators (A, B or D) is used as the offset, the postbyte specifies which. Neither register is altered by the operation.

Auto Increment/Decrement. Similar to zero offset, but with auto increment. After the pointer register is used it is incremented by 1 or 2 and then used.

Indexed Indirect. All indexing modes, except auto increment/decrement-by-one and 5-bit offset, can have an additional level of indirection. This means that the effective address is contained at the location specified by the content of the index register plus any offset.

RELATIVE. Branch instructions use the relative addressing mode, i.e. the byte(s) following the branch opcode is a signed offset which is added to the program counter. If the branch condition is true, the calculated address (PC + signed offset) is loaded into the program counter. Execution then continues from the new address. Short branches require a 1-byte offset and long branches require 2 bytes.

PROGRAM COUNTER RELATIVE. Another type of indexed addressing where the program counter is used as the pointer, with an 8 or 16-bit offset. This is very useful for pointing to blocks of data in a program which must be relocatable, i.e. runs anywhere in memory. The Load Effective Address instruction makes use of this mode. For example, to point the X register to a block of data by specifying an offset, relative to the current PC position, where the data block resides. This offset will remain constant wherever the program is run, whereas with a LDX instruction the absolute address must be specified. An additional level of indirection is available with this mode.

New instructions

PSH/PUL. These instructions allow any combination of registers to be pushed onto or pulled off the hardware (S) or user (U) stack. Which registers are pushed or pulled is defined by an immediate byte after the opcode. Each bit in the byte specifies a register.

CC = bit 0
A,D = bit 1
B,D = bit 2
DP = bit 3
X = bit 4
Y = bit 5
U,S = bit 6
PC = bit 7

TFR/EXG. Any register may be transferred or exchanged with any other register of the same size, i.e. 8-bit to 8-bit or 16-bit to 16-bit. Also, a 16-bit register can be transferred to an 8-bit. The registers to be

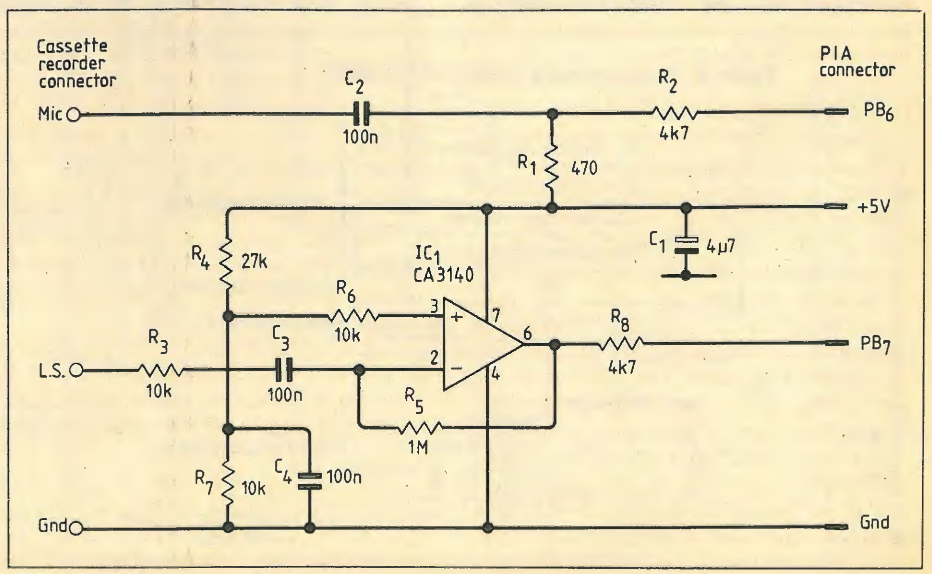


Fig.2. Cassette interface. This circuit is powered from the Nanocomp via the p.i.a. connector.

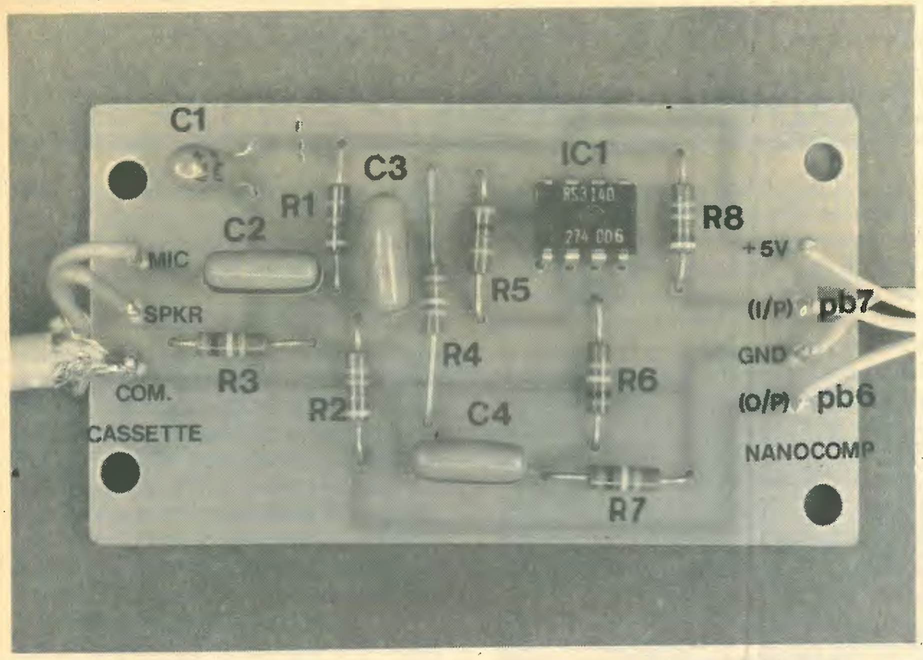
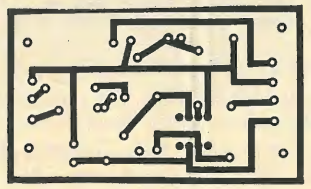


Fig.3. Layout and component placement for the cassette interface.



transferred are specified in an immediate byte. A code contained in the most significant four bits specifies the first register and the least significant four bits specify the second.

The register codes are

0000 = D
0001 = X
0010 = Y
0011 = U
0100 = S
0101 = PC
1000 = A
1001 = B
1010 = CC
1011 = DP

MUL. Multiplies the unsigned binary numbers in the A and B accumulators and places the unsigned result into the 16-bit D accumulator.

Although this short account of the 6809 is by no means complete, it should enable the constructor to start programming this very powerful processor.

Cassette tape interface

One facility which is more or less essential with any computer system is a means of storing programs. The cheapest convenient method of storage is a cassette tape and, as most users will have access to a cassette recorder, all that is required is the appropriate interface and software. This simple interface can be used with either version of the Nanocomp and will load the 1K memory in about 15s. An important part of the tape storage system is a set of routines, so readers using the original monitor will need to reprogram their e.p.r.o.m.

Data to be stored is transmitted to the recorder from a p.i.a. output line in the usual asynchronous serial format of a start bit, eight data bits and two stop bits for each data byte. Data bytes are transmitted in blocks of up to 16 bytes and each block starts with a 2-byte code, which identifies the start of a block on playback, followed by 2 bytes which give the start address of the block. The data bytes are then sent, followed by a checksum byte which is calculated by adding all the bytes in the block. The end of a recording is identified by an end-of-file code. Each bit is encoded onto the tape as one cycle of a square wave, and the period of 500µs or 2ms determines whether it is a 1 or 0 respectively. When loading a program, the period of each cycle is measured by checking whether it is greater or less than the average period, which makes the system reasonably tolerant of tape speed changes between different machines.

The interface plugs into the p.i.a. connector and is powered by the Nanocomp. Spare lines PB6 and PB7 are used for data transmission and reception so the interface can be permanently connected. The data to be recorded is transmitted from PB6 and reduced in amplitude by the potential divider R_1, R_2 in Fig. 2. On playback, the output from the recorder is limited and squared for driving the logic input of the p.i.a. A CA3140 is used for IC_1 because it operates satisfactorily from a single 5V supply.

The cassette interface can be assembled on a small p.c.b. as shown in Fig. 3. Only four connections are required to the Nanocomp and the connector numbers are

+5V	7a
0V	2a
PB6	12a
PB7	12b

If a ribbon cable is not available, ordinary stranded wire can be used and soldered onto the connector.

Operation

The L and P keys are used to load and dump data respectively. To save a program, key P and the display will request the start address of the memory block to be saved 5, followed by the finish address F. Transmission will start immediately the last key is released, so the recorder should be started before this. When the recording is finished, F will appear in the left of the display which indicates that the recorder can be stopped. Abort or Reset will return the monitor prompt.

To load a program, key L and start the recorder just before the beginning of the program. To provide a form of feedback, the top and bottom segments of the lefthand display are turned on as data is received. When a 1 is received, the top segment is on and when a 0 is received, the bottom segment is on. If the program is loaded correctly, when the end-of-file code is received F is displayed. Abort or Reset returns the prompt. If a checksum error is encountered in one of the data blocks, a C is displayed and loading is stopped. If this occurs the tape must be rewound and restarted.

With some experimentation the record and playback levels can be optimised although, with a reasonable recorder, they are not critical. It should be noted that the requirements for recording data on a cassette tape are high so only high quality audio cassettes or, preferably, certified data quality should be used. Also, a worn recorder which does not give an acceptable performance with speech or music is unlikely to produce reliable data recordings. Auto record-level machines may also cause problems because their circuits are not designed to be used with a low mean-to-peak ratio square wave.

Although the Nanocomp was originally intended as a microprocessor trainer, many constructors may want to uprate the unit as shown, and interface the circuit to other systems. We intend to support this design with a further article describing extra peripheral devices such as a-to-d and d-to-a converters and a simple e.p.r.o.m. programmer.

The original monitor/utility program has been revised to remove a potential bug in the master mind program, and to improve the performance if poor quality keys are used. A hex list of the new monitor, which also contains the cassette interface software, can be obtained from the editorial office by sending a large s.a.e. clearly marked 6802 or 6809.

A set of p.c.b.s for the 6809 Nanocomp (power supply and logic board) will be available for £9.00 and a cassette interface board for £1.50, inclusive of v.a.t. and UK postage, from M. R. Sagin, 23 Keyes Road, London N.W.2.

Technomatic Ltd, 17 Burnley Road, London N.W. 10, 01-452 1500, and Magenta Electronics Ltd, 135 Hunter Street, Burton-on-Trent Staffs, 0283-65435, will be offering a kit of components. Both companies will also reprogram e.p.r.o.m.s for both versions of the Nanocomp.

WORLD OF AMATEUR RADIO

CB – so close to 28MHz

One factor arising from the Home Office's draft 'performance specification' for 27MHz f.m. equipment, for what is now officially termed the "Citizens Band Radio Service", will be viewed with some dismay by many radio amateurs: the minimal frequency gap between "Channel 40" (27.99125MHz nominal carrier frequency) and the 28.000MHz low-frequency end of the 28MHz amateur band. This represents an unexpectedly savage turn-down of the RSGB request that any such service should *not* be located close to an amateur band.

It can be argued of course that if c.b.ers stick to the proposed conditions – for example that all equipment must be covered by a licence of which it will be a condition that "the apparatus fulfils, and is maintained to, certain minimum technical standards" – then there may be few problems. But there seem certain to be "social problems" when licensed c.b.ers find, as almost certainly they will, that their low-power, low-cost rigs cannot be expected to function satisfactorily when one of their neighbours is legally running a 28MHz amateur transmitter at 150 watts d.c. input or 400 watts p.e.p. output only a few kHz away from the c.b. channel!

Although the latest Home Office plans have received a good deal of criticism one cannot help feeling that if the same proposals had been made several years ago they would have been warmly welcomed by almost all those interested in the development of c.b. What remains to be seen is whether the proposed regulations will be obeyed or enforced.

For example, it is difficult to imagine even an otherwise conscientious c.b. operator actually taking care to insert a 10dB attenuator when using a high aerial!

Amateur television

The latest issue of *CQ-TV*, journal of the British Amateur Television Club, reports an increasing number of television contacts with Continental amateurs. Andrew Emmerson, G8PTH, of Canterbury mentions his successful reception of lockable SECAM colour transmissions from F1EDM at Le Havre. Several British amateurs are experimenting with video transmissions on the 1.3 and 10 GHz bands. In Melbourne, Australia a television repeater accepts signals on 440MHz and retransmits them on 579MHz and can thus be received on unmodified domestic television receivers. In the USA the FCC is continuing to permit a handful of amateurs to experiment with "medium scan television" on 29.150MHz with a maximum bandwidth of 36kHz. This concession is resulting in the exploitation of a number of novel techniques, including frame grabbing at an eighth of the 60 fields per second of standard American television. It has been found that at least 7.5 fields per second are needed to give a reasonable illusion of movement. One of the amateurs concerned in this work (W3EFG) was the originator, several years ago, of the General Electric (USA) "Sampledot" narrow-band system and plans are now being made to use some of the original Sampledot equipment in conjunction with a digital scan converter and frame grabbing to provide a 7.5 rather than 60 Hz field rate.

Slow-scan land and sea image data with a format of 256 by 256 pixels and 16 grey levels with digital transmission on the beacon signal at 145.825MHz are among the facilities that will be provided by the British amateur satellite UOSAT (University of Surrey) due to be launched in a few months time. UOSAT will carry an earth-pointing c.c.d. two-dimensional imaging array.

Amateurs at British Telecom's research centre at Martlesham are planning tv transmissions both for local "news" and for regular contacts with Holland. BATC deserves congratulations on the new "Amateur-Television Handbook" edited by John Wood, G3YQC and Trevor Brown, G8CJS. This excellent 96-page booklet is packed with eminently practical information and designs provided by some 20 amateurs and covering principles, aerials, receivers, transmission, vision sources, video processing and colour television (non-members £2 plus 35p postage from I. Pawson, 14 Lilac Avenue, Leicester LE5 1FN).

IARU Region 1 Conference

The many sessions of the IARU Region 1 Conference at Brighton, at which the national amateur radio societies of some 36 countries were represented among the 150 or so delegates, resulted in many recommendations that in the coming years should help to make as effective as possible both operating and technical investigations. But less happily this conference will also be remembered for the deaths of two of the delegates: Peter Balestrini, G3BPT and the Dutch amateur PAoOK. Peter Balestrini was the 1980 President of the RSGB and was attending the conference in his capacity of RSGB Emergency Communications Manager. Professionally engaged with Port of London Authority telecommunications, he was for many years one of the leading enthusiasts who built up the "Raynet" emergency system.

Although there can be few amateurs who did not wish the Conference well, some criticism has been expressed of the Home Office decision to permit the use of a special callsign, GB1IARU, since the use of "four-letter" callsigns is not specified in the international Radio Regulations. However the Home Office clearly regarded this as a very special "special event" and even gave blanket permission for the station to be operated by foreign delegates not holding a reciprocal British licence.

April solar storms

Highly disturbed h.f. propagation conditions were experienced during April, particularly during the periods April 7 to 13 and April 21 to 27, following intense solar flares. On some days F2 critical frequencies remained abnormally low and on April 13 between 0600 and 1700 hours the F2 layer was not detectable at The Appleton Laboratory, and the amateur h.f. bands remained virtually unusable during much of the day. A considerable number of severe h.f. blackouts and auroral conditions were experienced during the month. Such ionospheric disturbances tend to take place most frequently during the early decreasing phase of a sunspot cycle, but the events of April were unusual by almost any standard.

Observations made on 3.5MHz by G3XRJ and VK7AE in Tasmania, Australia during an eclipse of the sun on February 4 around 2030 hours showed a very marked enhancement of this low h.f. path between England and Australia during the total eclipse period. The effect, during the Australian "dawn", was to keep the path open almost an hour longer than normal, although there was a very rapid fadeout of signals after the sun re-emerged.

In brief

A weekend 'Hamfest' from Friday to Sunday, 26-28 June, is being organized by the Leeds & District Amateur Radio Society, opening with a "welly disco" and with arrangements for overnight camping and caravan facilities. A demonstration station, GB2WYR, will operate . . . The RSGB's v.h.f. national field day, probably now the biggest UK contest event of the year, is on July 4 to 5 . . . Mobile rallies include three on June 28: Longleat Park, Warminster, Wilts; Rolls Royce Sports and Social Club, Barnoldswick; and Crawfordsburn Scout Camp, Crawfordsburn County Park, near Bangor, Co. Down; July 12 Droitwich High School, Droitwich; July 19 Brighton Raceground, Brighton and Cornwall Technical College, Pool, Camborne. . . . Abuse of the South London 144 MHz repeater continues, including the weekend of the Brixton disturbances . . . J.T. Dolan of Seattle, USA, was fined $750 for operating the pirate broadcast station "RX4M Voice of Clipperton" after FCC engineers traced him using sophisticated mobile direction finders. In California, David Lee Grimm was fined $1500 for illegal c.b. operation after repeated warnings and equipment valued at about $8000 seized, including four linear amplifiers, two amateur radio transceivers and one c.b. radio transceiver.

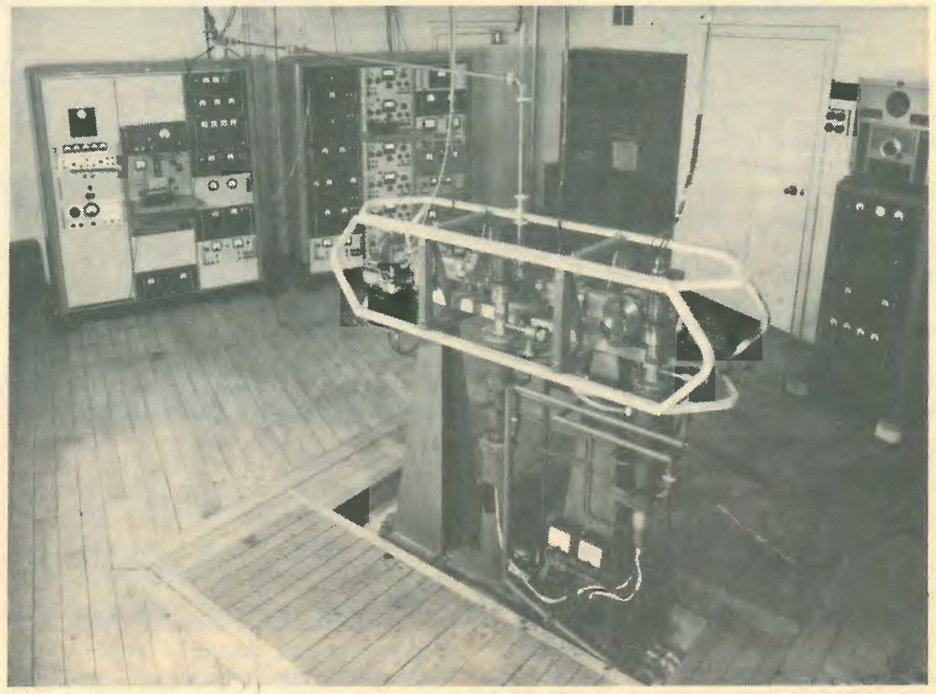
PAT HAWKER, G3VA

Leap seconds

Story of the transfer from astronomical to atomic time

by **L. Essen**, D.Sc., F.R.S.

Most people now know that all time measurements and time signals throughout the world are based on atomic clocks but the need to adjust them by one second at the end of the year is not well understood. It follows from the fact that the signals must not only give precise uniform intervals of time but must also give the time of day which is determined by the non-uniform rotation of the earth. The transfer from astronomical to atomic time and the co-ordination of the two systems was an important step in the advance of science and it is surprising that the full story has never been told. The requirements of radio engineers were always prominent in the discussions.



The original caesium resonator, designed at the NPL by the author and J. V. L. Parry, which led to the development of the atomic standard of time.

The time of day is not required very accurately for civil purposes – it is changed by an hour, twice a year – but for navigation at sea it should be fairly close to the time scale based on the position of the stars, known as UT1. Time intervals, on the other hand, are required to be as precise and uniform as possible, particularly for air navigation and the control of the frequencies of radio transmitters. For these applications the actual time or epoch of the signals is irrelevent.

These two requirements are so different that it might be asked why two separate sets of signals are not used, giving astronomical time for sea navigation and civil purposes and atomic time for everything else. This was indeed suggested by Dr G.M.Clemence of the US Naval Observatory who proposed that two units of time should be defined, adding, probably not very seriously, that the atomic unit should be called the Essen. The fundamental objection to this is that it would constitute a duplication of one of the basic units of measurement; and a practical objection is that the use of two time scales would undoubtedly lead to confusion, as our experience with standard frequency transmissions had shown. It was therefore worth while to make an effort to construct a single time scale, which would give the full accuracy of the atomic clock and the time of day as accurately as needed. This principle was accepted but it took 16 years to get international agreement on the details.

The first caesium atomic clock was put into operation at the National Physical Laboratory, Teddington, in June 1955; and it was immediately obvious to us that the necessary checks on its performance under different conditions could not be made in terms of astronomical time. A provisional atomic unit was defined and an atomic scale maintained by quartz clocks checked by the atomic clock, under standard conditions, as often as necessary.

It happened that the International Astronomical Union was meeting in Dublin that summer and through the courtesy of the Astronomer Royal, Sir H. Spencer Jones, I was able to attend this meeting to describe the clock and the initial results. One of the main topics of discussion at the meeting was a proposal to redefine the unit of time, making it in effect a fraction of the time of revolution of the earth round the sun instead of a fraction of the time of rotation on its axis. It was believed that this unit, the second of ephemeris time (ET) would be more constant than the second of universal time (UT1). It is difficult to measure it and the value being recommended was in effect the average value of the second of UT1 over a period of 200 years. Such a unit might be useful for astronomical work but it is not of the slightest use to the physicist and radio engineer. I suggested that it might be wise to delay a decision until agreement was obtained on the definition of an atomic unit which would certainly be required in the future.

However, the proposal to change to ET was adopted and was confirmed at the General Conference of Weights and Measures in 1956. It was a strange decision and it meant that from 1956 until 1967, when an atomic unit was defined, the definitive unit of time existed only on paper. The unit used in practice was the second of UT1; and at the NPL this was defined in terms of the provisional atomic unit, which was made available throughout the world by our standard frequency transmissions and their 1s timing pulses derived from the standard. These were used at the International Bureau de l'Heure to smooth out the irregularities of the astronomical signals.

Although the atomic clock had a lukewarm reception at the Dublin meeting an important resolution was passed with the advocacy of Dr W. Markowitz. It was agreed that when the relationship between the atomic frequency and the second of ET had been established the atomic clock

> The next leap second will be on 30th June 1981 in the last minute of the day. The minute before midnight will contain 61 seconds instead of 60 seconds.

would be used to make ET available. We planned together a programme of measurements to obtain this relationship: the time interval between certain agreed signals about a month apart was to be measured at the NPL in terms of the atomic clock and at the USNO in terms of ET. Markowitz had developed a method of obtaining ET more quickly than by direct observations of the sun; but even so the measurements were continued for three years before it was decided that further averaging was not likely to improve the accuracy of the result which was therefore announced. The result expressed as the frequency of the caesium atomic transition in terms of the second of ET was:

9192631770±20 cycles

The second of atomic time was therefore the time occupied by 9192631770 cycles of the caesium line, the limits of error being omitted since they were due almost entirely to the astronomical measurements. This value was used at the NPL in place of the provisional value, from 1958, in accordance with the Dublin resolution.

There was still strong opposition from astronomers to the formal adoption of the atomic unit. They regarded the atomic clock as a kind of superior quartz clock which could be used to smooth astronomical time, and ignored the fundamental difference between them. The quartz clock is simply a stable oscillator which can be adjusted to have any frequency by altering its dimensions, whereas the atomic clock has a frequency determined with great precision by natural constants. It is reproducible anywhere in the world and provides a unit of time which is immediately and readily available. It is ideally suited to be a definitive standard of measurement. It must be admitted, as was often pointed out, that unlike the earth, it does sometimes stop, but this is an academic point of no practical significance. When one clock stops it can be reset by reference to one that has not, with a precision enormously greater than any astronomical measurement. And even if they all stop they can be reset by reference to the stars so that one is no worse off.

It must be remembered too that the major observatories, including the Royal Greenwich Observatory, were founded with the specific object of providing the navy and merchant ships with time. Their responsibility was later extended to providing a uniform time scale for scientific purposes. The determination of astronomical time became a complex operation, the measurement made at many observatories being correlated at the Bureau de l'Heure which published the definitive corrections to time signals about 12 months in arrears. There was a considerable vested interest in retaining astronomical time as the definitive system. As several of those concerned jokingly said, there was no doubt that we must change to atomic time, but not before we retire, please.

Another question to be settled was the type of atomic clock to choose. In spite of the known performance of the caesium standard at the NPL and then at laboratories in Canada, the USA, and Switzerland, clocks based on the same spectral line of hydrogen and thallium were possible contenders. A lot of attention was also devoted to the study of a spectral line of ammonia; and although this was never a serious contender as a time standard it led to the development of the maser and the laser. The advantages of the caesium clock prevailed and in 1967 it was accepted for defining the unit of time, with the value given above.

The co-ordination of the 1s pulses carried on standard frequency transmissions with astronomical time signals presented some awkward problems. The first step was taken when they were made to coincide on 1st January 1958. It was realised that they would diverge because of the variations in the rate of rotation of the earth, and the question to be resolved was the amount of divergence that could be tolerated. The first figure suggested was 0.1s and to keep within this tolerance the actual frequency of the transmissions was offset from its nominal value by a stated amount each year, and in addition occasional step adjustments of 0.1s had to be made to the timing pulses. A further move towards co-ordination was made in 1960 when it was agreed with the RGO that all time signals transmitted from the UK would have the same epoch.

It was of course rather illogical to offset the constant unit in order to accommodate the variations of the astronomical unit and strong efforts were made to end this situation particularly through the International Scientific Radio Union. A satisfactory solution became possible when astronomers agreed that the signals could diverge by as much as 0.7s from astronomical time UT1. The frequency offset was eliminated, standard frequency transmissions operated on their true nominal values and the timing pulses on them gave true atomic time intervals. The divergence of the pulses from UT1 was compensated by a step adjustment of precisely 1s, when necessary on 30th June or 31st December. This enabled the pulses to continue undisturbed but the marker distinguishing the 1 minute pulse was moved along by 1s. The use of these leap seconds enables the time signals to be maintained within 0.7s of UT1, and for those who need it, the difference from UT1 is given more accurately by a code or Morse announcement. The only inconvenience caused to those measuring time interval is the need to check whether there have been any leap seconds if the interval extends through June or December. The astronomer no longer had to struggle to derive a uniform time scale from the complex and non-uniform periodicities of the solar system, but could measure these periodicities in terms of the atomic clock.

If I may finish on a personal note, I often think how lucky I was to work in a branch of science which was advancing rapidly, which exploited many different techniques and in which there was full international co-operation. The problem being tackled at the NPL when I joined in 1929 was the measurement of radio frequencies. The first solution was to measure them in terms of a tuning fork maintained in continuous oscillation. The accuracy achieved was 1 part in 10^7 which was considered by the Radio Research Board to be adequate for the foreseeable future, making further financial support unnecessary. The next advance was the quartz clock, which proved to be much more stable than the observatory pendulum clocks and gradually replaced them. They revealed an annual periodic change of 1 part in 10^8 in the rate of rotation of the earth. It was clear that any further improvement was prevented by the uncertainty in the value of the astronomical second. In 1945 I.I.Rabi, at Columbia University, suggested that the atomic beam magnetic technique might be adapted to form the basis of an atomic unit of time. The atomic clock has not only made the measurement of time and frequency far easier but has increased its accuracy by about one million times.

Louis Essen was born in 1908 and educated at High Pavement School in Nottingham and Nottingham University College, gaining a London external degree. Joining the NPL in 1929, he worked with D. W. Dye on tuning-fork and quartz oscillators and has continued to investigate frequency standards throughout his career. Working with A. C. Gordon-Smith from 1946 to 1950, he was able to establish, using a cavity resonator, a new value for the velocity of light, which is still accepted.

Taking up a proposal by I. I. Rabi in the United States, Dr Essen collaborated with J. V. L. Parry at the NPL to produce, in 1955, the first atomic caesium frequency standard: a later design now serves as the British national standard. Work in this field brought an involvement with relativity, which led to a belief that Einstein was wrong in one important respect and to a different interpretation of the Michelson-Morley experiment.

Dr Essen gained a Ph.D in 1941, a

D.Sc. in 1948 and was elected FRS in 1960. He was awarded the Popov Gold Medal of the USSR Academy of Sciences in 1959 and, in the same year, the OBE.

Parallel-tracking pickup arm modifications and improvements

Construction is not as difficult as you might think: "precision assembly is simply not required"

By Rod Cooper

A working model of the parallel-tracking pick-up arm, first described in the December 1979 and January 1980 issues, drew widespread interest at a recent exhibition as well as several constructive proposals for improvements, some of which are detailed in this article.

Two curious facts emerged from a showing of the parallel-tracking arm at the last Breadboard exhibition. Firstly, many people expressed doubts about their ability to construct an arm with sufficient accuracy, even when building from a kit of parts. This problem seems to have magnified out of all proportion. The parallel-tracking arm is far more tolerant of mechanical shortcomings in construction because of the "cleaning-up" effect of the servo system, and because of this particular design of gimbals, the inherent advantages of which were explained in the original article.

In addition, as the basic accuracy of the servo system is ±0.2 degrees which represents about 1mm at the stylus, precision assembly is simply not required. The human eye is very good at detecting parallelism and it is therefore not at all difficult to set up the reference arm and parallel track to well within this limit using an ordinary set-square and a straight rule.

Moreover, the parts have specifically been designed to be adjusted – they are not pre-set – and so any error in assembly can be adjusted out. The wear points such as bearings and pivots have been given particular attention in design so that any slack introduced by wear can also be adjusted out. It is salutary to compare this to the lack of serviceability and the built-in obsolescence of much of the equipment on the market today.

The second emergent fact was that the principle of parallel tracking had been dismissed out-of-hand, even by those who had read the original article and the analysis by Randhawa on the grounds that "it only saves 0.7% distortion, which isn't audible anyway". Nothing could be further from the truth! There is in fact not one isolated advantage to this technique but a package of benefits as listed below.

- Reduction of tracking distortion, as already mentioned.
- Reduction of stereo delay-distortion with elliptical styli.
- Capability for re-centering eccentric records. This deserves some comment as the design is the only one, as far as I know, which permits rapid and accurate correction of eccentricity. There are two important effects of eccentricity. On some types of music, the "wow" introduced by this defect is audible. That re-centering makes an audible difference I know to be true, from results obtained from my record collection. Also, the eccentric record is constantly levering the arm to the left and right every revolution, working against the inertia of the arm and the friction of the pivots. Unfortunately the audible effects of wear from this source cannot yet be quantified, but the loading on the record surface can be calculated in a similar manner to that given later in this article for record warp, and is not negligible.
- Low inertia of the arm means that seriously warped records, eg 6mm warp, can be tracked. The benefits gained by low inertia are similar to those achieved from re-centering the record – reduced wow and record wear. Again, the audible effects of wear are not quantifiable, but an analysis of the loading due to inertia is given at the end of this article.

While the reduction in tracking distortion is probably not audible on its own to most people, when it is added to the audible effects of the other three points, the result is noticeable. Add to this the increased "trackability" and reduction in record wear, and the parallel tracking technique can be justified on all grounds except that of cost. And the cost factor can be reduced to a minimum by building your own!

Improvements

Pivot system. On the original design, the cup-type horizontal pivot tended to be a natural collector of dust. By inverting the cup and placing the pivot pin underneath, this problem can be avoided. However it is then no longer possible to use the pivot height adjustment to help correct for neutral equilibrium as suggested in the January 1980 article because the effective height of the tracking arm above the horizontal pivot cannot now be altered. This is not so important as it might seem because the majority of modern cartridges can be set up for neutral equilibrium without having to resort to adjusting the horizontal pivots. With heavier-than-usual cartridges which cannot be set up by adjusting the vertical pivot, filing away some metal from the underside of the counterweight will help.

Light slit. The light slit is also the cue rest, but it can also be adapted to perform a third function as dust bug. It is in the perfect position to do this as a brush attached to the light slit will clean the record just in advance of the stylus. It can be raised for cleaning simply by cue-ing the arm, and as it is earthed can be used to remove static by incorporating carbon fibres in the brush.

Lead-out wiring. Litz wire can be used to greater effect than first realised. Because individual strands of litz wire are insulated it is possible to conduct most of the signals in just a couple of wires. The soldering technique for such fine wire is more demanding, but the unwanted forces introduced by the lead-out wires at the point where they exit from the tracking arm are reduced, considerably.

Tracking arm. The diameter of the duralumin tube used for the tracking arm has been increased to 9.5mm. The original smaller-diameter tubing performed well with most types of cartridge, but with the increased use of moving-coil cartridges I felt that a much stiffer tube was needed. A comparison of the new arm with a conventional arm is given at the end of this article.

Slider (part 19). The material now recommended for this part is Nylon 66, which is a high-tensile grade of nylon and has far superior low-friction and low-wear properties compared with the original brass/steel arrangement. It is also very easy to cut to shape.

Drive cords. A superior material has been found in the form of round-section expanded neoprene cord. This is a soft, resilient cord which has excellent vibration absorbing properties, and which is designed to be joined with cyanoacrylate "super-glue" to form a fitted drive band.

Acoustic isolation of the servo motor and gearbox was neatly solved by the introduction of Sorbothane. This is a remarkable visco-elastic compound (modestly described by the manufacturer as "a significant advance in polymer technology") which can recover from deformations of more than 500% and which is very lossy to any mechanical excitation, typically 90% absorption. The texture is somewhere between that of plasticene and soft rubber. Used as mounting pads for the servo assembly in place of the rubber grommets first specified, it gives superior results. It is also an excellent material for decoupling the counterweight.

Gimbals. On the original model, if the horizontal pivot of the gimbals was knocked off the support pillars, there was nothing to stop them from going completely adift. The design of the support pillars has therefore been modified to incorporate the pivot pins in a U-shaped recess so that this cannot happen. The improved design is shown on page 43.

Fast traverse. The criticism most often voiced concerned the two-minute return time, which was found by many to be inconveniently long, even for transcription purposes. This simple modification has been developed for a traverse time of just a few seconds. It can be retro-fitted to existing machines.

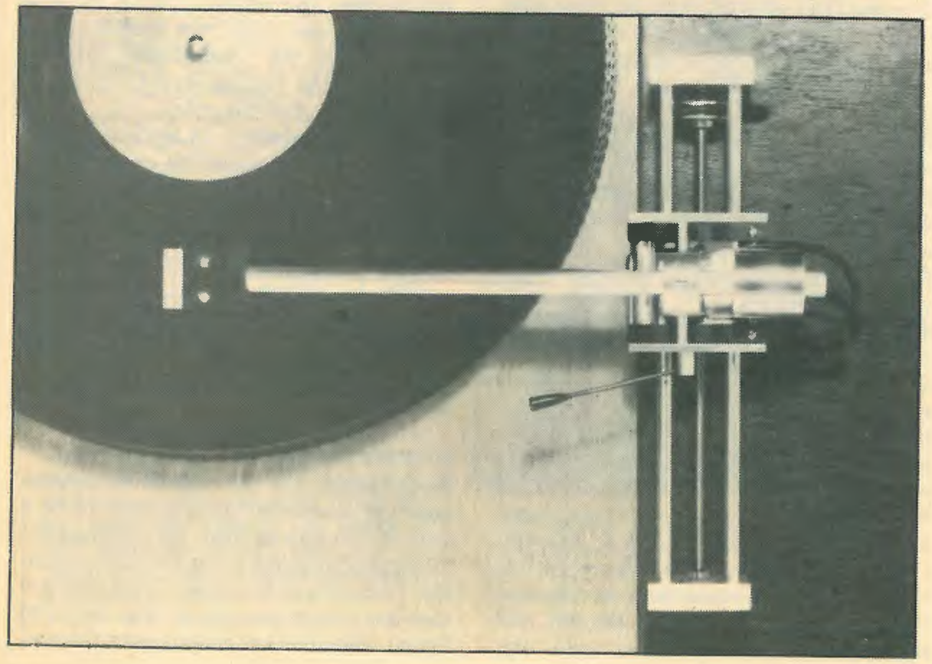
The modification consists of a second motor which drives the lead screw at speed without the assistance of the servo motor. Several constructors appear to have tried this method already, by driving the lead screw direct and simply slipping the drive band from the servo motor —not good practice because of the stretching and generally increased wear of the drive band. It also puts an unfair strain on the miniature gears in the worm gear transmission. A much more acceptable method is to drive the lead screw indirectly as on page 43.

By using a double-groove pulley wheel with a slipping clutch on the output shaft of the servo gearbox, the drive bands are operated within their limits, and the slipping clutch relieves the gear wheels inside the gearbox of excessive strain. Such a slipping clutch is easy to construct from a couple of wavy-type spring washers and set collars, as shown on page 43.

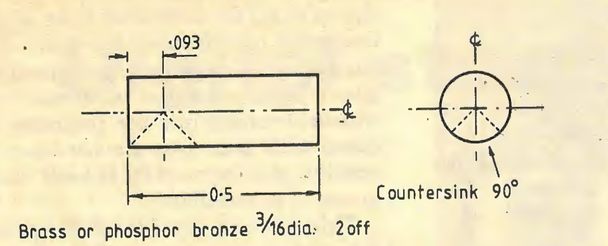
The servo motor now has to overcome the magnetic drag of the second motor during normal operation, if this second motor is a permanent-magnet type. This is avoided by applying a small bias current to the second motor of a value that will overcome the drag but not make the motor revolve. This can be done by a suitable resistor via the switching network. Alternatively, a motor with a field coil can be used, avoiding this requirement altogether. But whichever type of motor is used, it needs to be sufficiently powerful to overcome the slipping clutch *and* drive the lead screw, without the advantage of the reduction gearbox that the servo motor employs. There is no requirement for it to be vibration-free or quiet running like the servo motor, so a relatively robust and inexpensive motor can be used.

The new arm is of the same aluminium alloy as the Mk 1, HT30TF, which is a hard alloy fully heat-treated and cannot be manipulated (eg drawn, bent or compressed) in the usual way without cracking. The diameter of the 9.5mm tube was chosen to give an increase in overall stiffness over the Mk 1 arm. Wall

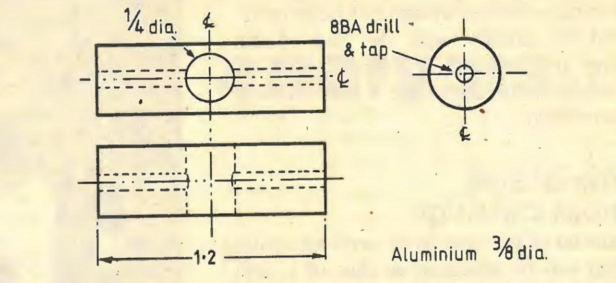
Modifications and improvements shown on page 43 include simplified side supports and pivots, new tracking arm, and fast traverse action and slipping clutch, as well as a suggested alternative parallel track (bottom). The track, which uses two steel rods instead of a long slot in a strip of aluminium alloy, is easier to make if you have a drilling stand for an electric drill. Accuracy of the assembled track depends on the straightness of the steel rods and not so much on the accuracy of drilling (drill both plates together); this simplifies the task of producing a well-trued track. Precision-ground steel rod of ¼in diameter is readily available from engineers merchants and is not expensive. The rods are fixed into the end plates with Loctite, which is allowed to set with the assembly resting on a flat surface such as a piece of plate glass.



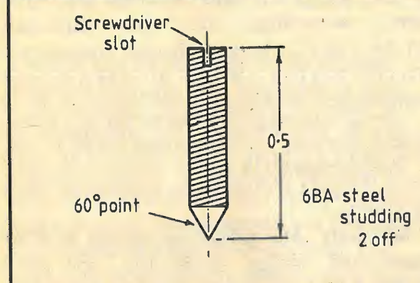
Alternative to original parallel track comprising two steel rods is easier to make if you have an electric drill and stand.



NEW SIDE PIVOT (replaces 2)



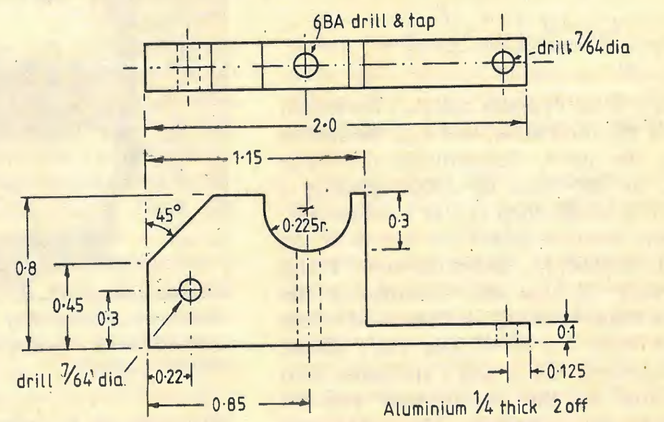
NEW REFERENCE ARM HOLDER (replaces 16)



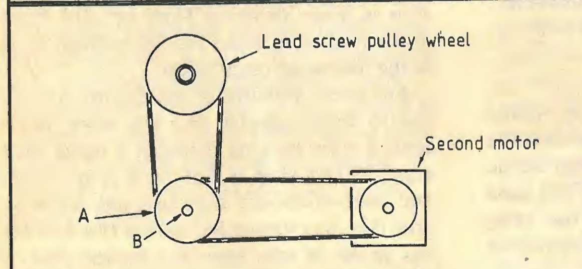
NEW SIDE PIVOT PIN (replaces 3)

DIMENSIONS ARE IN INCHES

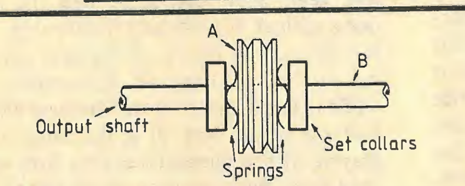
DRAWINGS ARE TO VARIOUS SCALES



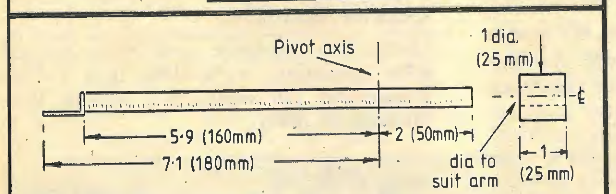
NEW SIDE SUPPORT (replaces 7,8&12)



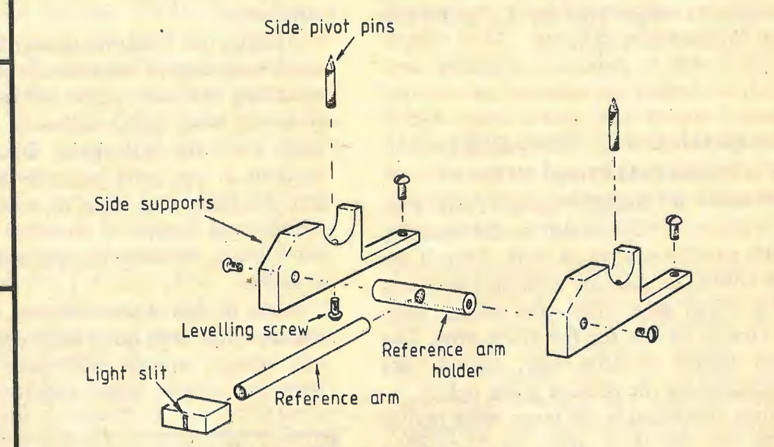
FAST TRAVERSE MODIFICATION



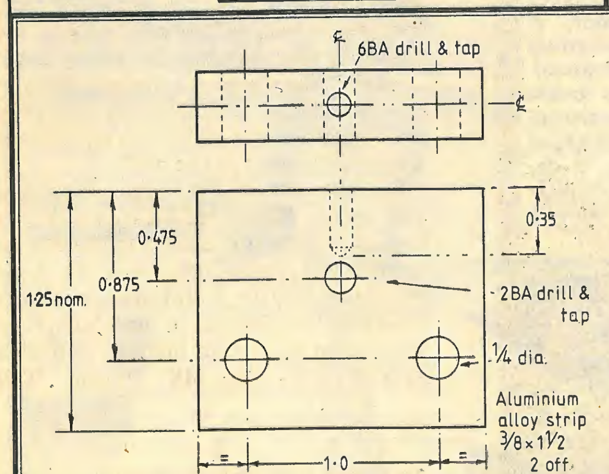
SLIPPING CLUTCH



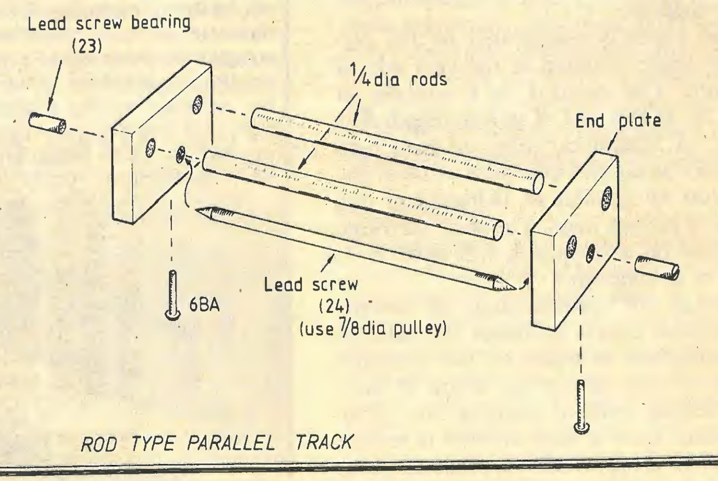
TRACKING ARM



SIDE SUPPORT & REFERENCE ARM



NEW END PLATE FOR ROD TYPE PARALLEL TRACK



ROD TYPE PARALLEL TRACK

thickness remains the same at 22s.w.g. The cartridge holder design has been modified to fit directly onto the end of the tracking arm instead of sliding along it. The weight of 100cm of the 9.5mm tubing is a mere 55gm.

Inertia of arm without cartridge

The inertia of the arm from pivot to stylus position can be assumed as that of a uniform circular cylinder 18cm long, ignoring difference in mass between cartridge holder and tubing. This is

$$I_{arm}=M\left(\frac{a^2}{4}+\frac{l^2}{3}\right)$$

where a is the cylinder radius, l the length and M the total mass, and I_{arm} the inertia about the pivot. Substituting the value 10gm for M, 18cm for l and ignoring a (which is small) then I_{arm} is 1080gm cm^2. To this must be added the inertia of the counterweight, I_{cw}, about the pivot. Using the same formula and substituting the values 80gm for M, 2.5cm for l and 1.2cm for a then I_{cw} is 185gm cm^2. These measurements for a and l are taken with the arm in the equilibrium position without the cartridge. Thus the total inertia is 1080+185gm cm^2=1265gm cm^2. Now $M_e=I_{tot}/R^2$, where M_e is the mass referred to the stylus point, I_{tot} is the total inertia of the arm about the pivot and R is the pivot to stylus distance. Substituting the values 1265gm cm^2 for I_{tot} and 18cm for R, then M_e is 3.9gm.

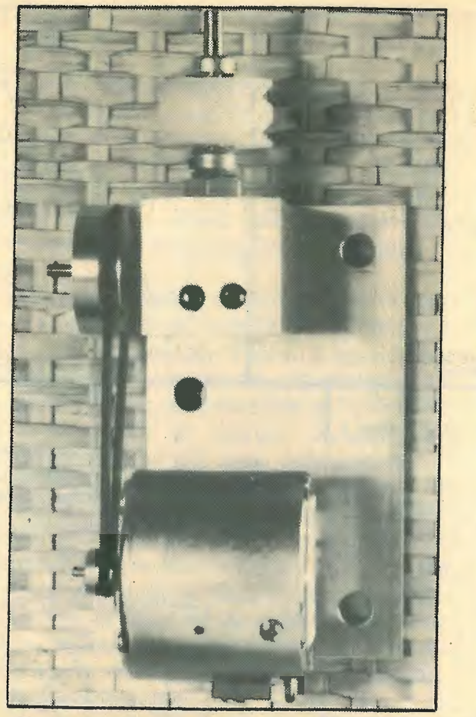
Comparison of new arm with conventional arm

As R and l are roughly equal in any arm, the terms in R^2 cancel out in the equation for M_e which becomes $M_e \propto M$. Thus if the same tubing is used for both an 18cm arm and a 23cm arm, then the overall mass will clearly be less for the 18cm arm. The actual figure is 22% less, but is not meaningful for the reasons given below.

More important is the large reduction in inertia for the 18cm arm. As $I_{arm} \propto R^2$ a small reduction in R will lead to a large reduction in I_{arm}. A simple calculation shows that an 18cm arm will have 39% less inertia than a 23cm arm made from the same material.

This effect is exaggerated by the cartridge being mounted at the very end of the arm. The inertia I_c of a cartridge of mass M_c at ther end of an arm length R is M_cR^2. A typical cartridge of mass 5gm mounted at the end of an arm of 18cm has therefore an I_c value of 1620gm cm^2 due solely to its own mass. The same cartridge mounted on a 23cm arm will have an I_c value of 2645gm cm^2!

Because the manufacturers of conventional arms cannot influence the mass of the cartridges as made by the specialist firms, or even reduce the length of their arm designs without running into other problems, most of them attempt to reduce inertia by using exotic materials for construction, or by using ultra-thin walled tube. As has been shown above, this is the least effective method of reducing inertia because it only reduces M. The most effective method is to shorten the arm, because of the presence of R^2 in the inertia equations.



One way of achieving faster traverse is to use a second, inexpensive, motor with slipping clutch.

Making use of exotic materials has good marketing appeal because of the aura surrounding titanium, carbon fibre etc. but it does not make good economic sense as it costs a lot for little gain. Using thinner sections is not good practice because the arm becomes less able to withstand the knocks and bumps of everyday use. Also, the thinner the material, the more likely it is to flex.

In the design of the new arm, the design principle has been quite different. A relatively robust straight stiff tube has been specified to give good rigidity. A light-

weight but inexpensive material has been chosen to get the economics right, and give reasonable overall mass. But more important, the arm length has been specified to give a large reduction in overall inertia without running into the problems associated with arms that are too short (e.g. stability, and the need for fail-safe tracking in case of servo failure).

This approach provides all the potential for a radical improvement in performance over the conventional arm.

Of what practical importance is M_e? Firstly it influences the resonant frequency of the pickup arm and cartridge combination, according to the equation $f_0 1/2\pi\sqrt{M_eC}$ where C is the compliance of the stylus. With modern high-compliance cartridges a low value of M_e is a prime requirement for avoidance of resonance problems. (See page 64 of April 1978 *Wireless World* for an analysis of these problems.)

Secondly, M_e influences record wear as mentioned earlier. Take the case of a record with a 1mm warp, which is not an uncommon amount even on a new record. This is taken to mean 1mm up and 1mm down from the mean record surface level in the following calculation.

For every revolution the record surface has to work against M_e, the work done against g by moving distance d being M_ed ergs. In this case d will be 0.2cm. Now, one state-of-the-art conventional tracking arm that has just appeared on the market has an M_e of just 9gm. If a typical disc of 650 grooves is played say once a week for five years with this arm then the work done against M_e will be 315,900 ergs. This is equivalent to lifting a 63kg man approximately 5cm into the air. Remember, this work is being done by the delicate playing surfaces of the record! If the same disc is played with a parallel-tracking arm of M_e only 4gm, then the work done will be only 140,400 ergs, or 56% less. These figures speak for themselves.

Carbon fibre, neoprene cord, Nylon 66, and other components are available from J. Biles Engineering, 120 Castle Lane, Solihull, West Midlands B92 8RN.

Born and raised in Birmingham, Rod Cooper now lives in Lichfield, working as Sales Manager for the electronics repair and calibration laboratory of DMR Ltd of Nottingham. A mechanical engineering background and an interest in applying electronics to the solution of mechanical problems undoubtedly contribute to the success of his parallel-tracking pickup arm design (not forgetting the mercury pickup switch, April 1980) and, coming soon, an electronic ignition circuit.

Digital storage and analysis of speech

1 – Storing waveforms digitally

by Ian H. Witten, M.A., M.Sc., Ph.D., M.I.E.E. University of Calgary

One of the difficulties with digital speech storage and analysis is that new signal-processing techniques have been developed to handle digital signals. Since these only appeared recently, and are rather mathematical, they are not understood very widely. Concepts like the z-transform, the discrete Fourier transform, and digital filters are quite unfamiliar to many practising electronic engineers. Although there are several textbooks on the subject, nearly all of them treat it in a frighteningly theoretical and abstract way. The aim of this article is to introduce some of these ideas in a down-to-earth manner by putting them in the practical context of the speech waveform.

Computer-generated speech is still a rather esoteric subject, despite the explosive growth in practical applications that we are witnessing. Texas Instrument's Speak 'n Spell toy – now about three years old – is probably the best example of a consumer device that uses speech output. But there are others. Cheap speech synthesizers intended for hobby computers have been on the market for several years now, as has a talking calculator. Digital transmission of speech is used in the telephone network, and the new System X exchange developed by the Post Office uses messages stored in digital form to guide the user and tell him what is happening to his call. Note that *analogue* storage of speech has been used in the telephone service for many years, for the speaking clock, weather forecasts, and even bedtime stories.

Analogue storage of speech. The most familiar device that produces speech output is the ordinary tape recorder. However, this is unsuitable for speech output from computers. One reason is that it is difficult to access different utterances quickly: although random-access tape recorders do exist, they are expensive and subject to mechanical breakdown because of the stresses associated with frequent starting and stopping.

Storing speech on a rotating drum instead of tape offers the possibility of access to any track within one revolution time. For example, the IBM 7770 Audio Response Unit, employs drums rotating twice a second which are able to store up to thirty-two 500 ms words. These can be accessed randomly, within half a second at most. Although one can arrange to store longer words by allowing overflow on to an adjacent track at the end of the rotation period, the discrete time-slots provided by this system make it virtually impossible for it to generate connected utterances by assembling appropriate words from the store.

The Cognitronics Speechmaker has a similar structure, but with the analogue speech waveform recorded on photographic film. Storing audio waveforms optically is not an unusual technique, for this is how soundtracks are recorded on ordinary films. The original version of the "speaking clock" of the British Post Office used optical storage in concentric tracks on flat glass discs. This was developed in the mid 1930s, and synchronization of utterances with real time was achieved in an intriguing manner. A 4 Hz signal from a pendulum clock was used to supply current to an electric motor, which drove a shaft equipped with cams and gears that rotated the glass discs containing utterances for seconds, minutes and hours at appropriate speeds!

A second reason for avoiding analogue storage is price. It is difficult to see how a random-access tape recorder could be incorporated into a talking pocket calculator or child's toy without considerably inflating the cost. Solid-state electronics is much cheaper than mechanics.

But the best reason is that, in many applications of speech storage, it is necessary to form utterances by linking together separately recorded parts. It is totally infeasible, for example, to store every possible telephone number as an individual recording! And utterances that are formed by linking individual words which were recorded in isolation, or in a different context, do not sound completely natural. For example, in an experiment performed in 1960, individual words were recorded on acoustic tape, which was spliced with the words in a different order to make sentences. The result was played to subjects who were scored on the number of key words which they identified correctly. The overall conclusion was that while embedding a word in normally spoken sentences *increases* the probability of recognition (because the extra context gives clues about the word), embedding a word in a constructed sentence, where intonation and rhythm are not properly rendered, *decreases* the probability of recognition. When the speech was uttered slowly, however, a considerable improvement was noticed, indicating that if the listener has more processing time he can overcome the lack of proper intonation and rhythm.

Nevertheless, many present-day voice response systems *do* store what amounts to a direct recording of the acoustic wave. However, the storage medium is digital rather than analogue. This means that standard computer storage devices can be used, providing rapid access to any segment of the speech at relatively low cost – for the economics of mass-production ensures a low price for random-access digital devices compared with random-access analogue ones. Furthermore, it reduces the amount of special equipment needed for speech output. One can buy very cheap speech input/output interfaces for home computers which connect to standard hobby buses. Another advantage of digital over analogue recording is that solid-state r.o.ms can be used for hand-held devices which need small quantities of speech. Hence this article begins by showing how waveforms are stored digitally, and then describes some techniques for reducing the data needed for a given stretch of speech.

Digital storage. When an analogue signal is converted to digital form, it is made discrete both in time (sampling) and in amplitude (quantizing). Much of the theory of digital signal processing investigates signals which are sampled but not quantized (or quantized into sufficiently many levels to avoid inaccuracies). The operation of quantization, being non-linear, is not very amenable to theoretical analysis, since it introduces issues such as accumulation of round-off noise in arithmetic operations, which, although they are very important in practical implementations, can only be treated theoretically under certain somewhat unrealistic assumptions (in particular, independence of the quantization error from sample to sample).

Sampling

A fundamental theorem of telecommunications states that a signal can only be reconstructed accurately from a sampled version if its highest component frequency is less than half the frequency at which the sampling takes place. Figure 1(a) shows how a component of slightly greater than half the sampling frequency can masquerade, as far as an observer with access only to the sampled data can tell, as a compo-

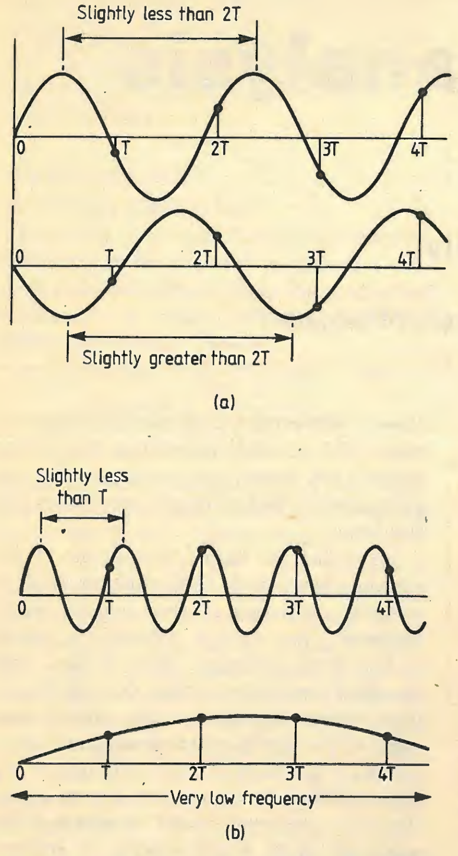


Fig. 1 Different sine waves which appear the same when sampled
(a) components near half the sampling frequency
(b) a component at just under the sampling frequency and its low-frequency equivalent

nent at slightly less than half the sampling frequency. Call the sampling interval T seconds, so that the sampling frequency is $1/T$ Hz. Then components at $1/2T + f$, $3/2T - f$, $3/2T + f$ and so on all masquerade as a component at $1/2T - f$. Similarly, components at frequencies just under the sampling frequency masquerade as very low-frequency components, as shown in Fig. 1(b). This phenomenon is often called "aliasing".

Thus the continuous, infinite, frequency axis for the unsampled signal, where two components at different frequencies can always be distinguished, maps into a repetitive frequency axis when the signal is sampled. As depicted in Fig. 2, the frequency interval $[1/T, 2/T)$* is mapped back into the band $[0, 1/T)$, as are the intervals $[2/T, 3/T)$, $[3/T, 4/T)$, and so on. Furthermore, the interval $[1/2T, 1/T)$ between half the sampling frequency and the sampling frequency, is mapped back into the interval below half the sampling frequency; but this time the mapping is backwards, with frequencies at just under $1/T$ being mapped to frequencies slightly greater than zero, and frequencies just over $1/2T$ being mapped to ones just under $1/2T$. The best way to represent a repeating frequency axis like this is as a circle.

* Intervals are specified in brackets, with a square bracket representing a closed end of the interval and a round one representing an open one. Thus the interval $[1/T, 2/T)$ specifies the range $1/T <$ frequency $< 2/T$.

Figure 3 shows how the linear frequency axis for continuous systems maps on to a circular axis for sampled systems. For present purposes it is easiest to imagine the bottom half of the circle as being reflected into the top half, so that traversing the upper semicircle in the anticlockwise direction corresponds to frequencies increasing from 0 to $1/2T$ (half the sample frequency), and returning along the lower semicircle is actually the same as coming back round the upper one, and corresponds to frequencies from $1/2T$ to $1/T$ being mapped into the range $1/2T$ to 0.

As far as speech is concerned, then, we must ensure that before sampling a signal no significant components at greater than half the sample frequency are present. Furthermore, the sampled signal will only contain information about frequency components less than this, so the sample frequency must be chosen as twice the highest frequency of interest. The telephone network aims to transmit only frequencies lower than 3.4 kHz. This region will contain the information-bearing formants, and some – but not all – of the fricative and aspiration energy*. Transmitting speech through the telephone system degrades its quality very significantly, probably more than you realize since everyone is so accustomed to telephone speech – try the dial-a-disc service and compare it with high-fidelity music for a striking example of the kind of degradation suffered.

Since speech contains significant amounts of energy above 3.4 kHz, it should be filtered before sampling to remove this. Otherwise, the higher components would be mapped back into the baseband and distort the low-frequency information. Because it is difficult to make filters that cut off very sharply, the sampling frequency is chosen to be rather greater than twice the highest frequency of interest; for example, the digital telephone network samples at 8 kHz. The pre-sampling filter should have a cutoff frequency of 4 kHz; aim for negligible distortion below 3.4 kHz; and transmit negligible components above 4.6 kHz – for these are reflected back into the band of interest, namely 0 to 3.4 kHz. Figure 4 shows a block diagram for the input hardware.

Quantization

Before considering specifications for the pre-sampling filter, let us turn from sampling in time to amplitude quantization. This is performed by an a-to-d converter (analogue-to-digital), which takes as input an analogue voltage (produced by the sampler) and generates a corresponding binary value as output. The simplest correspondence is *uniform* quantization, where the amplitude range is split into equal regions by points termed "quantization levels", and the output is a binary representation of the nearest quantization level to the input voltage. Typically, 11-bit conversion is used for speech, giving 2048 quantization levels, and the signal is adjusted to have zero mean so that half the levels correspond to negative input voltages and the other half to positive ones.

It is, at first sight, surprising that as many as 11 bits are needed for adequate representation of speech signals. Research on the digital telephone network, for example, has concluded that a signal-to-noise ratio of some 30 dB is enough to avoid poor speech quality, loss of intelligibility, and listener fatigue for speech at a normal level. But 11-bit quantization seems to give a very much better signal-to-noise ratio than this figure. To estimate its magnitude, note that for N-bit quantization the error for each sample will lie between

$$-\tfrac{1}{2}.2^{-N} \text{ and } +\tfrac{1}{2}.2^{-N}.$$

Assuming that it is uniformly distributed in this range – an assumption which is likely to be justified if the number of levels is sufficiently large – leads to a mean-squared error of

$$\int_{-2^{-N-1}}^{2^{-N-1}} e^2 p(e)\,de,$$

where $p(e)$, the probability density function of the error e, is a constant which satisfies the usual probability normalization constraint, namely

$$\int_{-2^{-N-1}}^{2^{-N-1}} p(e)\,de = 1.$$

Hence $p(e) = 2^N$, and so the mean-squared error is $2^{-2N}/12$. This is $10\log_{10}(2^{-2N}/12)$ dB, or around -77 dB for 11-bit quantization.

This noise level is relative to the maximum amplitude range of the conversion. A maximum-amplitude sine wave has a power of -9 dB relative to the same reference, giving a signal-to-noise ratio of some 68 dB. This is far in excess of that needed for telephone-quality speech. However, look at the very peaky nature of the typical speech waveform given in Fig. 5. If clipping is to be avoided, the maximum amplitude level of the a-to-d converter must be set at a value which makes the power of the speech signal very much less than a maximum-amplitude sine wave. Furthermore, different people speak at very different volumes, and the overall level fluctuates constantly with just one speaker. Experience shows that while 8- or 9-bit quantization may provide sufficient signal-to-noise ratio to preserve telephone-quality speech if the overall speaker levels are carefully controlled, about 11 bits are generally required to provide high-quality representation of speech with a uniform quantization. With 11 bits, a sine wave whose amplitude is only 1/32 of the full-scale value would be digitized with a signal-to-noise ratio of around 36 dB, which is not much greater than the figure mentioned above for adequate quality. Even then it is useful if the speaker is provided with an indication of the amplitude of his speech: a traffic-light indicator with red signifying clipping overload, orange a suitable level, and green too low a value, is often convenient for this.

*See "The Chatterbox," *Wireless World 84* and *85* (December 1978 and January 1979), for a simple explanation of formants, frication, and aspiration.

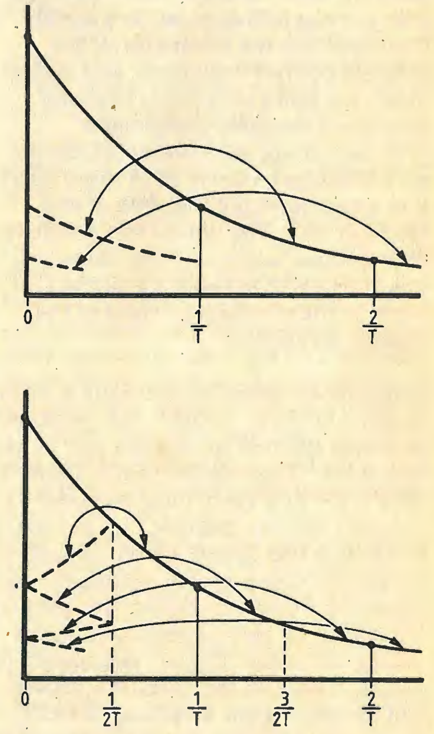


Fig. 2 How sampling "folds" the frequency spectrum

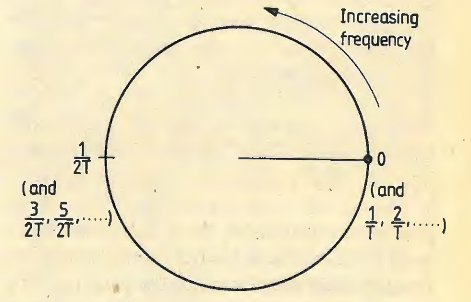


Fig. 3 The circular frequency axis of sampled systems

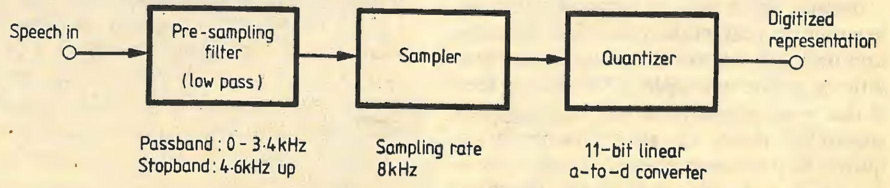


Fig. 4 Block diagram of input hardware for speech digitization

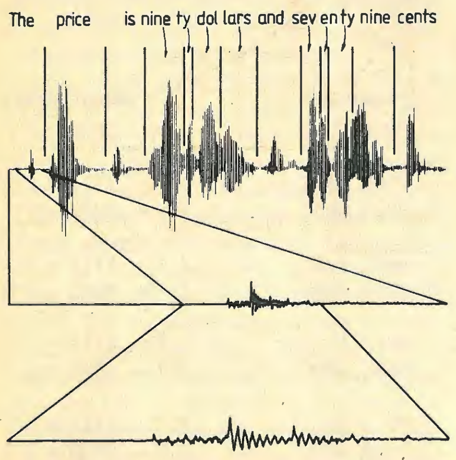


Fig. 5 Typical speech waveform

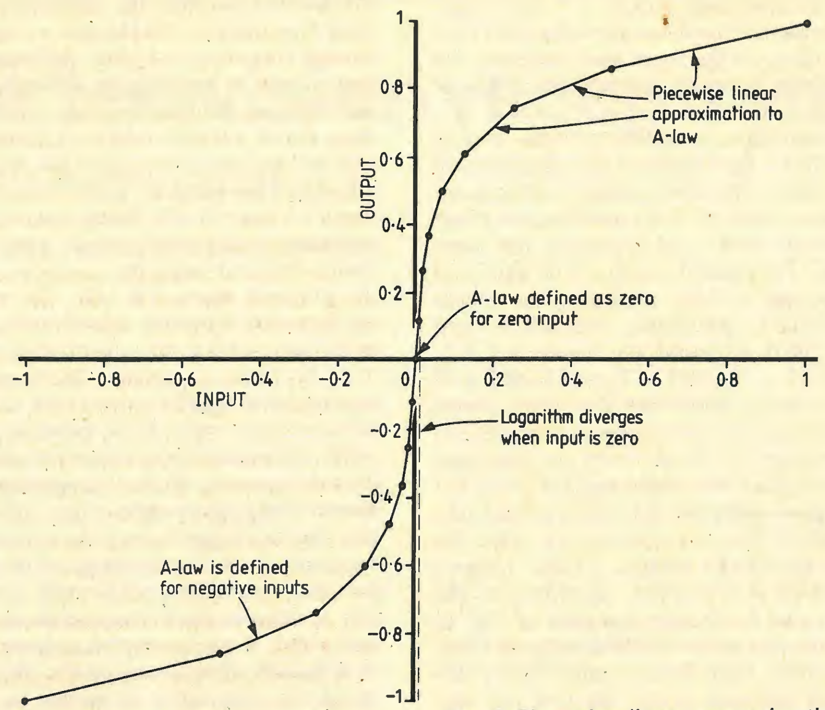


Fig. 6 Piecewise linear approximation to the A-law input/output relationship

Logarithmic quantization

For the purposes of speech *processing*, it is essential to have the signal quantized uniformly. This is because all of the theory applies to linear systems, and nonlinearities introduce complexities which are not amenable to analysis. Uniform quantization, although a nonlinear operation, is linear in the limiting case as the number of levels becomes large, and for most purposes its effect can be modelled by assuming that the quantized signal is obtained from the original analogue one by the addition of a small amount of uniformly-distributed quantizing noise, as in fact was done above. Usually the quantization noise is disregarded in subsequent analysis.

However, the peakiness of the speech signal illustrated in Fig. 5 leads one to suspect that a non-linear representation, for example a logarithmic one, could provide a better signal-to-noise ratio over a wider range of input amplitudes, and hence be more useful than linear quantization – at least for speech storage (and transmission). And indeed this is the case. Linear quantization has the unfortunate effect that the absolute noise level is independent of the signal level, so that an excessive number of bits must be used if a reasonable ratio is to be achieved for peaky signals. It can be shown that a logarithmic representation like

$$y = 1 + k \log x,$$

where x is the original signal and y is the value which is to be quantized, gives a signal-to-noise *ratio* which is independent of the input signal level. This relationship cannot be realized physically, for it is undefined when the signal is negative and diverges when it is zero. However, realizable approximations to it can be made which retain the advantages of constant signal-to-noise ratio within a useful range of signal amplitudes, one widely used approximation being called called the A-law. The idea of non-linearly quantizing a signal to achieve adequate signal-to-noise ratios for a wide variety of amplitudes is called "companding", a contraction of "compressing-expanding". The original signal can be retrieved from its A-law compression by antilogarithmic expansion.

Figure 6 shows one common 8-bit coding scheme which is a piecewise linear approximation to the A-law. This provides an 8-bit code, and gives the equivalent of 12-bit linear quantization for small signal levels. It approximates the A-law in 16 linear segments, 8 for positive and 8 for negative inputs. Consider the positive part of the curve. The first two segments, which are actually collinear, correspond exactly to 12-bit linear conversion. Thus the output codes 0 to 31 correspond to inputs from 0 to 31/2048, in equal steps. (Remember that both positive and negative signals must be converted, so a 12-bit linear converter will allocate 2048 levels for positive signals and 2048 for negative ones.) The next segment provides 11-bit linear quantization, output codes 32 to 47 corresponding to inputs from 16/1024 to 31/1024. Similarly, the next segment corresponds to 10-bit quantization, covering inputs from 16/512 to 31/512. And so on, the last section giving 6-bit quantization of inputs from 16/32 to 31/32, the full-scale positive value. Negative inputs are converted similarly. For signal levels of less than 32/2048, that is 2^{-8}, this implementation of the A-law provides full 12-bit precision. As the signal level increases, the precision decreases gradually to 6 bits at maximum amplitudes.

Logarithmic encoding provides what is in effect a floating-point representation of the input. The conventional floating-point format, however, is not used because many different codes can represent the same value. For example, with a 4-bit exponent preceding a 4-bit mantissa, the words 0000:1000, 0001:0100, 0010:0010, and 0011:0001 represent the numbers 0.1×2^0, 0.01×2^1, 0.001×2^2, and 0.0001×2^3 respectively, which are the same. (Some floating-point conventions assume that an unwritten "1" bit precedes the mantissa, except when the whole word is zero; but this gives decreased resolution around zero – which is exactly where we want the resolution to be greatest.) Table 1 shows the 8-bit A-law codes, according to the piecewise linear approximation of Fig. 6, written in a notation which suggests floating point. Each linear segment has a different exponent except the first two segments, which as explained above are collinear.

Logarithmic encoders and decoders are available as single-chip devices called "codecs" (for "coder/decoder"). Intended for use on digital communication links, these generally provide a serial output bit-stream, which should be converted to parallel by a shift register if the data is intended for a computer. Because of the potentially vast market for codecs in telecommunications, they are made in great quantities and are consequently very cheap. Estimates of the speech quality necessary for telephone applications indicate that somewhat less than this accuracy is needed – 7-bit logarithmic encoding was used in early digital communications links, and it may be that even 6 bits are adequate. However, during the transition period when digital networks must coexist with the present analogue one, it is anticipated that a particular telephone call may have to pass through several links, some using analogue technology and some being digital. The possibility of several successive encodings and decodings has led telecommunications engineers to standardize on 8-bit representations, leaving some margin before additional degradation of signal quality becomes unduly distracting.

Unfortunately, world telecommunications authorities cannot agree on a single standard for logarithmic encoding. The A-law, which we have described, is the European standard, but there is another system, called the μ-law, which is used universally in North America. It also is available in single-chip form with an 8-bit code. It has very similar quantization error characteristics to the A-law, and would be indistinguishable from it on the scale of Fig. 6.

The pre-sampling filter

Now that we have some idea of the accuracy requirements for quantization, let us discuss quantitative specifications for the pre-sampling filter. Figure 7 sketches the characteristics of this filter. Assume a sampling frequency of 8 kHz and a range of interest from 0 to 3.4 kHz. Although all components at frequencies above 4 kHz will fold back into the 0-4 kHz baseband, those below 4.6 kHz fold back above 3.4 kHz and are therefore outside the range of interest. This gives a "guard band" between 3.4 and 4.6 kHz which separates the passband from the stopband. The filter should transmit negligible components in the stopband above 4.6 kHz. To reduce the harmonic distortion caused by aliasing to the same level as the quantization noise in 11-bit linear conversion, the stopband attenuation should be around −68 dB (the signal-to-noise ratio for a full-scale sine wave). Passband ripple is not so critical, for two reasons. Whilst the presence of aliased components means that information has been lost about the frequency components within the range of interest, passband ripple does not actually cause a loss of information but only a distortion, and could, if necessary, be compensated by a suitable filter acting on the digitized waveform. Secondly, distortion of the passband spectrum is not nearly so audible as the frequency images caused by aliasing. Hence one usually aims for a passband ripple of around 0.5 dB.

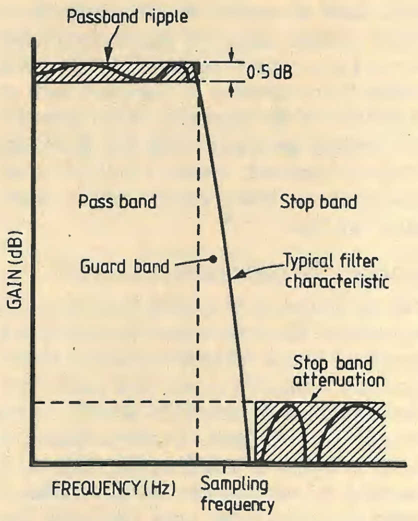


Fig. 7 General characteristics of the pre-sampling filter

The pass and stopband targets we have mentioned above can be achieved with a 9th order elliptic filter. While such a filter is often used in high-quality signal-processing systems, for telephone-quality speech much less stringent specifications seem to be sufficient. Figure 8, for example, shows a template which has been recommended by telecommunications authorities. A 5th order elliptic filter can easily meet this specification. Such filters, implemented by switched-capacitor means, are available in single-chip form. Integrated c.c.d. filters which meet the same specification are also marketed. Indeed, some codecs provide input filtering on the same chip as the a-to-d converter.

Instead of implementing a filter by analogue means to meet the aliasing specifications, digital filtering can be used. A high sample-rate a-to-d converter, operating at, say, 32 kHz, and preceded by a very simple low-pass pre-sampling filter, is followed by a digital filter which meets the desired specification, and its output is subsampled to provide an 8 kHz sample rate. While such implementations may be economic where a multichannel digitizing capability is required, as in local telephone exchanges where the subscriber connection is an analogue one, they are unlikely to prove cost-effective for a single channel.

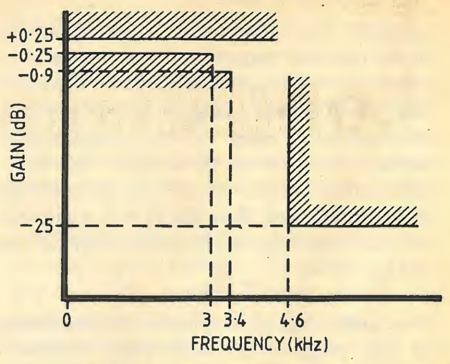


Fig. 8 Specifications of the pre-sampling filter for telephone-quality speech

continued on page 59

Table 1. *8-bit A-law codes, with their floating-point equivalents.*

8-bit codeword

–	– – –	– – – –
sign bit	exponent	mantissa

codeword	*interpretation*
0000 0000	$.0000 \times 2^{-7}$
. . .	. . .
0000 1111	$.1111 \times 2^{-7}$
0001 0000	$2^{-7} + .0000 \times 2^{-7}$
. . .	. . .
0001 1111	$2^{-7} + .1111 \times 2^{-7}$
0010 0000	$2^{-6} + .0000 \times 2^{-6}$
. . .	. . .
0010 1111	$2^{-6} + .1111 \times 2^{-6}$
0011 0000	$2^{-5} + .0000 \times 2^{-5}$
. . .	. . .
0011 1111	$2^{-5} + .1111 \times 2^{-5}$
0100 0000	$2^{-4} + .0000 \times 2^{-4}$
. . .	. . .
0100 1111	$2^{-4} + .1111 \times 2^{-4}$
0101 0000	$2^{-3} + .0000 \times 2^{-3}$
. . .	. . .
0101 1111	$2^{-3} + .1111 \times 2^{-3}$
0110 0000	$2^{-2} + .0000 \times 2^{-2}$
. . .	. . .
0110 1111	$2^{-2} + .1111 \times 2^{-2}$
0111 0000	$2^{-1} + .0000 \times 2^{-1}$
. . .	. . .
0111 1111	$2^{-1} + .1111 \times 2^{-1}$
1000 0000	$- .0000 \times 2^{-7}$
. . .	. . .
1111 1111	$-2^{-1} - .1111 \times 2^{-1}$

Negative numbers treated as above, with a sign bit of 1

Long distance television reception

1 – An introduction

by Keith Hamer and Garry Smith

In these occasional articles, the authors will introduce readers to the hobby of long-distance television reception, or DX-tv as it is often called, and pass on their experiences as dedicated amateurs. This first part discusses how tv signals are affected by weather and atmospheric conditions, basic tv set requirements, simple aerials and signal identification.

There are many factors, such as transmitter powers and terrain, which will influence the range over which a television signal can be reliably received, but in general, the strength of the signal becomes weaker as the distance between the transmitter and receiver increases. Reliable reception is normally limited to approximately 70 miles from the transmitter.

Readers have probably noticed that the strengths of signals from the more distant transmitters vary during certain weather conditions. Distant signals, which are normally very weak, may become comparable in strength to that of the local transmitter for a matter of hours, or even days.

Sometimes a distant signal will be received on the same channel as the local transmitter. This is termed 'co-channel reception' (or interference, depending on whether you are an enthusiast or a viewer). These temporary extensions in the range of disant signals are connected with variations in the troposphere, which extends from the earth's surface to about 20,000ft above. For example, when an anticyclonic weather condition exists, together with a cold front stretching between Scandinavia and the UK, a temperature inversion in the troposphere usually takes place. Temperature inversions enhance long-distance television reception.

Fortunately for the average viewer, but not for the DX-tv enthusiast, widespread interference on u.h.f. television caused by tropospheric conditions of the type described above is relatively rare. Enhanced reception on Bands I and III is also associated with these conditions.

Ionized patches in the E layer of the atmosphere often cause interference on Band I frequencies between early May and September. The E layer is between about 60 and 80 miles above the earth's surface. Before BBC 1 transmissions were duplicated on u.h.f., viewers had to rely on 405-line UK Band I transmissions, on which sporadic E signals would cause quite a lot of interference. This interference often manifested itself as a herringbone pattern superimposed on the picture which could last for up to several hours. At times, the BBC 1 picture was totally obliterated. Viewers relying on channel 2 might also have experienced a loud buzz on the sound channel from the video signal of foreign transmissions on the same frequency. Unfortunately, there was little the viewer could do apart from switch over to ITV or turn off the set! Later, in some areas, the BBC duplicated their BBC 1 transmissions on higher frequencies in Band III to help overcome the problem.

If the viewer was curious enough to tune through the Band I frequencies while sporadic E signals were present, he/she would obtain video information resembling a mass of unlocked white lines without the sound channel. At other frequencies, a distorted sound signal may have been present. The reason for the unlocked video is fairly simple: The 405-line system, as used on the v.h.f. channels in the UK, employs positive video modulation whilst most Continental countries employ a 625-line system with negative video modulation. This is in some ways similar to our own 625-line system but with different sound and vision spacings and channel bandwidths. Also, most Continental countries employ the 625-line system on both v.h.f. and u.h.f. channels, unlike our own system which is only used on the u.h.f. channels. We will cover the difference in transmission standards in greater detail in a subsequent article.

Some readers will have already realised that, as the European 625-line system is similar to our own, we should, at certain times, be able to resolve u.h.f. television signals from the Continent on a standard u.h.f. receiver designed for use in the UK. This is precisely the case and if your existing u.h.f. receiving aerial is already directed towards the Continent, you should be able to receive Continental transmissions when the right atmospheric conditions exist. It is unlikely that the sound channel will be received because of the different sound and vision spacings in use but good quality colour pictures may be received. It is possible to re-tune the sound stages of the receiver but, unless you are well versed in foreign languages, there is little point.*

Resolving signals enhanced by sporadic E in Band I is slightly more difficult due to the greater differences in transmission standards. We have already said that a 625-line signal received under sporadic E conditions will show up as a mass of unlocked white lines when displayed on the screen of a British receiver operating on 405-lines v.h.f. To resolve these signals the receiver will need to operate on the 625-line system but with the tuner covering v.h.f. frequencies. Fortunately the problem can be overcome in several ways.

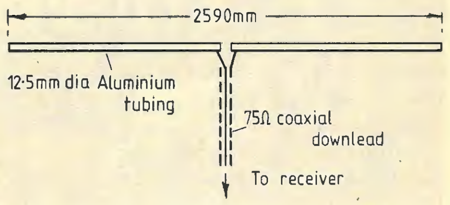


Fig. 1. A simple dipole for frequencies around 55MHz.

Certain portables are available which were originally intended for the European market. These sets have 625-line coverage on Bands I and III and this is probably the easiest way round the problem.

If an old dual-standard receiver is on hand it may be modified so that band selection, that is u.h.f. to v.h.f., is independent of the system switch setting. The system switch is left permanently in the 625-line position.

If a single-standard receiver is available, it is possible to fit an additional inexpensive tuner and incorporate a change-over switch at the i.f. input to select the output from the existing u.h.f. tuner or the additional v.h.f. tuner. The latter two suggestions will of course depend on the competence of the individual to carry out such modifications.

Another way is to employ a frequency converter which is connected directly to the aerial input of a single-standard receiver. Such converters are sometimes used in conjunction with communal aerial distribution systems, in which translated u.h.f. signals are distributed at v.h.f. frequencies, to minimise cable losses, and a converter at the receiver converts the signals back to u.h.f. Hence, if we feed the input of the converter with a DX signal in Bands I or III, the unit will translate the signals to a u.h.f. frequency to enable a single-standard receiver to be used for both systems. Suitable converters may be obtained from aerial suppliers currently advertising in various magazines.

* On Dutch television many programmes are in English with Dutch subtitles. – Ed.

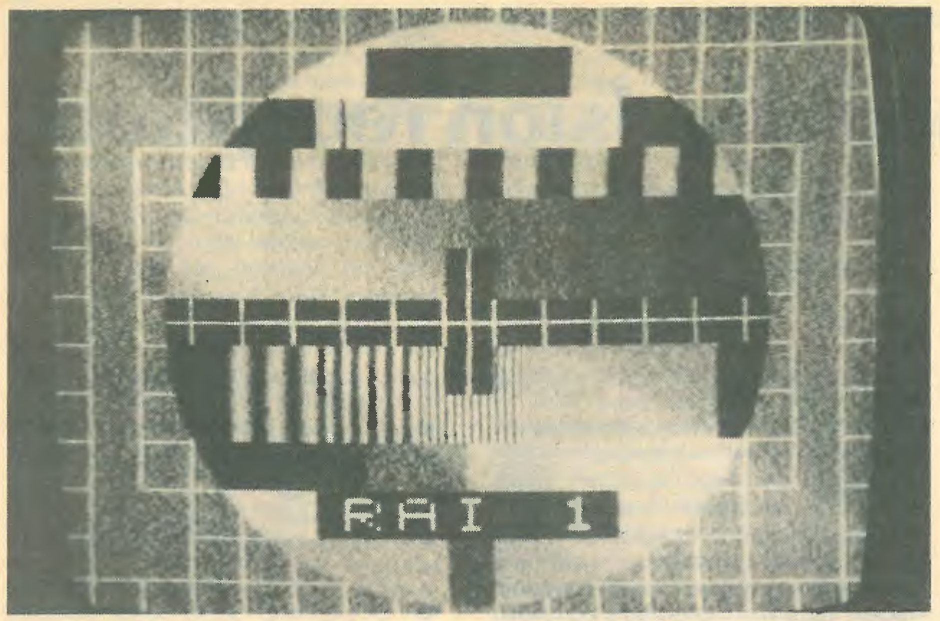


Fig. 2. The Philips PM5544 electronically generated test pattern. This photograph, taken directly from the screen, shows typical reception quality of the Italian RAI under sporadic E conditions.

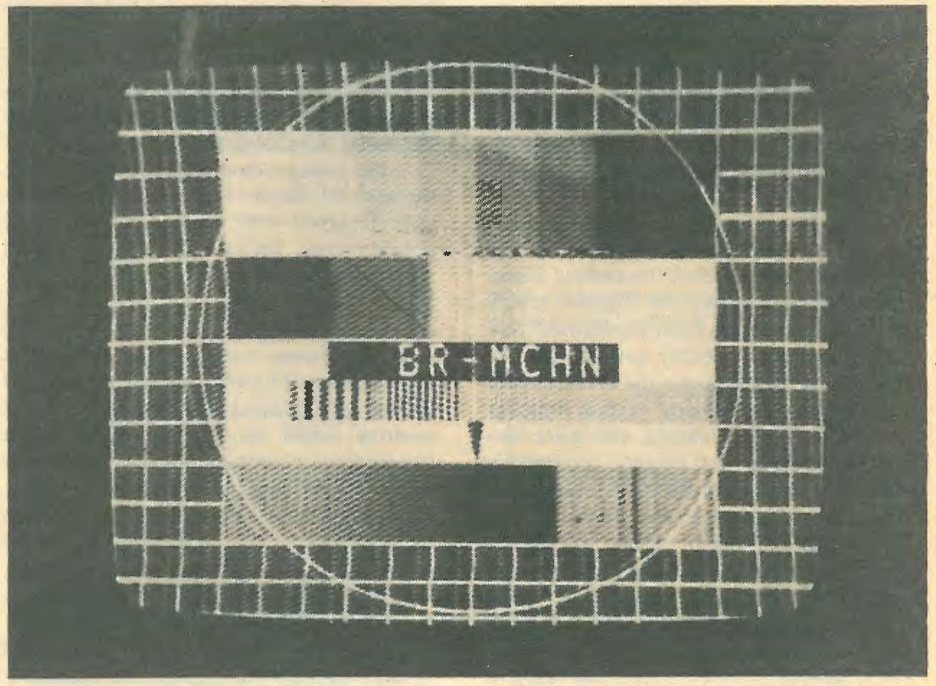


Fig. 3. A photograph of the FuBK electronically generated test pattern used by the West German Bayerischer Rundfunk. This signal was also received under sporadic E conditions.

Aerials

In the minds of most people, the very mention of receiving television signals from other countries conjures up an elaborate array of aerials atop an enormous lattice mast. This need not be the case. Sporadic E enhanced signals can attain very high signal strengths, especially during an intense opening, and consequently the simplest of aerials will suffice.

It should be noted that for serious DX work and the reception of weak signals, an outdoor multi-element system should be considered. Use can be made of the directional properties of the aerial if some method of rotation is used. As the majority of Continental transmissions are horizontally polarized, the receiving aerial should be mounted in the same plane, i.e. with its elements horizontal.

A simple aerial system for the beginner can consist merely of a half-wave dipole, as shown in Fig. 1, mounted outside for best results. The rods can be cut to suit a frequency in the centre of Band I, i.e. around 55MHz. As a horizontal dipole will be directional to some degree, best results will be obtained if the aerial can be rotated.

Signal identification

After a distant signal has been received, one will automatically want to identify its source. This can be difficult if the source happens to be a programme, but if a test pattern is received the chances of identification are greatly improved.

Until fairly recently there were many different test patterns in use throughout the world and almost every country had its own design. Unfortunately a growing number of broadcasting organizations have introduced similar electronically generated test patterns and at present there are two main types; the Philips PM5544 and the FuBK-type as shown in Figures 2 and 3 respectively. But most services now incorporate some form of station identification and so during sustained reception it is relatively easy to identify the country of origin and sometimes even the transmitter.

Books

Until recently there was very little information available for the would be televesion DXer, but the situation has now changed. One publication which should be of interest to both the beginner and the established DXer is 'Long Distance Television Reception For The Enthusiast' by Roger Bunney, published by Babani. Other books and publications which may be of interest to television DXers will be mentioned in due course.

The authors will be pleased to hear from readers with experiences of long-distance television reception and will hopefully be able to assist with any identification problems. Reception reports and any photographic examples of DX reception will be welcomed. □

Readers wishing to respond to the authors' invitation should write to them c/o WW editorial dept.

Literature received

Application note 757-4, from Ailtech, describes the use of the Ailtech 757-57 **GPIB Interface** Unit in conjunction with their 757 spectrum analyser. Copies are available from Eaton Ltd, EID, Sherwood House, High Street, Crowthorne, Berkshire. **WW405**

Reference guide to HBM **strain gauges,** which lists hundreds of types and presents information on mounting adhesives and accessories, can be had from Carl Schenck (UK) Ltd, Stonefield Way, Ruislip, Middlesex HA4 0JT. **WW406**

A great many **housings** and accessories from the UK and overseas, together with tools, instruments and small components are described in the new West Hyde catalogue, which is obtainable from West Hyde Developments Ltd, Unit 9, Park Street Industrial Estate, Buckinghamshire HP20 1ET.

LETTERS TO THE EDITOR

CB PIRATES — OR PROTESTERS?

In your editorial in the May issue you were rather hard on the c.b. pirates. If a reasonable request is unreasonably refused it is unreasonable to expect the applicant to accept the decision. The applicant therefore has a moral right to ignore the decision and the blame for the consequences lies with the person who made the wrong decision.

You admit that the request for a citizens' band service was reasonable and that the initial refusal of the Home Office was unreasonable. The blame for the effects on the community therefore rests with the negligent robots in the Home Office, and the pirates have every reason to grumble at the expense of changing to the new system. Indeed, if logic ruled the world the officials in the Home Office would be made to pay for the new equipment out of their own pockets. That would teach them to be reasonable in the future.

S. Frost
Edinburgh 2

JAMES CLERK MAXWELL

Mr Wellard's recent two-part appreciation of James Clerk Maxwell published in your March and May issues was rather forceful in depreciating the work of Albert Einstein. Undoubtedly it will evoke reaction from the disciples of Relativity but, in my view, Wellard is to be applauded for his forthright contribution. It was indeed deplorable that the 1979 celebration of the centenary of Einstein's birth did not take into account the memory of Maxwell who died in the same year. More to the point, however, it is fitting to note that in 1980 experimental proof showing that the ether can assert a force was reported in *Nature* (G. M. Graham and D. G. Lahoz, *Nature, 285,* 154 (1980) and it was Maxwell and not Einstein that was supported.

I hope we will see further acceptance of Maxwell's principles in the years ahead, perhaps in regard to the third of the four alternative empirical laws of electrodynamics presented in Maxwell's treatise. This particular law is an inverse-square law of attraction with force acting directly between like charged bodies when moving at the same velocity. It can, therefore, give physical basis to Newton's law of gravitation and may even extend to provide accord with the equations, but not the underlying philosophy, of General Relativity (H. Aspden, *J. Phys, A, 13,* 3649 (1980)).

H. Aspden
Chilworth
Southampton

It pains me to find two glaring fallacies in M. G. Wellard's discussion in the March issue of the Michelson-Morley aether-drift "experiment", as it is generally termed. The first, that a mirror may function as a frequency-changer, is probably peculiar to Mr Wellard alone; the second, that the Doppler effect may be produced by the movement of the medium across the source, appears to be quite widely held.

With respect, I would merely comment on the first fallacy by saying that a fortune awaits the inventor of so simple a means of providing superheterodyne radio reception; for the second fallacy, may I perhaps be granted a slightly more comprehensive comment? For our argument we require confidence in one assumption, however: that energy manifested in a simple coherent wave train may be represented by a set of uniform material objects, which may be arranged in a regular pattern in space and in particular in a line representing the line of advance of the wave, each object standing for either a peak, zero-crossing or other phase-state. We could construct a mechanical model, then, with a launcher which rolls a series of balls at regular intervals onto a straight level track, along which they would propel themselves at a steady velocity to a reception device with a counting mechanism, which would be matched by a similar counter on the launcher. We could then say what is the frequency of dispatch, and of arrival at the receiver, and how many balls are in transit. Now suppose that the track is the surface of a continuous transporter-belt, and that this is set to run steadily towards the launcher (to match Mr Wellard's example); what would then have changed? Not necessarily either the rate of dispatch or arrival at the end of the track. The balls would be more closely spaced along the track, in accordance with its speed, but they would travel between launcher and receiver more slowly in a compensating measure. Would we expect to detect the equivalence of the Doppler-effect in this model?

Now suppose the belt to be halted, but either the launcher or receiver to be moving along it. What would be changing in this case? Not necessarily the rate of dispatch. But the rate of reception would have to change, because the number of balls in transit would be constantly changing in proportion to the speed with which the effective track-length was either increasing or decreasing. Now could we be said to recognise the change of frequency at the receiver of this model as the equivalent of the Doppler effect?

Surely the implication of this, and of Mr Wellard's discussion (erroneous though it may be in some details) is that the designers of the aether-drift "experiment" were suspending their principles of scientific method. If this were so, the members of the scientific faculties have been somewhat slow in offering criticism of this lapse. Perhaps it is pertinent to mention here that Fizeau's aether-drag "demonstration" should be subjected to closer inspection; the use of a "control" beam of light propagated in static water, to be compared with its "twin" in water flowing in either one or the other direction relative to the light's direction would, I rather suspect, provide indications against the drag hypothesis.

To conclude, could I suggest, with all due respect, that criticism be always welcome, as is needed if the scientific ideal is to be upheld, but that criticism should be more critically examined before publication? And that applies to this, if it is considered worthy of print!

If by trial and error we may learn, then let us by all means make errors — and then learn to recognise them!

C. B. V. Francksen
Farnborough
Hants

The author replies:

In C. B. V. Francksen's working model of the Michelson and Morley experiment the balls represent the energy of consecutive cycles of a light wave, the launcher the source of light and the semi-transparent mirror, the receiver represents the reflecting mirror, and the stationary or moving track represents the stationary or moving ether. The model can be improved by allowing the launcher and receiver to change positions when the light beam is reflected in the experiment. In the fourth paragraph of the letter the receiver's changed rate of reception is analogous with the frequency changing effect of the moving reflecting mirror.

Mr Francksen need have no fear that his letter is unworthy of print. In the fifth paragraph he has pinpointed the basic flaw in the reasoning that gave rise to the experiment. The history of this experiment is dealt with by Dr Berkson in his "Fields of Force" from page 261 onwards. Fresnel had explained the phenomenon of stellar aberration by assuming the ether did not interact with the Earth. When Arago discovered that this phenomenon did not occur when light passed through a prism, Fresnel said that the ether was trapped within the volume of the prism and dragged along the light. Fresnel calculated his 'dragging coefficient', and by passing light through a moving column of water Fizeau proved Fresnel's 'dragging coefficient'. The moving volume of water dragged along the light wave. Stokes had already proposed an alternative theory to explain stellar aberration — the ether was dragged along by the moving Earth — and Stokes's theory cannot explain Fresnel's 'dragging coefficient'.

Michelson and Morley ignored Fresnel and Fizeau and accepted Stokes's theory that the Earth created an ether wind. If the Michelson-Morley experiment is repeated, effectively immersed in a flowing volume of water, their interferometer will show signs of interference.

M. G. Wellard

TELEVISION FOR NO-SIGNAL AREAS

Mr Osborne's case history of a practical application of an 'active deflector' system (May issue) was read with great interest but with some apprehension. This article could well give the impression that such schemes are very simple and demand little more than redundant aerials, salvaged coaxial cables and modified standard television distribution amplifiers employed with ingenuity by an experienced amateur.

My company has become very involved with 'self help' schemes and supplies standard, and specialised equipment together with engineering advice and assistance where necessary, As a result of our involvement and experience, I would like to make the following points:

1. Communities forced to consider 'self help' systems, usually of populations less than 200, are entitled to the best possible television reception, with a target of standards comparable to well-engineered cable systems.
2. Cable systems should be used whenever possible with the advantages of multi television channels, v.h.f./f.m. radio, teletext operation and provision for future channel services.
3. Active deflector systems should be engineered to the same standard as cable systems, where we comply with BS 5603 and CTVR1/1. Due regard must be paid to filtering of received channels, minimum transmitter power, and cal-

culation of s/x and s/n ratios, for broadband amplifiers, relative to all known variations of signal levels due to 'off air' and cable/equipment temperature variations.

4. As advised under "Licences", full use should be made of the BBC/IBA transmitting authorities, who share the difficult task of assisting the remaining unserved 0.1% population not catered for under Phase 3 of the UK television coverage plan which is projected to 1986.

Please be assured that this is not a criticism of Mr Osborne's article and successful endeavours.

V. Lewis
Wolsey Electronics
Porth, Rhondda
Mid Glamorgan

SCIENCE AND SOCIETY

The quotation from the policy statement by the British Society for Social Responsibility in Science (BSSRS) in May letters contains serious ambiguities, if not explicit errors, which do great harm to the Society's good cause, and which must therefore not pass unchallenged. The policy statement declares: "Science is not neutral. It cannot be separated from politics. It both reflects and helps to determine the values of society." Now if the term "science" is used to denote the activities of the members of a social group known as the "scientific community", then these assertions are essentially true. For the activities in question are inextricably linked to the society within which they take place.

Unfortunately, the definition of science as "the set of all activities by scientists" is rather problematic, because one will then have to specify what this peculiar breed of social species, the scientist, is. And if one naturally says that the scientist is a person who practises science, then the circle becomes obvious. In fact, there has taken place inside BSSRS a debate on whether "Science is a labour process" or "Science is not just social relations" (see *Science for People* No 43/44, 1979). Sadly, it is now evident that the former slogan has overwhelmingly prevailed.

I would argue that the BSSRS in particular, and a wide spectrum of political and philosophical opinion in general, in going out of their way to stress the social influences on scientific research and the impact of scientific discoveries upon society, have been carried away by their bubbling enthusiasm for radical or revolutionary policies, have thus missed the more fundamental content of the meaning of science, have therefore fallen inevitably in serious errors, and so have generated a great deal of dangerous confusion.

Science is best defined as, in the first place, objective knowledge, plus, in the second place, the activity to enlarge, and make use of, this permanent and universal knowledge. Scientific objectivity stubbornly and irrefutably exists and refers to the permanent and universal knowledge of facts and phenomena of nature which are independent of any individual's whim: political affiliations, ideological persuasions, moral convictions, religious beliefs, and so on. Facts and phenomena of nature are always the same for every member of the human race.

If one disregards, as so often is the case, the existence of objective knowledge (upon which all scientific activity, of any political orientation, must securely rest) one will unhappily be forced to say that science is just another ideology, a mere branch of politics, not better and not worse than religion, ethics, and the like. It is true that scientific facts are discovered usually as a result of the activities of scientists, which, we agree, are prone to (good or bad) political influences. It is also true that there are certain difficulties in one's attempt to state the scientific facts objectively – free, that is, of experimental, theoretical, and linguistic limitations or uncertainties, and independently of any political context. For these reasons, many people, not being competent enough to surmount these difficulties, and having gone out of their way to lay great emphasis on the political influences on scientific research, have ridiculously concluded that objective facts do not exist, and they have declared that one cannot separate (the supposedly) certain facts from uncertain theories or from political prejudices. I have very strong feelings about these issues, and suggest that those who are incapable of distinguishing fact from theory or from context should admit their incompetence, rather than cynically persist with these preposterous assertions.

The mix-up between science and ideology is confounded by the fact that all sorts of dubious science (e.g. race and IQ studies, astrology, cosmology) or faulty science (e.g. relativity, duality) are frequently mistaken as authentic science. This badly misguides philosophers into creating dismally erroneous theories of science. Conversely, the realization of the full extent of the confusion between science and ideology is necessary if one wishes to understand why *impossible* hypotheses have been foolishly accepted as tenable and even as true ones (especially in the sphere of theoretical physics).

The most striking instance of the mix-up between science and ideology, and that which generated the greatest harm is the following: Many elements of so-called "modern physics" (relativity, quantum) were rejected by the Nazis because many (but by no means all) of their creators happened to be Jews or socialists or both. In this way, the military defeat of Hitler sealed the fate of twentieth century theoretical physics. As Hitler was (morally) wrong, those who criticise modern physics must be (scientifically) wrong, too. This is one reason why so much scientific criticism of relativity went into deaf ears. The sooner these and other facts are recognised, the earlier the vagaries of relativity will be retired to their well-deserved resting place in the history of science, next to epicycles, phlogiston and the like.

By speaking out in this way, I run the risk of being dubbed a reactionary. But for the sake of truth I do take the risk and I suggest that BSSRS should correctly understand first the full and exact meaning of science, if they really want to ensure, as I do, that science serves the people as a whole. And I earnestly appeal to the comrades of the BSSRS to re-examine the issues I have raised with their brains, not with their hearts; otherwise they will continue to alienate the rank and file scientist, and allow the political establishment to strengthen its position.

T. Theocharis
London SW18

ENGINEERING EDUCATION

The article by Professor D. A. Bell in the January issue reviews the technologist vs theoretician question. In the USA we have recently taken a different path, with separate schools and degrees for technologists and engineers. Whether this is better or worse than the drop down to "pass" level of the UK is yet to be determined.

The question is so old that it should have been solved. This is shown by the editorial in your near-relative publication, *The Electrician*, in volume 21, page 579, September 14, 1888:

"Lord Armstrong, like most captains of industry, knows exactly what he wants and how to get it; but he is rather afraid of getting more than he wants, which he probably would do if Sir Lyon Playfair had his own way . . . Lord Armstring approves os technical and even scientific training only when and where they are needed; Sir Lyon Playfair would scatter these accomplishments broadcast in case they may be needed.

"We suspect that the chief value of technical training in the estimation of the artisan is that it will help him to better his condition – to rise above his fellow workers. The case of 39,000 workmen being thrown out of employment by the invention of a new method of making steel does not help the argument, unless we are to believe that those men would have been kept in work had they understood the process as well as Bessemer.

"The learned doctor hopes to create an unlimited supply of Watts, Stephensons, Arkwrights, Cartwrights, and Bessemeers, by giving the multitude technical education, whilst his practical opponent apprehends that there would be nobody left to work their inventions if we succeeded, and everybody left discontented if we failed."

Somehow, I feel that a definition of *inertia*, conveniently placed on the same page of that musty old volume, applies. This is attributed to Prof Ayrton:

"There are two possible definitions of *inertia*: in this country (England) it is defined as resistance to motion, and in America as resistance to standing still."

It appears that the motion on this question has been a circular orbit for 92 years, and it is time that we selected a re-entry point!

J.D. Ryder
Ocala
Florida, USA

The writer was formerly Dean of Engineering at Michigan State University, USA – Ed.

The author replies:

If the problem has been with us for nearly a century, and yet such a leading figure as John D. Ryder cannot give an authoritative answer, one's first reaction is that the problem is insoluble. However, I think it is worth while pointing out that my remarks were made within the context of the British university system. Firstly, it appears that as the comparison between "technologist" and "engineer" in American terminology is set against our honours/pass discrimination, it must distinguish between "technician" and "professional engineer" rather than between "technologist-engineer" and "engineer-scientist". (In Britain the term "technologist" is of top ranking and covers both professional engineers and their equivalents in other types of technology, in contrast to "technician" which implies lower academic standing, whatever the value to industry and to society.) Secondly, all British universities have in theory the same academic standards: this is supposed to be ensured by the general use of the system of external examiners, i.e. every degree examination is monitored by a senior member of some other university. None the less, special prestige attaches to some universities: one might perhaps compare Oxford, Cambridge and Imperial College with Harvard, Yale and MIT. The inhibition here of any further discriminatory classification is part of a very deep-rooted reluctance in Britain to declare openly that anyone is inferior to others or is finally and irrevocably judged incapable of reaching the highest level.

A personal view is that the British university pass degree is too often no more than a safety net for those who (for one reason or another) fail to reach honours standards. It is responsible for the comparatively low drop-out rate from British universities. (The system of financial grants to students must also influence drop-out rates.) There is little doubt that separate institutions could produce better technicians, but the question is how much human unhappiness would be created by the forcible separation of school leavers (high-school graduates in US terminology) into two streams, professional engineers versus technicians. It would depend partly on the opportunities for exchange between the two streams, which would seem to be minimised if separate institutions are involved. In any case, I do not believe that the vocational content of education is such an important factor in national prosperity as is sometimes assumed, for example in the Finniston Report on engineering education.

D.A. Bell

RADIO AMATEURS' EXAMINATION

I was glad to see the validity of the Radio Amateurs' Examination queried at last (May issue, p.54). Since the Nuffield foundation introduced many changes – even corrections – in the way Physics is taught, many examiners have persisted in regarding the "new approach" as wrong, and marking it so.

"Traditional" and "modern" answers to a question such as "describe the changes which take place when a capacitor is discharged through an inductor" may be quite different at first glance, whilst both could be right. Unfortunately there are too many in authority who would dismiss the latter.

W. H. Jarvis, G8APX
Preston
Lancs

I agree with Pat Hawker (May 1981 issue) that the two errors in the December 1980 Radio Amateurs' Examination Paper 2 were inexcusable, but that is about the only point with which I can agree. Even his comment about the proposed c.b. arrangements permitting radiotelephony on 27MHz whilst Amateur Licence B holders may only operate on frequencies above 30MHz has no relevance since the amateur service is an international service while c.b. is a national one and completely different considerations apply. However, this is no concern of the City of Guilds of London Institute.

I would very much like to see RAE question papers published but the City and Guilds of London Institute has its difficulties here which are entirely connected with the integrity of the examination and are not due to a desire for secrecy in the way the examination is conducted. One is tempted to ask whether what Mr Hawker calls his good fortune did not, in fact, arise from someone breaking faith with undertakings given to the Institute.

As for the charge of a lottery, what of the old written type examinations where only a very few topics from the syllabus could be tested at each examination? In spite of being reasonably well prepared a candidate could find that the questions were all on his weakest topics and he or she had no opportunity to demonstrate their strong points.

The present multiple choice scheme tests every topic in each section of the syllabus at every examination and candidates know they will have a chance of demonstrating their strongest topics as well as being tested in the weakest. As long as they have as many strong topics as weak ones they have some chance of passing.

Multiple choice questions were not dreamed up for the RAE; they have been widely used for many years and the principles are well established. The setting up of a bank of question items is a long process and each item is tested and edited at several stages and finally pretested by volunteers in a mock examination before being accepted for the bank.

The question items are so constructed that the correct answer cannot be selected simply because the alternatives are obviously wrong. Each option offering an incorrect answer must have some credibility so that the candidate must use knowledge of the topic to select which of the options is correct in all respects and fully answers the stem of the question. Errors and omissions typical of those expressed by candidates in the pre-1979 written answers are used in the incorrect options to give them credibility.

Multiple choice is not an easy way out and the candidate needs as much knowledge of the syllabus as he or she did when writing essay type answers. If all this is thought to be unfair to candidates, what is the explanation for the number of candidates having increased from about 1850 in May 1978 and 900 in December 1978 to some 3000 in May 1980 and 2800 in December 1980 and that the percentage of successful candidates has increased slightly?

As regards syllabus content, there has always been a section on electrical theory and it has always been supported by lecturers and other interested bodies, in particular the RSGB, as being valuable groundwork. The volume of such theory has been reduced over the years as technical considerations have changed and the units now involved consist of volt, coulomb, ampere, ohm, watt, hertz, farad and henry and this does not seem excessive. Neither does there seem any reason why knowledge of licence conditions should be less under multiple choice conditions than it was under written answer conditions.

As regards valves, the alternative would have been a massive increase in training time, and I for one see no need to ask would-be radio amateurs to undertake a two-year training course.

Wilfred Dunell, G3BYW
City and Guilds Radio Amateurs' Examination Subject Committee
Cambridge

The views expressed are those of Mr Dunell and not necessarily those of the Subject Committee. – Ed.

Pat Hawker, G3VA, comments:

Wilfred Dunell seems to have misunderstood the point of my criticisms of the RAE held in December. I am all in favour of the multiple-choice form of examination, although, as in the equivalent American exam, it might be worth adding some requirement for candidates to draw a few very simple diagrams. But there are good multiple-choice papers and bad multiple-choice papers. Too many of the questions seem irrelevant to deciding whether somebody should be entrusted with operating an amateur transmitter; and unless one knows the "pass" marks then one cannot avoid the suspicion that a lucky pin would have been almost as useful as careful preparation.

So I remain convinced that not all the questions were either fair or relevant; that it is ridiculous to include coulombs but omit valves; and that at least some questions should be concerned with safety. Far from wishing that would-be amateurs should have to take a two-year training course, it would seem better to scrap the RAE altogether than to continue to set such unsatisfactory papers. As to anyone "breaking faith" to show me the papers, surely such a charge would be better levelled at those in any way responsible for approving the papers! I notice that Mr Dunell does not comment on the question I quoted about s.w.r. meters.

SCIENTIFIC COMPUTER

In the eighteen months since I first wrote to you (December 1979 issue) considerable evolution of John Adams' scientific computer design has occurred.

At the time of my first letter, the high level language available (BASIC using Reverse Polish – "BURP") was very restricted in its facilities and therefore attracted my criticism. Subsequently, Mr Adams has made available a Mark II and then a Mark III version of BURP and I understand that Mark IV is about to appear. A floppy disc interface has been described (October and December 1980) and a 32K memory expansion board is about to become available.

The presently available high level language (Mk III BURP) represents a vast improvement on the original and has answered virtually all the criticisms I made. It now offers a full range of variables, multi-dimensional arrays and virtually all of the statements that one would expect of an "8K BASIC", yet occupies only 4K of memory. It is certainly more than adequate for all "scientific" purposes and one imagines that the Mk IV will be even better.

Much of the evolution of the design has been facilitated by the creation of a users' group associated with a monthly newsletter. Through this medium, many advances in hardware, firmware and software have been made available to users of the computer; the updated BURP interpreter is available via the users' group.

Anyone still using the original, or even the Mk II, monitor is struggling under unnecessary difficulties. Those wishing to remedy this and /or ensure that they keep abreast of future advances would be strongly advised to contact the users' group c/o Mr Phillip Probetts, 50 Cromwell Road, London SW19.

What was originally a very sound basis for development has now blossomed into a very satisfactory and useful machine and, as a final comment, I would like to express the gratitude of all concerned for the tremendous efforts made by Mr Adams and Mr Probetts.

John Whittington
North Harrow
Middlesex

MICROCHIPS AND MEGADEATHS

I was absolutely delighted to read your November editorial both because of your stand on the matter and because you have raised the issue in the technical press.

It seems particularly sad that such high levels of effort and intellect must be employed on the mutually assured destruction of mankind. Those of us who have bothered to inform ourselves and are astride the technology of nuclear warfare can do nought but agree that a halt must be called.

John B. Gibson
Winchester
Hants

I am absolutely appalled by the sentiments expressed in the editorial "Microchips and Megadeaths" (November 1980 issue), the article in Sidebands (May issue) and a great many of the published letters.

Can any of these people put together a viable programme of action which would be completely successful in persuading the world's engineers to stop working on "defence" projects? Obviously no less than one hundred percent success is acceptable, and equally obviously that is not possible.

Lately we engineers have been attempting to improve the status of our profession; e.g. the Finniston Report. If we do not wake up and stop behaving like naive children, we will neither get nor deserve any respect at all. True engineers have to operate in the real world, not in the rarefied atmosphere of the ideal one.

The only way to preserve world peace is to maintain a balance of power. The West has already fallen dangerously behind; therefore en-

gineers should be redoubling their efforts to make maximum use of their limited budgets.
Jack Anderson
Dunmurry
Belfast

I do hope that the proportion of letters in favour of your editorial "Microchips and megadeaths" in the November 1980 issue is typical of your postbag and of engineers in general.

I am sorry to recall that, for two years after leaving university, I too worked in 'defence' projects for a leading electronics manufacturer. However, engineers and computer scientists are fortunate in having a wide range of job opportunities available. I would encourage anyone who is employed on 'defence' work (especially projects for other countries which help to fuel wars in which Britain has no interest!) to look for more useful employment. When one leaves defence projects it is a great joy to be able to talk freely about one's work, and to contemplate its use without envisaging catastrophe.

Could *Wireless World* take matters further by publishing one or more detailed articles listing the firms students should avoid when looking for employment? The Campaign Against Arms Trade (5 Caledonian Road, Kings Cross, London N1 9DX, tel: 01-278 1976) would be only too happy to supply information to any other interested readers.
David Bailey
Manchester 16

OPTO-ELECTRONIC CONTACT BREAKER

Your article on opto-electronic contact breakers (April issue) suggests that they can be fitted to any make of distributor. My own Hillman Hunter uses a distributor in which vacuum advance moves one of the contacts of the contact breaker and, as you can see from the enclosed pages of the maintenance manual, all vacuum advance would be lost if the contact breaker were changed as the author suggests.
M.D. Samain
University of Salford

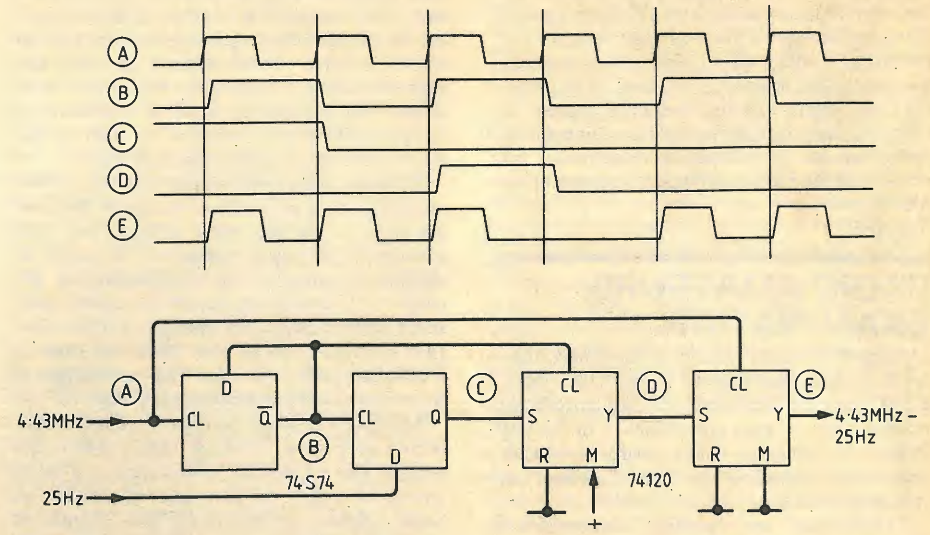
The author replies:
Mr Samain is, of course, correct in saying that the opto-electronic contact breaker is not suitable for sliding contact type distributors. This type of contact breaker is designed to extend contact life by spreading the area of contact erosion, but must be regarded as a palliative rather than a cure for the well known problems of conventional ignition systems. It is particularly unfortunate that no proprietary devices are available to replace such a contact breaker, for the same reasons which rule out my own device.

On re-reading the article as published I could not, however, see where it was suggested that any make of distributor was suitable for conversion.
J.R. Watkinson

DIVIDING BY FRACTIONS

Referring to the article by Gilbert Pearson in your April 1981 issue, which described a method of division from PAL sub-carrier frequency to line frequency by digital counters, I would like to suggest a simpler way to accomplish this.

By using the dual pulse synchronizer SN74120 together with a dual D flip-flop SN74S74, you can easily "remove" a single period of the 4.43MHz signal 25 times per second. After counting down by 1.135 you have a frequency of 3906.25Hz with very low jitter. Using a simple phase locked loop, either a 4MHz master clock or a 31250Hz double line frequency is easily produced.



Looking at the signal diagram and the 74120's truth table, you can see how the circuit works with only two digital integrated circuits.
Knut A. Lyster,
Lyster Elekronikk
Royken
Norway

With reference to the article "Dividing by fractions" in your April 1981 issue, I would like to draw your attention to a more general method of generating a sequence of p pulses, as regularly-spaced as possible in q clock periods. The technique is described in a paper 'The use of digital techniques in television waveform generation' presented at the 1974 International Broadcasting Convention and it is the subject of British Patent No. 1 455 821.

A particular feature of this method is that it generates a 'residue' function, which represents the time difference (jitter) between each output pulse and its ideal position. This residue can be added with appropriate polarity, amplitude and timing to the control loop of a voltage-controlled oscillator in such a way as to eliminate the need to filter any of the systematic jitter components in the phase-locked loop.

This technique is used in commercial equipment (such as the HP 8662A Synthesised Signal Generator described in February 1981 Hewlett-Packard Journal) and the associated counting methods are used frequently in digital television processing when a line harmonic clock rate is used to handle signals related to PAL subcarrier, whether or not it is 'mathematically' locked.
John Chambers
BBC Research Department
Tadworth
Surrey

ETHICS IN ACTION

There is no escaping the moral responsibility placed on all of us to examine our role and function in society (June letters). We should see whether we are contributing directly or indirectly to the design and manufacture of armaments, or other socially unacceptable products, and then reconcile this role with our conscience, ethics, religious beliefs, or whatever standards we live by, and then act upon the outcome. All my life I have refused to work on anything whatsoever to do with armaments or warfare, and any price I may have paid has been trifling in comparison to the degree of sympathy and respect I have encountered, often from the most unexpected quarters.

Western civilisation and technology cannot continue much longer without facing the facts and realising that there will be consequences arising directly from its actions – mostly, I fear, very unpleasant ones – but faced they must be, and your courageous editorials will do much to start electronic engineers thinking.
Robin H. Mann
C.E.G.B.
Barnet
Herts

PICKABACK SPARKS

Regarding Mr A.R. Churchley's remarks in April letters, it may be of interest to refer to the paper in the *Journal of the Institution of Electrical Engineers*, vol. 93, part IIIa, no. 5, 1946, "The development of triggered spark gaps for high power modulators" by J.D. Craggs, M.E. Haine and J.M. Meek. This paper describes the development of triggered spark gaps, during the war years, for use in short pulse modulators for magnetrons for radar applications.

The pulses generated by the discharge of artificial transmission lines were one or two microseconds in duration and up to a few megawatts power. Repetition frequencies up to 2,500Hz were achieved. Early work was on three electrode spark gaps in air. Later this was extended to similar gaps sealed in glass vessels containing a pressure of up to three atmospheres of a mixture of argon with a 6-7% oxygen; the latter to suppress the long lived metastable state in argon which inhibited deionisation. The ratio of the trigger pulse energy to that of the main pulse was 10^3-10^4 to 1.

The transmission lines were charged from a d.c. source through a choke. At first this was done at the resonant frequency of the choke and the transmission line capacitance, so that the line charged to twice the direct voltage. To achieve a variable frequency system a series diode allowed the line to charge to twice the direct voltage and then await the occurrence of the trigger pulse. However, it was later found that, without the diode, the frequency could be increased to any value above the resonant frequency and still give the doubling of voltage. The charging waveform then tends to a linear rise.

It may be interest that patents were applied for and granted only for the sealed systems. The open air gaps system was rejected by the Patent Office because of a similar system patented in the last century for a lightening arrestor.
M.E. Haine
Much Hadham, Herts

Wafer-scale integration

Reducing costs by using i.c. chips on the wafer

by Ivor Catt
Microprocessor Applications Project, Watford College

Much of the cost of manufacturing electronic equipment with integrated circuits lies in making connections to the chips and interconnecting them. Considerable reduction in this cost is claimed for the method proposed here in which memory chips are used while they are still on the semiconductor wafer, the whole of which is permanently built into equipment. On the wafer, a chain of good chips is formed under external control to produce a long serial memory. Any bad chips are automatically by-passed without requiring programming of the metallization that interconnects them or advance knowledge of the distribution of the bad chips on the wafer.

The traditional method of manufacture of a "silicon chip" microcircuit is as follows. A wafer of pure silicon material several inches in diameter is sent through a series of furnaces where hot gases are diffused into selected areas of the surface, creating some 500 identical two-dimensional microcircuits ("chips") on the surface, half of them perfect and half of them faulty. At this stage, a minute fraction, perhaps 1%, of the total manufacturing cost of a complete computer system has been spent.

The microcircuits are tested using a wafer probe and marked to distinguish the good from the bad. The wafer is then cut up into individual microcircuits measuring perhaps one tenth of an inch square, and each good one individually packaged in a one inch long black box with about fourteen contacts. The black boxes are tested and assembled into printed circuit boards. Then the boards are tested and assembled into systems which are also tested (see Fig. 1).

What is being called "the microelectronics revolution" is the successful attempt to reduce the cost of all these stages by squeezing more and more circuitry into each microcircuit (or black box) so that a complete deliverable system can be made with fewer of them. However, more circuitry on a chip means that each chip must be larger and more likely to be useless as a result of its including a faulty spot on the wafer. This leads to lower yield and increased cost, and the practical limit to the size of a chip is in the region of one or two tenths of an inch square. Also, as the complexity of a microcircuit increases, the cost of testing escalates in geometric proportion, so that even today's conventional, relatively simple microprocessors and r.a.ms are expensive because of appalling testing problems.

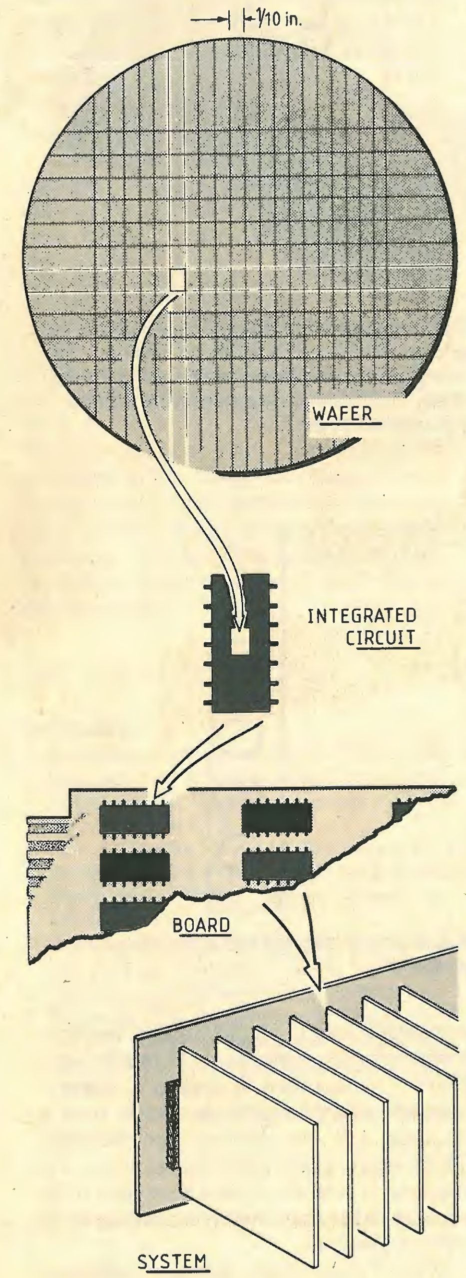


Fig. 1. Main steps in the construction of electronic equipment from the conventional silicon chip.

Wafer scale integration is an alternative approach to the above. Although nominally divided up into "chips", the wafer is never dissected, and there are built-in interconnections between chips. The full wafer, including faulty chips, is installed in the final electronic system. All the costly conventional manufacturing stages – testing the wafer, dicing, packaging, testing, interconnection, testing – are omitted.

The wafer is conventional except that metallization overlaps between chips to give the inter-chip connections mentioned above. Grids of metallization lines across the wafer distribute voltage supplies and clocks. Crossovers between grids are achieved by two layer metallization. An array of fusible links on the grids localizes the effect of any shorts between voltage supplies. Each chip contains bonding pads for voltage supplies and clock inputs, but only a small number of these pads are connected to the outside.

There are four classes of w.s.i. as shown in the chart in Fig. 2. Of these, two were tried and abandoned or found wanting. One is a possible dream for the future. That leaves the fourth, "fault tolerant w.s.i." Now that everyone realizes that the more complex microcircuits already on the market are untestable, it is coming to the fore as the main contender for further advance in microelectronic technology.

The "fault tolerant" interconnection approach is based on the fact that today's "chip" contains a massive quantity of circuitry – more than 5,000 transistors – the same amount of logic as was contained in a complete general purpose computer in the 1960s. The process of getting rid of bad chips and linking up good chips into a perfect machine is delayed until after the wafer has been installed in a working machine, and even after the machine has been switched on for use in the morning. Further, the interconnections between good chips are "broken" when the machine is switched off, so that every time it is switched back on the machine is rebuilt from virgin circuitry during the first five minutes of operation. A very small proportion (some 5%) of the circuitry in each chip is devoted to this reconstruction process after switch on. The reconstruction is under the control of a control board containing logic of conventional design (100 packages which could of course be integrated into a single microcircuit). This control board is called "chip Z". The rest of this article describes the author's approach to fault tolerant w.s.i.

The aim is to build up on the wafer a

spiral of interconnected good chips which avoids the bad chips. This is achieved by a gradual growth process, shown in Fig.3, where additional chips (for example F) are added to the growing spiral, one by one; the latest chip being tested and discarded if found by chip Z to be faulty. Chip Z communicates with it *via* the good chips ABCDE already in the spiral.

We end up with one or more spirals of perfect tested chips (Fig.4), which for architectural purposes might just as well lie on a straight line.

In the simplest machine, of which the working model has already been built under Russell C. Aubusson at the Middlesex Polytechnic, the wafer accommodates one (or more) shift registers which can usefully replace computer disc memory and get rid of the inconvenience of rotating parts.

The next machine in the family has the addition of a fast (or control) line to the previous slow (or data) line, as shown schematically in Fig.5. Serial commands travel rapidly down the spiral along the fast line, checking the address field in each chip they pass and completing a read or write with the appropriate word. The addition of the fast line speeds up memory access from 20 milliseconds to about 5 microseconds, a speed approaching that of conventional random access memory. Although somewhat slower than r.a.m. of conventional design it is attractive because of its extremely low cost, between 10 and 100 times cheaper than what conventional fabrication can achieve, and also because it is self-repairing. If a fault develops, it is only necessary to switch off the machine and the memory will be repaired on switch-on, the newly failed chip being avoided when the new spiral is formed. Because of cost reduction and reliability improvement, computers could be expected to incorporate r.a.ms using w.s.i. as a matter of course when the memory size is 256,000 words or more.

The rest of this article outlines the opportunities open to us via w.s.i. once we break out of the stranglehold of the Von Neumann computer architecture, an archaic design more than a third of a century old which has set the pattern for all computers, microprocessors and microcomputers up to the present time (see editorial, February 1981 issue, p.31).

Over the years the idea has become entrenched that electronic computers are 'information processing' devices, a phrase which implies sequential processing in the same way as a doctor sees his patients sequentially, forgetting all about one patient when he turns to the next. To develop the analogy further, it has become accepted that the doctor should have no recollection of what the patient's third finger looked like when he examines the fourth, and so on. Before moving on to examine the fourth finger, the doctor notes down in the record the state of the third finger, and then forgets all about it.

It is remarkable, and in my opinion unfortunate, that the conventional, schizoid computer is regarded as able to make a reasonable showing at performing quite complex tasks in spite of its being virtually

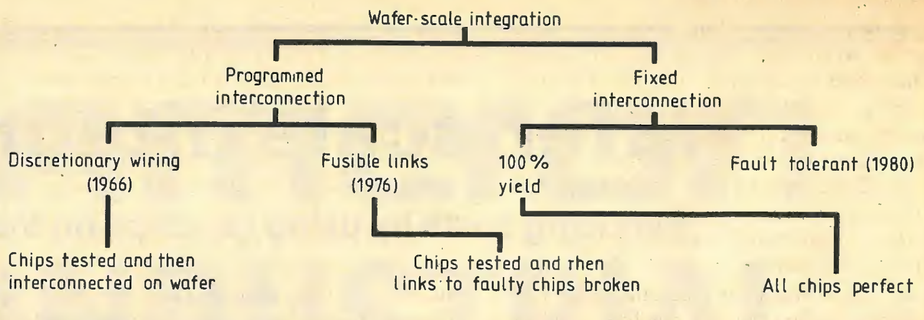


Fig. 2. Chart showing variants of wafer-scale integration and the condition of the chips resulting from these methods.

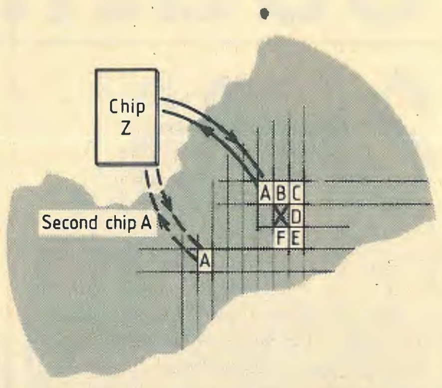


Fig. 3. Process of building up a spiral (or spirals) of chips on a wafer by adding contiguous good chips and avoiding faulty chips. This is done by external control via the external chip Z.

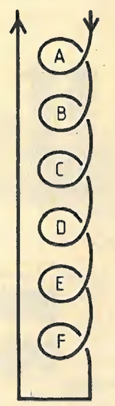


Fig. 4. Schematic of a spiral built up on a wafer.

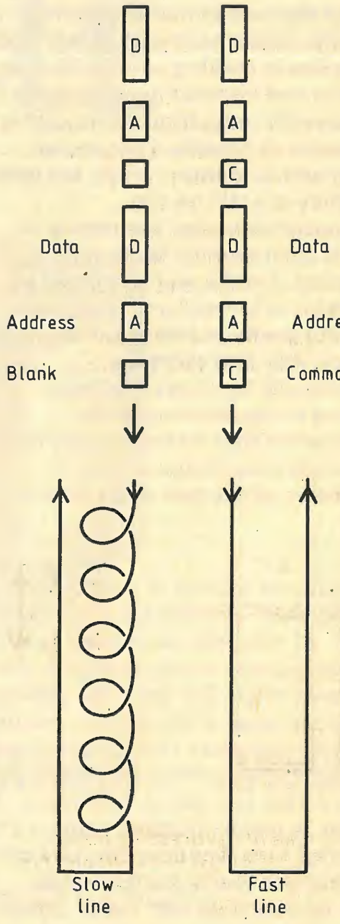


Fig. 5. Schematic of a more advanced system in which a fast, or control, line is added to the slow, or data, line. This fast line carries commands to the data line and allows more rapid memory access than with the simple memory system.

completely split down the middle, between memory and processing. However, my book "Computer Worship" lists a number of applications in which such a machine will not perform satisfactorily. These are generally applications where it is required to operate on data according to its content rather than merely according to its address location.

Wafer scale, fault tolerant hardware leads us to the possibility of a very cheap, reliable machine of a different kind. It is clear that more sophisticated operations than "read" and "write" could easily be performed in a processing node. For instance, the data field on the fast line in Fig.5 could be *added* to the data field on the slow line rather than merely replace it. That is, we could have an "add" command instead of a "write" command. This is the first step towards operating on more than one word in the store at the same time – that is, towards *distributed processing* (a much misused phrase). A number coming down the fast line can be added to more than one word in memory *at the same time*.

A major break with tradition should be noted. Whereas a word in memory has traditionally been addressed (accessed) by its *physical location*, words in this kind of memory are addressed by one field within the word. That is, each word carries its address around with it. We actually have a content addressable memory (=associative memory) masquerading as a r.a.m.

We can consider moving forward towards even more powerful, more complex machines. Basic principles are sketched in Fig.7. It is possible to send a "loop" command down the fast line, with the result that all words get trapped in tiny loops rather than continuing in a "follow my leader", barrelling mode. Further, a "mixed mode", or "precess" command can be sent down the fast line, causing words of one class to loop while words not of that class barrel.

The "mixed mode" makes it possible for any word in memory to have rapid access to all other words in the memory. For example, in the case of a machine used to monitor aircraft circling above an airport, one word, containing the co-ordinates of one aircraft, could be caused to barrel past the records of all other aircraft stacked up waiting to land, so that co-ordinates could be compared and a collision risk by that aircraft foreseen.

The next step in sophistication comes when we realise that when a barrelling word passes by a looping word, the situation is similar to a word on the fast line passing a word on the slow line. It is possible to cause barrelling words to act as commands and operate on looping data words so that the overhead on the fast line is reduced.

Methods have been worked out whereby segments of the slow line behave as autonomous subroutines, the relevant words leapfrogging past each other like a line of children, and flagging when a computational task is completed. We can get an extremely powerful machine which performs many processes at the same time although the hardware is very cheap and self repairing.

The first project based on the principles described here proved the feasibility of the microelectronics aspects of the subject. With E.A. Newman as its technical head, ACTP (Advanced Computer Technology Project, a section of the Department of Industry) financed the project in the Microelectronics Centre at the Middlesex Polytechnic, where it was led by Dr R.C Aubusson. ACTP then funded projects to develop a computer architecture. These were at Brunel University under R.M. Lea, and at Prestwick Circuits Ltd.

The Royal Signals and Radar Establishment, Malvern, has funded two projects on the airborne digital signal processing implications of the computer architecture. This work, at Prestwick Circuits Ltd, is led by Ken Wood. Burroughs Corporation, Cumbernauld and San Diego, is now investing in the development of both the microelectronics and of the computer architecture. This work is led by Dr Malcolm Wilkinson. Wafers designed at Cumbernauld, processed in San Diego and then tested in Cumbernauld have successfully generated spirals of more than 200 chips on an imperfect wafer. This lays to rest any technological doubts about the overall feasibility of the invention.

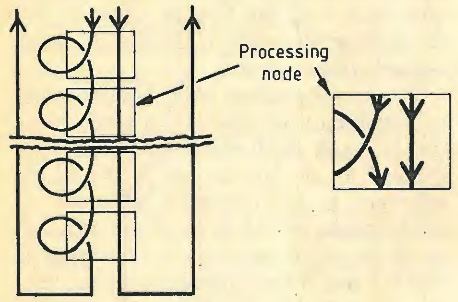
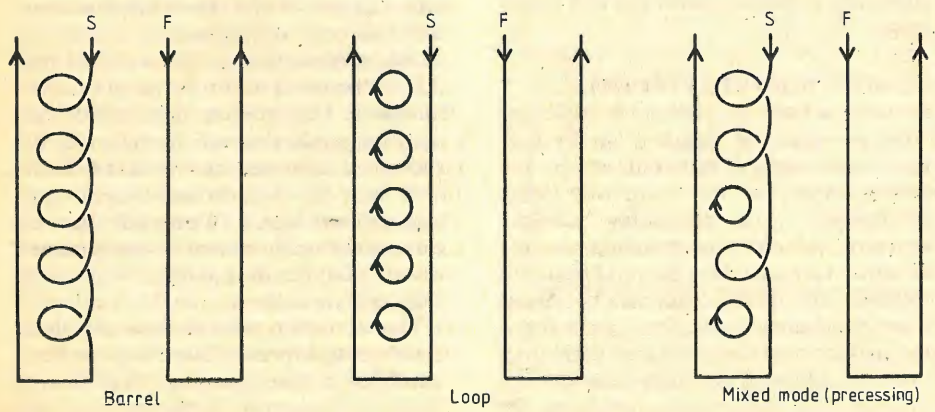


Fig. 6. The idea of a processing node, involving both the slow line (left) and fast line (right) and allowing more advanced operations than simply "read" and "write".

Fig. 7. Different modes of processing: (left) "follow-my-leader" or barrelling mode; (middle) mode in which words are trapped in tiny loops; (right) mixed mode in which some words loop and others barrell.



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Digital storage and analysis of speech

continued from page 48

Reconstructing the analogue waveform

Having digitized and stored a signal, it needs to be passed through a d-to-a converter (digital-to-analogue) and low-pass filter when replayed. D-to-a converters are cheaper than a-to-d ones, and the characteristics of the low-pass filter for output can be the same as those for input. However, the desampling operation introduces an additional distortion, which has an effect on the component at frequency f of

$$\frac{\sin(\pi f/f_s)}{\pi f/f_s},$$

where f_s is the sampling frequency. An "aperture correction" filter is needed to compensate for this, although many systems simply do without it. Such a filter is sometimes incorporated into the codec chip.

For telephone-quality speech, existing codec chips, coupled if necessary with integrated pre-sampling filters, can be used, at a remarkably low cost. For higher-quality speech storage the analogue interface can become quite complex. Comprehensive studies of the problems as they relate to digitization of audio, which demands much greater fidelity than speech, have identified the following sources of error:

- slew-rate distortion in the pre-sampling filter for signals at the upper end of the audio band;
- insufficient filtering of high-frequency input signals;
- noise generated by the sample-and-hold amplifier or pre-sampling filter;
- acquisition errors because of the finite settling time of the sample-and-hold circuit;
- insufficient settling time in the a-to-d conversion;
- errors in the quantization levels of the a-to-d and d-to-a converters;
- noise in the converters;
- jitter on the clock used for timing input or output samples;
- aperture distortion in the output sampler;
- noise in the output filter as a result of limited dynamic range of the integrated circuits;
- power-supply noise injection or ground coupling;
- changes in characteristics as a result of temperature or ageing.

Care must be taken with the analogue interface to ensure that the precision implied by the resolution of the a-to-d and d-to-a converters is not compromised by inadequate analogue circuitry. It is especially important to eliminate high-frequency noise caused by fast edges on nearby computer buses.

To be continued

Sound synthesis using Walsh functions

Simple introduction to the synthesis of complex vibration modes

by **Alan A. Thomas**

An experimental approach to additive synthesis employing digital techniques is described. The system enables an infinite number of waveshapes to be generated by a basic fixed Walsh function generator feeding a set of digitally programmed attenuators. By mathematical analysis of known waveshapes the system may be used as a source of sound for music synthesis, provided that a voltage-controlled oscillator and filter are added to the basic system. Using additional hardware, time-dependent spectrum changes are possible.

A sound may be represented by a series of sinusoidal components of particular frequency, amplitude and phase. The lowest frequency component is referred to as the fundamental, first mode, or first partial. Remaining components are then related to this fundamental frequency by simple ratios. Such a relationship is termed harmonic. Not all musical sounds are entirely composed of harmonically related partials; non-harmonic components, that is partials which do not bear simple direct integral ratios to the fundamental, may also be present. This is the reason that simple harmonic analysis may result in a synthesized sound which lacks some of the character of the original, even though care is taken to mimic all other basic properties.

In harmonic analysis, each partial is given the corresponding value of N in the harmonic series; the fundamental is the first harmonic. For a sound composed of frequencies in the ratios 1: 3: 5 for example, the second and fourth harmonics have zero amplitude, and it follows that the frequencies three and five may be referred to as the non-zero coefficients in the harmonic series of the sound under analysis.

Consider now a further sound composed of frequencies in the ratios 6: 12: 15. Can this series be termed harmonic? It is always possible to find a fundamental frequency of which a given series are harmonics; in this example the ratios are all multiples of three and can therefore be regarded as the second, fourth and fifth harmonics respectively of a fundamental frequency, three. In this case both the fundamental and third harmonic are said to have zero coefficients. The fundamental of a harmonic series need not necessarily be present; if the fundamental is present it should be considered as a non-zero coefficient in the normal manner. An interesting point is that if frequencies of 6, 12 and 15Hz were combined, the resulting complex function would repeat exactly three times per second although the fundamental has zero amplitude. In general therefore, any collection of frequencies can be arranged to fit into a harmonic series, although the fundamental may not be present.

A second important point which must now be made is that there is only one characteristic phase and amplitude for each harmonic which will result in the desired waveshape being realised. How therefore can a harmonic series be set down such that both phase and amplitude information is given for all non-zero coefficient harmonics? A wave of arbitrary phase can be represented as the sum of a sine and cosine wave both of zero phase with amplitudes given by the phase relationship of the original. It follows that a complex periodic function may be represented by a series of sine and cosine functions whose amplitude and period are dependant variables. All that remains is to derive some method whereby the relevant amplitudes may be located. This is Fourier analysis and was first formalized from the basic ideas of other workers by Fourier in 1822 during his work on heat flow. The series of terms derived by Fourier analysis for a particular function is terms the Fourier series and indicates the magnitude of the sinusoidal components. In short, a complex periodic function such as a musical sound may be represented by a series of sine and cosine functions. But first it is necessary to perform harmonic analysis of the waveform to locate the non-zero coefficient sinusoidal components and then apply the Fourier analysis to determine the amplitude of the individual sine and cosine terms.

Fourier sound synthesis

By using a bank of quadrature oscillators —the frequency of which is set by harmonic analysis and amplitude set by the Fourier series of the waveform to be synthesized — a reasonably accurate synthetic sound corresponding to the mode of vibration may be produced. To maintain the same characteristic sound when fundamental frequency is changed the frequency of the generated harmonics must be altered proportionately. In practice this requirement has been the death knell of Fourier synthesis in commercial electronic instruments. For accurate synthesis, a large number of oscillators are required and the task for the electronic engineer, while not impossible, is complex since it is necessary to arrange that all oscillators remain in quadrature and track each other accurately in frequency while maintaining constant amplitudes.

Clearly some method is desirable whereby the attributes of Fourier analysis as applied to sound synthesis may be maintained but the method of waveform generation altered to remove the inherent practical limitations. The method discussed removes these limitations by transformation of the sine and cosine functions associated with the Fourier series to the rectangular functions of the Walsh closed normal orthogonal set.

The transformation from Fourier series to Walsh/Fourier series for a given function is purely mathematical, and has been detailed by K. Simens and R. Kitai, see reference 1. The principal advantage in transforming to the Walsh/Fourier series as far as sound synthesis is concerned is that the bank of quadrature oscillators employed in direct Fourier synthesis is replaced by a single master oscillator controlling an appropriate digital function generator. Thus by using a single voltage-controlled oscillator the facility to play tunes is realised and the analogous Walsh harmonics, derived within the function generator, automatically track the master oscillator maintaining the characteristic sound of the synthesized mode of vibration, independent of pitch.

Properties of Walsh functions

Walsh functions were first investigated by J. L. Walsh in 1923 and are of purely mathematical origin[2]. Collectively, they form a closed set of orthonormal functions. The functions are defined on a basic interval, in this case time. The sequence may then be repeated to form a set of periodic functions. During each interval the functions may only take on the values of ± 1 and are thus rectangular in form. If the basic interval is subdivided into 2^n equal segments where n is an interger, then the corresponding number of Walsh functions which may be incorporated within the basic interval is $2^n - 1$.

The recursion relationship governing the form of individual functions has been translated to the appropriate digital form by H. F. Harmuth[3]. Harmuth has shown

that once Walsh functions have been converted to zero and one logic levels, the recursion relationship reduces to modulo-two addition, the logical exclusive-or function.

Certain Walsh functions are analogous to a further set of mathematical functions: Rademacher functions. Rademacher functions are a set of square waves in simple geometrical progression, the recursion relationship for Rademacher functions, and hence the analogous Walsh functions, once translated in a similar manner to the appropriate digital form reduces to modulo-two counting, the logical binary function. It follows that a digital representation of the complete Walsh orthonormal set for a given value of n may be produced by a logic system comprising of exclusive-or gates and binary counters driven from a master oscillator.

Before producing a suitable function generator it is necessary to decide on a suitable value of n. If harmonic followed by Fourier analysis is performed to obtain the appropriate Fourier series for a given function, the resulting series tends toward infinity; that is, the number of sine and cosine functions should ideally be infinite for perfect harmonic representation.

It is no surprise that when the parallel mathematical analysis is performed to obtain the Walsh/Fourier series the number of Walsh functions required for perfect representation also tends toward infinity. This implies that the greater the value chosen for n, the more accurate the final waveform synthesis. In practice n must be limited to a value which is a compromise between acceptable accuracy of synthesis and the amount of hardware involved in the function generator. The effect of limiting n to a finite value will be considered in more detail later.

Basic Walsh function generator

Given n=5 a generator will produce 2^5-1 Walsh functions and the number of Rademacher functions will be equal to n, that is 5. The first requirement is to produce the five Rademacher functions. This is achieved by a simple five-bit synchronous binary down counter driven by the master oscillator. The analogous Walsh functions thus produced are wal31, wal15, wal7, wal3 and wal1 at consecutive outputs of the binary counter. The remaining Walsh functions are formed by performing modulo-two addition of the functions so far derived in the appropriate order. Wal2 for example is formed by modulo-two addition of wal1 and wal3. The three functions lying between wal7 and wal3 are formed as follows: wal6 is formed by modulo-two addition of wal7 and wal1; wal5 is formed by modulo-two addition of wal7 and wal2 and wal4 is formed by modulo-two addition of wal7 and wal3. The sequence is straightforward from the examples given. The table lists the complete arrangement for all 31 Walsh functions when n=5. The system may be extended for higher orders of n if desired by simply increasing the number of counter sections and exclusive-or gates and using the same basic sequency.

Generation of first 32 Walsh functions (wal0 excluded) using binary counters and exclusive-or gates.

Function	Modulo – 2 Division	Modulo – 2 Addition	Function	Modulo – 2 Division	Modulo – 2 Addition
wal31	Oscillator		wal15	wal31	
wal30		wal31, wal1	wal14		wal15, wal1
wal29		wal31, wal2	wal13		wal15, wal2
wal28		wal31, wal3	wal12		wal15, wal3
wal27		wal31, wal4	wal11		wal15, wal4
wal26		wal31, wal5	wal10		wal15, wal5
wal25		wal31, wal6	wal9		wal15, wal6
wal24		wal31, wal7	wal8		wal15, wal7
wal23		wal31, wal8	wal7	wal15	
wal22		wal31, wal9	wal6		wal7, wal1
wal21		wal31, wal10	wal5		wal7, wal2
wal20		wal31, wal11	wal4		wal7, wal3
wal19		wal31, wal12	wal3	wal7	
wal18		wal31, wal13	wal2		wal3, wal1
wal17		wal31, wal14	wal1	wal3	
wal16		wal31, wal15			

Synthesis of functions using Walsh harmonic bank

To synthesize a function it is necessary to resolve the Walsh/Fourier series. The non-zero coefficient functions of the series which lie within the range of the generator are then selected and mixed in the proportions indicated by the series.

For example, the non-zero coefficient functions in the range 0 to 31 for the triangular wave given by the Walsh/Fourier series are wal2, wal6, wal14 and wal30. Their relative amplitudes are +0.5, +0.25, +0.125 and +0.0625 respectively. Thus, by selecting these four functions from the Walsh harmonic bank and summing them in the relevant proportions, a triangular wave is synthesized.

The frequency of the waveform depends on the basic interval chosen for the Walsh functions which is in turn determined by the frequency of the master oscillator. If the waveform is to have a frequency f, then the master oscillator frequency must be $2^n f$, where n is as previously defined.

Perfect harmonic synthesis is only possible when an infinite number of Walsh functions are employed. When a finite number is used the synthesized waveform appears in a sampled form, the sample rate being 2^n per period. This results in the wave having 2^n discrete levels within each period. To remove this appearance, it is necessary to integrate the function; in practice this can usually be achieved by simple low-pass filtering. Fig. 1 shows the appearance of the triangular wave just discussed before low-pass filtering. Naturally the number of samples and

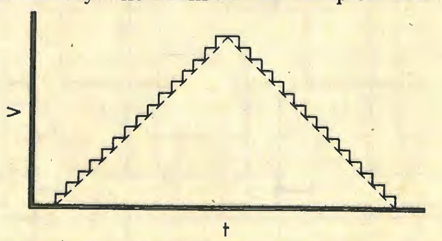

Fig. 1. Triangular wave is synthesized by selecting four functions, wal2, wal6, wal14 and wal30, and summing in relevant proportions

therefore the accuracy of the waveform can be increased by employing a higher order of n but at the expense of more hardware.

Summing of the various Walsh functions may be performed by a standard virtual-earth operational amplifier arrangement, the proportions of mix being scaled to best suit the practical device.

If the master oscillator is made voltage-controlled the frequency of synthesized waveform may be adjusted in the traditional manner. If large variations of frequency are required, the low-pass filter must also be voltage-controlled.

Digitally programmable attenuators

If each of the Walsh functions are fed to a digitally programmable attenuator the outputs of which are then mixed an entirely flexible system is produced which can produce virtually any desired waveshape. This, coupled with a voltage-controlled master oscillator and filter, enables a musical device with infinite tonal qualities to be realised. Further, by altering the program of the attenuators during the life of the wave, the spectrum may be made time-dependent, enabling wave shapes such as that of the piano to be synthesized.

An experimental system is shown in Fig. 2. Referring to this figure, a voltage-controlled oscillator generates a rectangular waveform at a frequency 2^n times higher than the frequency desired for the synthesized waveform. A Walsh function generator comprising binary counters and exclusive-or gates then generates, under control of the v.c.o., 2^n-1 Walsh functions. Each Walsh function is then fed to a digitally programmable attenuator (d.p.a.); only one path is shown in Fig. 2. The d.p.a. is controlled by a read-only memory (r.o.m.) which stores up to 32 eight-bit digital words. This enables up to 256 levels of attenuation to be programmed, any 32 of which may then be selected by addressing the appropriate digital word. The order in which the digital words are selected is controlled by a sequencer which comprises of JK flip-flops and logic gates; the sequencer may also be made programmable if desired. The voltage-controlled oscillator which feeds the Walsh function generator also feeds a divide-by-n counter. In this manner the period over which the coefficient of the particular Walsh function is varied is controllable. Once again, the counter cycle is made programmable.

The output of each d.p.a. is then summed in a traditional virtual earth summing amplifier, the output of which is fed to a voltage-controlled filter (v.c.f.), this being controlled by the same control voltage which controls the v.c.o. Thus, the v.c.o. and v.c.f. track together. The total system results in a waveform being synthesized in which the spectrum may be altered in a programmable manner, both in terms of type and rate of spectrum change. In practice the sequence is initiated by the keyboard controller.

Polyphonic waveform synthesis

By the application of appropriate Walsh/Fourier series both triangular and sawtooth waveforms may be synthesized in a manner compatible with existing organ divider techniques.

The principle by which polyphonic operation is achieved in electronic organs is well known. Briefly, pitches ratioed in accordance with the scale of equal temperament are generated for the highest octave; either 12 independent oscillators are employed or a single master oscillator working in conjunction with a digital function generator. Lower octaves of each scale member may then be generated by the use of binary dividers, as tones spaced at octave intervals have a 2:1 frequency ratio. By this method, any number of pitches may be generated polyphonically, while the number of oscillators required need not exceed 12. Being of digital form the method has the disadvantage that only one waveshape is directly available at the divider outputs, namely a squarewave. For reasonable additive sound synthesis a minimum of two additional waveshapes should also be simultaneously available: triangular and sawtooth waves.

If the organ dividers are arranged to be of the form shown in Fig. 3, the signals present at the various outputs become not only octave-related but also take the form of useful Walsh functions and may be employed in direct Walsh/Fourier synthesis, enabling a practical circuit for the simultaneous generation of square, triangular and sawtooth waveforms to be constructed.

Referring to Fig. 3, given that the index $n = 5$, five Walsh functions are directly available from the divider chain wal31, wal15, wal7, wal3 and wal1 at consecutive outputs of the divider. The Walsh/Fourier series of a sawtooth waveform, limited to the first 32 functions applicable when $n = 5$ is as follows

-1wal1, -0.5wal3, -0.25wal7, -0.125wal15, -0.0625wal31.

The negative signs in the series are interpreted as function inversion for practical purposes. All the necessary functions for sawtooth waveform synthesis are directly available from the divider outputs, provided function inversion is taken into account.

Now consider the Walsh/Fourier series of a triangular waveform:

$+0.5$wal2, $+0.25$wal6, $+0.125$wal14, $+0.0625$wal30.

None of these four functions are directly available at the divider outputs. But the table shows that these four functions may be derived by the use of only four exclusive-or gates. The complete arrangement for deriving all the necessary function for synthesis of both triangular and sawtooth waveforms is detailed in Fig. 4.

To sum these functions accurately in the relevant proportions they are rewritten in more familiar binary-weighted form:

$+2^4$wal2, $+2^3$wal6, $+2^2$wal14, $+2^1$wal30.

and for the sawtooth wave:

-2^4wal1, -2^3wal3, -2^2wal7, -2^1wal15, -2^0wal31.

By applying the functions to the appropriate inputs of two d-to-a converters, accurate summation of the functions may be realised. Although of higher cost, d-to-a converters have two distinct advantages over operational amplifier summators. Firstly, as the output of a converter is in binary-weighted proportion to a single reference voltage or current, the accuracy of summation becomes independent of any variations in the logical 1 or 0 levels present at the outputs of the dividers or exclusive-or gates. Secondly, high accuracy summation resistors need not be fabricated.

Fig. 5 shows a practical circuit developed for evaluation of the system using readily available integrated circuits. For economy, the facility for simultaneous waveform generation has been dropped during evaluation; only a single d-to-a converter is employed together with some additional data selection logic.

Digital-to-analogue conversion

The d-to-a converter is the six-bit Motorola MC1406L, whose digital inputs are compatible but inverting which must be taken into account when selecting appropriate outputs from the dividers. The device requires an external reference for its operation and, as the output is in the form of a current ratio, current-to-voltage conversion is also necessary in this particular application. The reference for the MC1406L device, IC_8, consists of the temperature-compensated zener diode with a current of 7.5mA supplied through R_1, with C_1 providing a.c. decoupling. Because the negative reference input (pin 13) of IC_8 is the high impedance node of the internal reference amplifier, buffering is not necessary. The device requires its reference in the form of a current, determined by resistors to pin 12 and the reference voltage. With the potentiometer set to mid-position, the values are selected to produce a reference current of -2mA. The value of R_3 is selected so that both reference input points have the same source impedance, to reduce reference current error and temperature drift. The internal reference amplifier also requires compensation to maintain stability; with the values selected for the input resistances, the compensation capacitor C_2 must have a minimum value of 180pF to maintain an acceptable phase margin.

The output of IC_8 (pin 4) provides a current which is a linear product of a six-bit digital word and an analogue reference voltage. The output current is negative and is defined from the equation

$$-I_o = I_{ref}\left(\frac{A_1}{2}+\frac{A_2}{2^2}+\frac{A_3}{2^3}+\frac{A_4}{2^4}+\frac{A_5}{2^5}+\frac{A_6}{2^6}\right)$$

where I_{ref} is the reference current and A_1 through to A_6 are the digital inputs, m.s.b. through l.s.b. respectively, $A_n = 0$ if the input is at logical 1, and $A_n = 1$ if the input is at logical 0. As the voltage at the

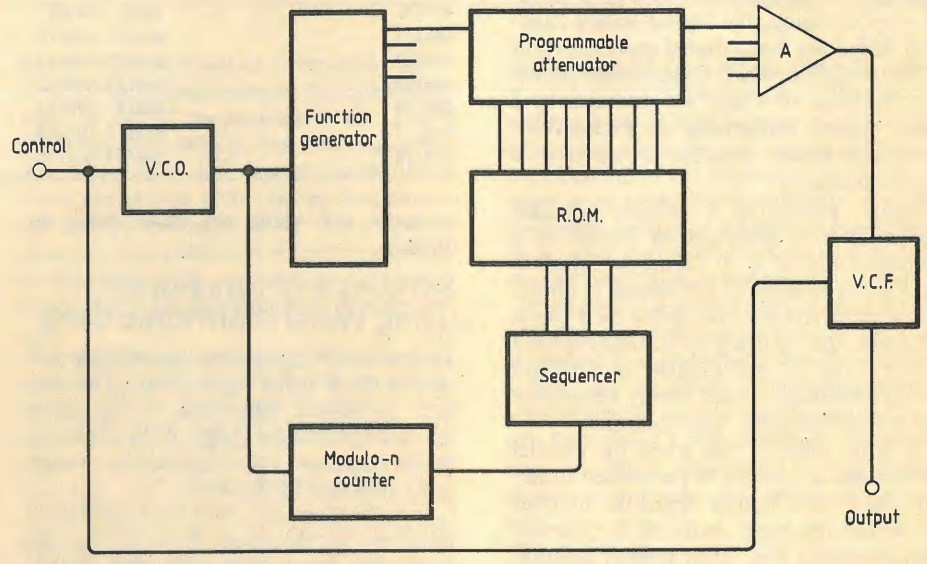

Fig. 2. *If each of the Walsh functions are fed to a digitally programmable attenuator and the outputs mixed virtually any waveshape can be produced.*

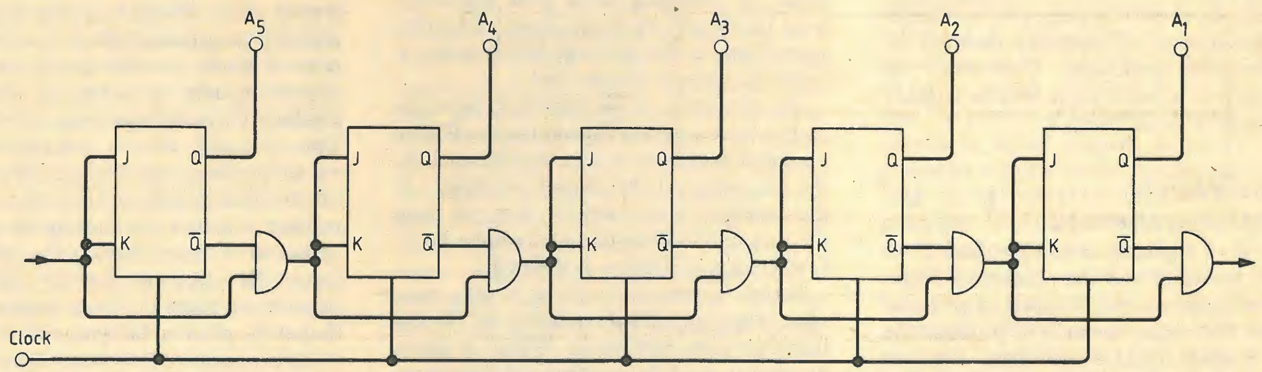

Fig. 3. *Binary divider chain providing wal31, wal15, wal7, wal3 and wal1 at consecutive outputs.*

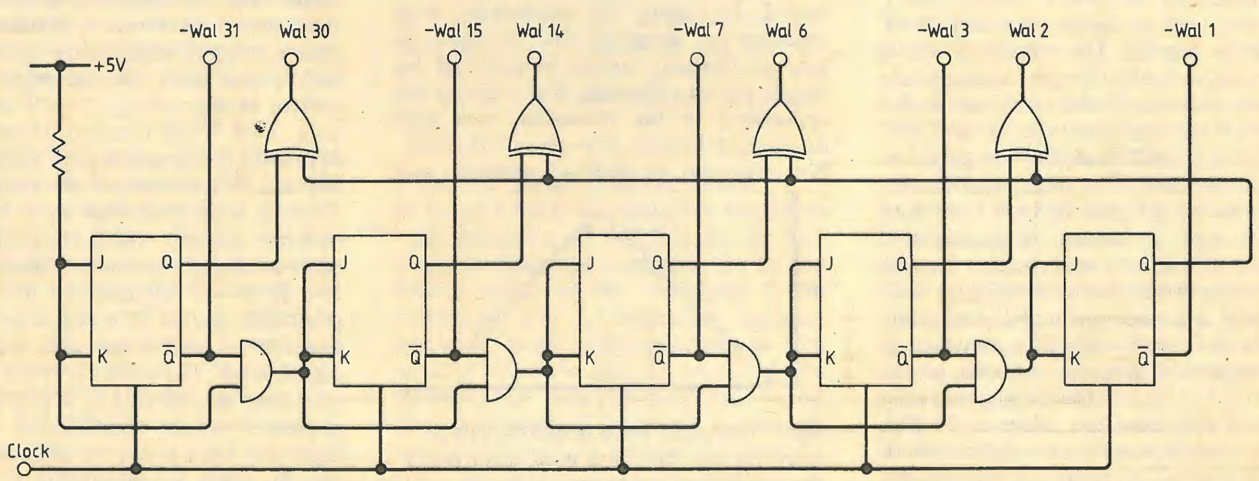

Fig. 4. *By adding inverters and four excusive- or gates triangle and sawtooth waveforms can be synthesized.*

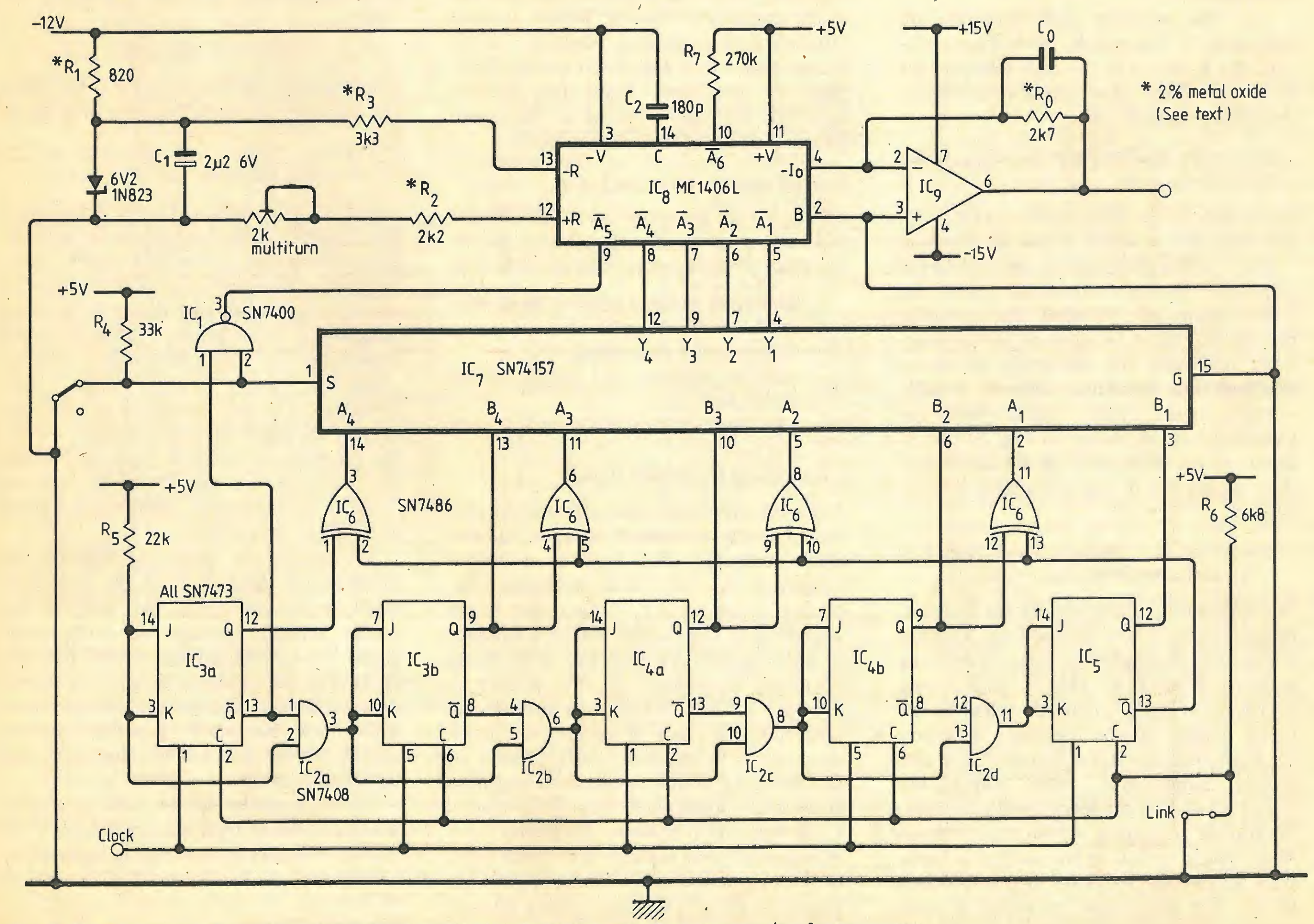

Fig. 5. *Practical circuit for system evaluation omits simultaneous waveform generation for economy.*

output must not rise above ±0.4V for accurate conversion, simple resistive current-to-voltage conversion is not practical and an op-amp converter IC_9 is used. The virtual-earth effect of the amplifier maintains the voltage at pin 4 of IC_8 within the permitted value, while the output voltage $(-I_oR_o)$ may be set to any reasonable value by the suitable selection of R_o. With R_o set at 2.7kΩ, the output voltage may be set to a peak value of +5V by adjustment of the reference current control. Capacitor C_o provides low-pass filtering of the output waveform; the operational amplifier is a 741 general-purpose device.

Digital function generation and selection logic

Although the MC1406L device is a six-bit d-to-a converter, only five-bit conversion is required in this application. To maintain maximum accuracy during conversion, the input corresponding to the least-significant-bit is dropped and disabled by connecting to +5V through R_7. The remaining most-significant-bits are supplied through data selection gates. The four most-significant-bits are supplied with an SN74157N, quadruple 2-to-1-line data selector, IC_7. Hence either of two functions may be presented to each of these inputs as required. The least-significant fifth-bit is a special case, since it is not required during triangular waveform synthesis if the desired sample-rate is defined on the time axis. This bit is therefore supplied through a simpler nand-gate arrangement, IC_1.

The data selectors and nand-gate are controlled by the switch. With it open-circuit, the B-inputs of the data selectors are allowed to their respective d-to-a conversion points, namely:

wal1 to A_1, wal3 to A_2, wal7 to A_3, and wal15 to A_4.

In the case of the least-significant fifth-bit, the nand-gate is allowed and the function −wal31 is inverted and transferred to the respective d-to-a conversion point A_5. After taking into account the inversion provided by the d-to-a inputs, all the functions necessary for sawtooth waveform synthesis are presented, namely −wal1, −wal7, −wal15, and −wal31. With the switch closed, as shown in Fig. 5, the A-inputs of the data selectors are allowed to their respective d-to-a conversion points, namely:

−wal2 to A_1, −wal6 to A_2, −wal14 to A_3, and −wal30 to A_4.

In the case of the least-significant fifth-bit, the nand-gate is now disabled and a logical 1 is applied to disable the respective d-to-a conversion point A_5. Hence, after taking into account the inversion provided by the d-to-a inputs, all the functions necessary for traingular waveform synthesis are presented, namely wal2, wal6, wal14, and wal30. Dropping the least-significant fifth-bit during triangular waveform synthesis must result in this wave having a lower peak amplitude than that of the sawtooth wave. The amplitude variation is only around 3%, and is sufficient to warrant the

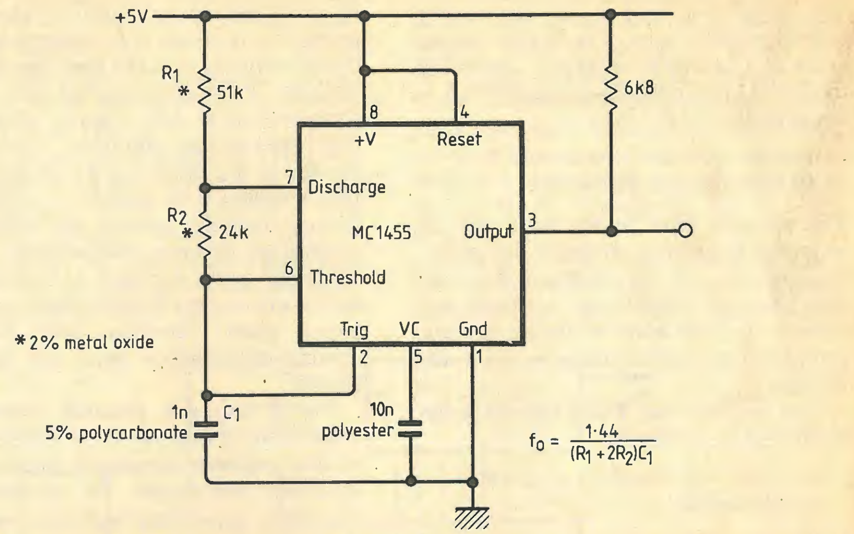

Fig. 6. Clock generator frequency is set to 2^5f for testing dynamic operation of Fig. 5.

otherwise necessary switching of the current reference.

The divider, comprising IC_3, IC_4 and IC_5, is a series of individually clocked master/slave flip-flops controlled appropriately at their JK inputs via and-gates IC_2. Collectively they constitute a five-bit synchronous ripple-through gated binary down-counter which generates the control of a clock-generator, five basic Walsh functions. Four true functions are supplied to the appropriate B-inputs of the data selectors, while a fifth and inverse function is supplied to the nand-gate as required. Four true functions are also fed to the exclusive-or gating where, in conjunction with a common function −wal1, the necessary four additional inverse functions are generated. These four inverse functions are then supplied to the appropriate A-inputs of the data selectors.

Setting-up procedure

Setting up the generator is straightforward and only requires the adjustment of the reference potentiometer. The procedure is

- set switch to open position as in sawtooth waveform synthesis
- fit temporary link shown
- monitor positive d.c. output of the generator
- adjust potentiometer to set d.c. output to +5V
- remove temporary link.

The generator may now be tested for correct dynamic operation using a suitable clock generator, Fig. 6. For an output frequency f_o, the clock generator frequency is set to 2^5f_o. Using the values suggested in Fig. 6, the output frequency is approximately 440Hz. Maximum operating frequency of the divider is around 5MHz, while the maximum operating frequency of the d-to-a conversion section is predominantly limited by the slew-rate of the operational amplifier current-to-voltage converter. The value of C_o depends on the output frequency f_o. It is suggested that initially the −3dB point of the operational amplifier is set to 2^5f_o. Thus $C_0=1/2\pi 2^5f_0R_0$. This gives a value of 4.7nF.

Practical extension for full polyphonics

By applying appropriate Walsh functions to separate summators any number of different waveshapes may be synthesized simultaneously at a given frequency. But for full polyphonics, simultaneous multi-frequency generation of these waveshapes must also be arranged. As an aid to locating functions which form a useful geometrical progression in sequency, an analogy with sine and cosine notation is again useful. Designating the odd and even indexed functions sal and cal respectively, one obtains

$$\text{sal}(a') = \text{sal}(2a+1)$$

where the sal function of index a' has twice the sequency of the sal function of index a, and

$$\text{cal}(b') = \text{cal}(2b)$$

where the cal function of index b' has twice the sequency of the cal function of index b. From this it may be deduced that the functions at consecutive outputs of the divider are octavely related and form a geometrical progression in sequency. For multi-octave generation of the functions −wal31, −wal15, −wal7, −wal3, and −wal1 therefore, it is only necessary to select the correct extended-divider outputs. −wal1, for synthesis purposes at pitch A_2(880Hz) for example, is the identical function −wal3, for synthesis purposes at pitch A_1(440Hz), and so forth.

To extend the generator scheme for multi-octave generation of the functions wal30, wal14, wal6, and wal2 however requires separate groups of exclusive-or gates. For correct sequency, wal2 at pitch A_2(880Hz) for example should be formed by modulo-two addition of the functions wal1 and wal3 at pitch A_2, giving frequencies of 880Hz and 1760Hz for wal1 and wal3 respectively.

Thus extension of the basic generator scheme to full polyphonic capability, while viable, requires a formidable amount of hardware in m.s.i. form. With a view to

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Which way h.f. broadcast receivers?

Proposals for the development of s.w. sets

by **Y.-C. Heng** and **R. C. V. Macario,** University College of Swansea

With a vast number of shortwave receiver sets around the world, estimated as being over 100 million sets in regular use, and with a majority of listeners with little or no technical knowledge, using their sets in a wide variety of environments, it is worth taking a look at methods for improving the design of h.f. sets. The use of digital tuning techniques and the incorporation of microprocessors are discussed.

According to conservative estimation, there exist in the world today between 200 and 300 million radio sets capable of shortwave broadcast reception. A regular audience approaching 100 million is also estimated. The figure must surely encourage shortwave broadcasters, but also indicates how important is the function of shortwave broadcasting. It is also estimated that there are one million amateur radio enthusiasts (class A) around the world, but as this is only 1% of the suggested audience clearly the majority of shortwave broadcast listeners have relatively little technical interest or perhaps background and accept comparatively inexpensive receivers. In addition, listeners operate their sets either in an environment with a very high level of man-made noise or have a very inefficient aerial. On the other hand, they are usually hampered by difficult tuning operation, undefined signal reception, and poor receiver stability, yet form the majority of shortwave boradcast listeners. This article therefore sets out to discuss which way a shortwave broadcast receiver designer might go with regard to alternative design approaches and the discussion is supported by practical demonstrations. The possibility of applying microprocessors in popular shortwave broadcast receiver designs must also be considered and views on this approach are also included.

What is required?

In this section, difficulties of both manufacturers and users of shortwave broadcast receivers are mentioned, but firstly requirements of users and recommendations of broadcast unions are also set down.

In order to bring out the difficulties facing the shortwave service, it is reasonable to know the distribution of shortwave broadcast frequencies in the radio spectrum. It seems that the arrangement of radio spectrum has never been able to totally satisfy any shareholder of the spectrum. "How to best share the radio spectrum for each different service?" will always be a difficult technical and political exercise. Shortwave broadcasting in particular is briefly considered here.

In the past twenty years, the total shortwave broadcasting service (including in-band and out-of-band) has grown up from 11,000 to 27,000 daily frequency hours[1], and the problem of congestion is well understood. Re-allocation and expansion suggestions of the boradcast bands on shortwave from the Asian Broadcasting Union (ABU), the European Broadcasting Union (EBU) and the United Kingdom before the 1979 World Administration Radio Conference (WARC) are listed on Table 1. At WARC 1979, the frequency allocations in Table 2 were agreed and these will be available for allocation from January 1982. Table 2 also lists the present band planning. A glance at Table 2, and Table 1 for that matter, shows that the broadcast bands are scattered between 3 and 27MHz, with no simple arithmetic relation among them.

TABLE 1. Current proposals of h.f. broadcasting service

PRESENT FREQUENCY ALLOCATION	PROPOSAL FROM E.B.U. (1)	PROPOSAL FROM U.K. (2)	PROPOSAL FROM A.B.U. (1)
–	–	2300 to 2495	3900 to 3950 (2)
3900 to 3950 (2)	3900 to 4060	3200 to 3400 (except 3260 to 3265)	3950 to 4000 (2)
3950 to 4000 (2)	4750 to 4995 (2)	3900 to 4000	4750 to 4995 (2)
4750 to 4995 (2)	5005 to 5060 (2)	4750 to 5060 (except 4995 to 5005)	5005 to 5060 (2)
5005 to 5060 (2)	5740 to 6200	5830 to 6200	5950 to 6200
5950 to 6200	7100 to 7500	7100 to 7500	7100 to 7300
7100 to 7300 (2)	9400 to 9900	9400 to 9800	9500 to 9775
9500 to 9775	11500 to 12025	11600 to 12000	11700 to 11975
11700 to 11975	13600 to 14000	13360 to 13560	13600 to 14000
15100 to 15450	15100 to 15700	15100 to 15600	15100 to 15450
17700 to 17900	17500 to 17900	17500 to 17900	17700 to 17900
21450 to 21750	21450 to 21850	21450 to 21850	21450 to 21750
25600 to 26100	25600 to 26100	25600 to 26100	25600 to 26100

(1) E.B.U.: European Broadcast Union
U.K.: United Kingdom
A.B.U.: Asian-Pacific Broadcast Union
(2) Shared with other services
(3) Frequency in kHz

TABLE 2. Present and proposed h.f. broadcasting frequency spectrum

CURRENT HF BANDS	WARC PROPOSAL (AFTER 1982)	
–	3.200 to 3.400 (2)	BAND 1
3.900 to 4.000 (2)	3.950 to 4.000 (2)	BAND 2
4.750 to 4.995 (2)	4.750 to 4.850 (2)	
–	4.850 to 4.995 (2)	BAND 3
5.005 to 5.060 (2)	5.005 to 5.060 (2)	
5.950 to 6.200	5.950 to 6.200	BAND 4
7.100 to 7.300 (2)	7.100 to 7.300	BAND 5
9.500 to 9.775	9.500 to 9.900	BAND 6
11.700 to 11.975	11.650 to 12.050	BAND 7
–	13.600 to 13.800	BAND 8
15.100 to 15.450	15.100 to 15.600	BAND 9
17.700 to 17.900	17.550 to 17.990	BAND 10
21.450 to 21.750	21.450 to 21.850	BAND 11
25.600 to 26.100	25.670 to 26.100	BAND 12

(1) Frequencies are in MHz
(2) Shared with other services

Design difficulties

Despite the general difficulties faced by radio receiver designers, there are some distinct problems for a popular low-cost shortwave receiver design.

In 1959, there were only a few transmitters with transmitting powers of over 200kW, but during the last 20 years, their number has increased to about 400. They generate tens, in some cases hundreds, of millivolts at the antenna terminals when received. The trouble caused in the receiver is that strong signals generate a large number of intermodulation products, strong enough to give the appearance of liveliness, yet masking weak wanted signals. How to distinguish the wanted weak signal from massive strong unwanted signals is always a major technical task.

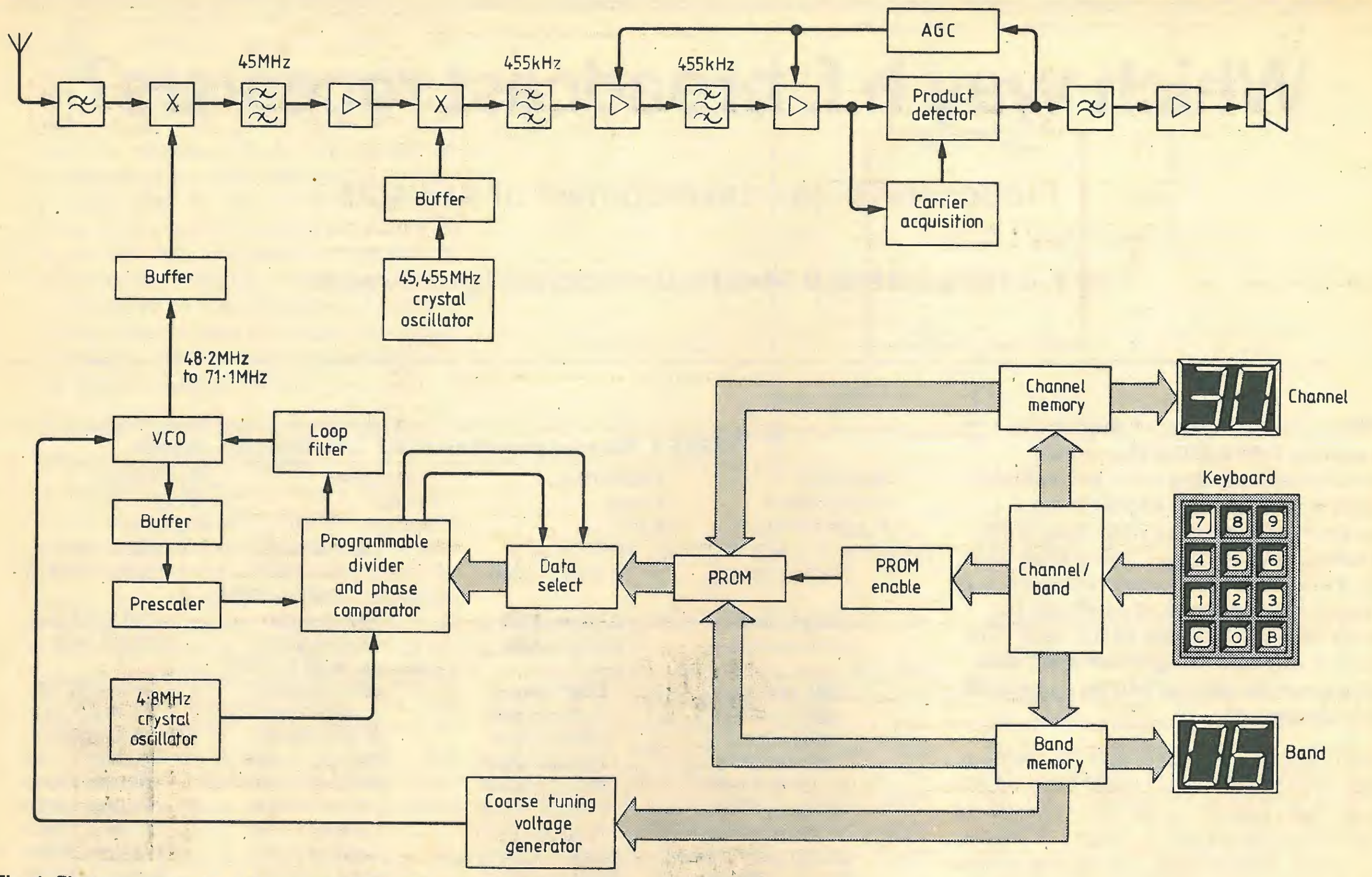

Fig. 1. First approach for a functional system.

A free-running local oscillator in a superhet receiver is always troublesome, especially when the first intermediate frequency is set to a high frequency to improve image rejection ratio.

Even with the most sophisticated mechanical tuning dial design, a resolution of 10Hz at 30MHz can really never be achieved. One can therefore imagine the outcome of the accuracy of a normal popular shortwave broadcast receiver.

Good shaping of the selectivity curves of the r.f. and i.f. stages offer a direct way of rejecting unwanted signals, but cost is a factor when seeking good selectivity curves.

Due to skywave transmission, a fading phenomenon is inherent with shortwave broadcast reception; a way to conquer this problem should always be considered.

User's difficulties and requirements

No need to say, as often as not the designer's difficulties mentioned above are overcome in a popular-model shortwave broadcast receiver design by being transferred to user operation and reception difficulties.

Difficulties to tune to a desired station, and maintain that listening station from drifting, unavoidable interference and spurious signals due to poor linearity and selectivity, audio output variations due to fading effects, are some of the major difficulties facing users. What do the users want? The users simply want easy operation, good performance and low cost receivers, requirements of course, in almost direct conflict with manufacturers.

After a joint meeting between representatives of national receiver and transmitter manufacturers associations and an EBU study group concerned with h.f. broadcasting[2], a brief and pertinent description was suggested for a popular shortwave broadcast receiver design: it should be reasonably-priced, stable with product demodulator and easy-tuned.

Following this suggestion, the design philosophy is divided into four sections: easy operation, high stability, low cost and good performance.

One way and better way to relieve the difficult task of mechanical tuning is to apply a digital tuning technique. Digital tuning can make it possible to tune quickly and accurately over a large number of shortwave broadcast stations. Incorporation by means of frequency synthesizer circuits is discussed below.

Tuning a station can be achieved by keying in frequency information, wavelength information, or a pre-assigned code. Before the idea of programme-labelling[3,4,5] can be widely implemented, listeners still need to look up from a handbook or simply memorize the identity information of a station. It is tiresome to find out station identity information from a handbook each time, but it is also impractical to memorize such things as 5.339MHz or 56.19 meters of more than a few stations. Therefore a station assignment plan similar to the m.f. could be considered[10,11]. For instance, one plan is to divide the whole shortwave broadcast spectrum into several "frequency bands". Then in each band, stations with agreed channel spacing are given unique channel numbers. For example, the above-mentioned station could now have a pre-assigned code such as Band 3, Channel 79. With a station identity information simpler than a telephone number and using a keyboard entry technique, the user could tune to a favourite programme station easily and accurately.

After tuning to a given frequency, an ideal shortwave broadcast receiver should stay tuned to that frequency without readjustment over an extended period. By applying the frequency synthesis technique, the ideal condition can be approached.

A frequency synthesiser can generate a very large number of local oscillator frequencies by programming and have the stability and accuracy equal to that of a single master crystal oscillator. Today, a crystal oscillator stability of 1 part in 10^6 is easily achieved in a non-ovened but room-type environment; this implies remaining within ±5Hz when tuned to 10MHz. Many interesting synthesiser devices are now appearing on the open market, not necessarily originally developed for shortwave receivers, but which can be readily adapted for such purposes. In this article the Philips LN 123 and Plessey NJ 8811 synthesisers are used in two different design approaches.

To keep receiver cost down is almost mandatory. In general, manufacturing cost can be subdivided into material cost, testing cost and assembly cost. By using cheaper components, such as integrated circuits, ceramic filters, etc., not only the material cost, but also the testing and assembly costs can be reduced. A suggested frequency allocation proposal which can reduce the price of the receiver system design is given in design approach 2.

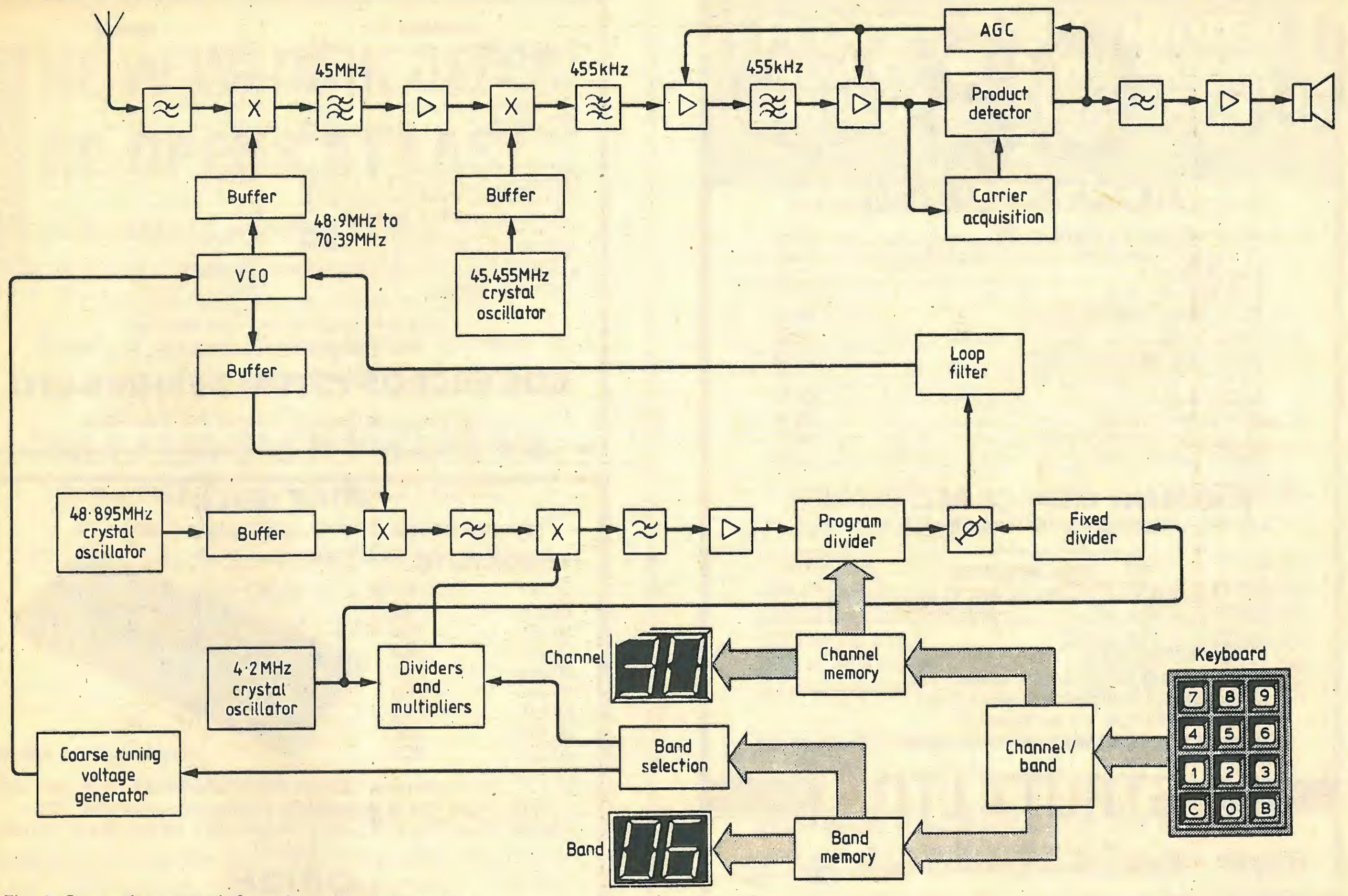

Fig. 2. Second approach for a functional system.

Good performance and low cost are not easy to reach at the same time by a designer, sometimes the two requirements are in direct conflict, but this does not mean a low cost receiver need not have good performance. To some extent, the art is how to distribute the expense over the design. Nevertheless, some specifications which should be considered as a "must be good" are listed here:

(1) Linearity
(2) Sensitivity
(3) Selectivity
(4) Image rejection ratio
(5) Frequency stability

H.f. Receiver Design Approaches

Having just specified the design requirements, we now describe two designs which achieve the requirements, but which are based on quite different approaches.

Fig. 1 shows a system block diagram. In this first system design approach, frequency allocation is based on the WARC 1979 new agreement, listed in Table 2. The whole frequency spectrum is arranged to have 12 frequency bands and a channel spacing of 5kHz is assumed. Under this scheme, a broadcast station with a transmitting frequency at 9.645MHz would now have an identity code: Band 6; Channel 30. To tune to this station, the operator presses the key 'B' first, opening the gate to the band memory unit and at the same time closing the gate to channel memory unit. The number '6' is then pressed and the memory display unit then shows this band number. The user then presses key 'C' reversing the above gate switch functions and then the number '30'. The channel display unit should then show this channel number. The actual digits stored in the band and channel memory units are b.c.d. coded. These b.c.d. numbers are then used as address codes to fetch the correspondent set of words from the eprom to progam the programmable divider. The vco (voltage-controlled oscillator) output, via a buffer and prescaler stages, is divided down in the programmable divider and then sent to the phase comparator unit to compare with the reference frequency signal. If a different of frequency or phase exists, an error voltage is generated through the loop filter to correct v.c.o. frequency or phase in the usual way. With the correct v.c.o. frequency, the receiver is tuned to the wanted station frequency.

The antenna r.f. signal is selectable by converting to the i.f. frequency. An up-conversion superhet system with a first i.f. of 45MHz and second i.f. of 455kHz has been adopted so as to ensure a high image rejection ratio. Double-balanced modulators are used in these two conversion stages to improve various interference characteristics such as intermodulation products, spurious noise, etc. New low-voltage high-level balanced modulators, with which the manufacturers claim a third-order intermodulation of -60dB and a 1dB compression point of 15dBm, are currently available.

Although at the forthcoming WARC HF conference in 1983, any possible planning of the shortwave broadcasting bands will be based on a double-side band (d.s.b.) sound broadcasting system, the introduction of single-side band (s.s.b.) transmissions has to be taken into account[2]. A carrier reduction in excess of 6dB, with respect to peak envelope power, is also likely. A residual carrier is necessary for the operation of automatic-gain-control circuits in the receiver and for frequency-locking or carrier acquisition purposes. On the other hand, a 12dB reduction makes for a sensible reduction of transmitter power consumption and running costs[8].

The upper-side band (u.s.b.) transmitting mode is likely to be used in the future shortwave broadcast s.s.b. transmission, therefore only u.s.b. detection is considered in the s.s.b. detector design. As indicated a regenerated carrier signal from the carrier acquisition circuit mixes with the received carrier signal in the product detector stage. The audio information is then amplified after a low-pass filter to the required level through audio amplifiers. The nature of possible carrier acquisition circuits is not discussed here for two reasons. Firstly such circuits are not easy to devise and secondly they deserve a long separate discussion.

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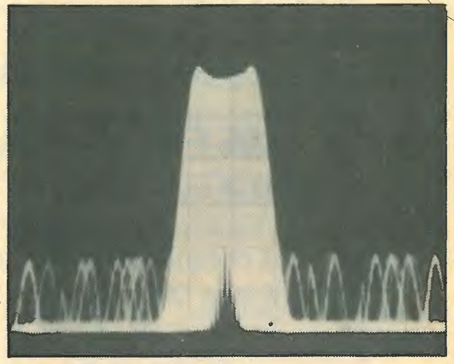
NEWS OF THE MONTH

Frequency-hopping military radio produced

A British firm, Racal-Tacticom Ltd, claims to be the first in the world to go into production with a frequency-hopping military radio. Some of the first models, which operate at v.h.f., have been ordered by the Ministry of Defence for evaluation by the British Army. Some are going to other NATO member countries and, according to the company, will be in service in Europe within the next few months. The purpose of frequency-hopping (an "electronic counter-countermeasure" in military jargon) is to avoid the unwelcome attention of jamming or interception of messages (known as "electronic countermeasures"). Instead of operating continuously in one channel, the radio communication system is designed so that the frequency, of both transmitter and receiver, automatically jumps about from channel to channel in a random sequence. The equipment developed by Racal-Tacticom is a speculative commercial venture which they have been working on for only three years. Gerry Whent, chairman and managing director of the company, says confidently that sales of the product, which includes vehicle and manpack versions, "throughout the 1980s are likely to run into hundreds of millions of pounds from our traditional markets alone".

Parts of the v.h.f. band from 30 to 88MHz are available for use by military communications. Within this range nine 6.4MHz bands have been selected by Racal for frequency hopping; and within a chosen 6.4MHz "hop band" the frequency hops among 256 channels, each 25kHz wide. The method of achieving this, and the necessary synchronization between transmitter and receiver, were outlined in our earlier report on the prototype (December 1979 issue, p.85). The hopping rate is described by the maker as "medium", which means somewhere between 50 and 500 hops per second. Some idea of the spread-spectrum character of the transmission can be gained from the spectrum analyser display here. The horizontal, frequency axis represents the extent of one "hop band" of 6.4MHz. The small peaks are signal spectra and are a record of the successive frequency positions of the signal in about 35 of the 256 channels over a fraction of a second. The large-amplitude peak in the middle of the screen is the spectrum of a strong jamming signal, and it can be seen how this is avoided by most of the positions of the frequency-hopped communication signal.

Up to 50 "hopping nets", each using a different hopping code, can be operated in the same hop band simultaneously – and possibly up to about 200 if they are not all working at the same time. Fixed frequency nets can also be operated in a hop band. The system can function with one third of the available channels occupied by other signals, such as fixed frequency, other hopping transmissions or jammers. Transceivers are controlled by a keyboard (see photo) and three rotary switches. The keyboard is used for changing the mode of operation, for entering codes and for checking. Day-to-day operation requires the use of only two of the rotary switches. Transmission modes are: F3 simplex, voice, analogue information, and digital data at rates up to 16kbit/s. To protect certain frequencies in the hop band, or to avoid strong signals, up to 16 frequencies may be barred from the hopping sequence in any hop band. Racal say that the price of their frequency hopping radio set is about 20% higher than that of a conventional military transceiver.



Spectrum analyser display shows a frequency hopping signal (small peaks) spread out over a 6.4MHz hop band. The large amplitude signal in the middle is from a jammer.

A 50-watt vehicle station. The central unit, with the keyboard, is the transceiver (output 10mW or 4W) which is common to both the vehicle station and the manpack version.

Long distance digital music

Casually switching on my tuner to Radio 3 around lunchtime on the 17th May, I heard a superb performance of a Vaughan Williams symphony. Consulting the *Radio Times*, I discovered that the music was coming live from *Shanghai* as part of a tour made by the BBC Symphony Orchestra. The second half of the concert consisted of Beethoven's Fifth Symphony, and as an encore, the orchestra played a rip-roaring bravura Chinese piece called 'How the good news was brought from Peking to the villages'. All through the concert one was aware that the quality of the transmission was superb and it astonished me to realise that it was coming from the other side of the world.

On checking with the BBC, I learned that they had used for the first time NICAM-3 (Near Instantaneously Companded Audio Multiplex) which converts the stereo signals to digital form and then compressses them so that up to three stereo pairs may be sent over conventional 2048kbits digital telephone systems. The signal was encoded at Shanghai, sent through a radio link to Peking, transmitted again via the geostationary Intelsat over the Indian Ocean, received at the British Telecom station at Madley, sent through 'conventional' circuits to the BBC where it was decoded and retransmitted to us. It took about a quarter of a second for sound made in China to reach our ears at home in the U.K.

Should we buy Dutch radar?

Although the value of the defence industry may be questioned in its ability to actually defend us against any potential enemies, one thing in its favour is that it provides work for the manufacturers of defence equipment. All the more puzzling then is the proposal by the MoD to purchase missile tracking radar from the Netherlands. The radar would be used in place of the Marconi GWS25 Seawolf tracker. The MoD seems to be willing to accept a degraded performance and a lower environmental standard in exchange for lighter weight.

Marconi Radar Systems are, understandably, upset about this; the Seawolf has been in use with the Royal Navy and is in full-scale production. Over the past 35 years they have built up an expertise in tracking systems and have been working to enhance the performance of the system against low level missiles.

Marconi have proposed a series of modifications to make the Seawolf lighter while retaining the performance improvements at a comparable price. They point out that such equipment would also have considerable export potential, but if the Navy's decision goes against them there would follow the destruction of the design team and loss of employment in various factories.

TV direct by satellite

It seems that we are going to need to learn another set of initials to denote yet another medium for telecommunications. This one is DBS, for direct broadcasting by satellite. The Home Office has issued a report on the options available and a possible strategy for instituting a system.

Under a plan drawn up by the International Telecommunications Union (ITU) in 1977, the UK has been allocated five DBS channels which could be beamed towards the UK from a geostationary satellite of 31°west. Each channel would be capable of providing one tv service or a number of radio services with national coverage. Reception could be by individual households, in which case an antenna and the appropriate converter would cost around £150 to £200; alternatively there could be a community receiving station, distributed to households by cable.

Various satellite systems are discussed in the document and their likely cost. For instance, a two channel system using ESA's European Communications Satellite would cost about £15m per channel per year over a ten-year period; a five-channel system broadcast via the L-Sat, ESA's large satellite would cost about £10.5m per channel. Cost could be reduced by starting with a pre-operational system with a spare satellite held for launching, though if there were a breakdown in the operational satellite, there would be no service until the replacement was launched.

Also discussed at length is the content and quality of any proposed DBS service. With a worldwide reputation or the high quality of our domestic tv services and any new service should maintain that standard. Competition for the sake of audience figures can lead to a reduction in the range and quality of programmes available to the public. With the introduction of the fourth tv channel in the UK and the pilot cable services recently announced, there could be many channels available to the public. Another possibility is the extension of cable tv to a national service to provide broadcast programmes and other telecommunications services to the home. Bearing all this in mind, the report suggests that a modest start would be preferable, with perhaps only two channels.

The report goes on to discuss some of the programme options. The BBC has proposed that it should provide television programme services on two channels, one would be a subscription films, and other BBC special productions, opera, drama, music and extended coverage of sporting events; all these would be to run in the normal schedules. This service would not be financed from the net revenue of the tv licence fees. The second BBC DBS channel would be used for a service of retransmissions of 'the best of BBC-1 and BBC-2' especially for those who are unable to view the programmes at the time of the original transmission. Another proposal for a subscription channel has come from the Granada group to consist principally of recent feature films. The Open University has proposed that priority should be given to an educational channel and this idea has been supported by a number of other organisations. Teletext and information services are also mentioned.

As regards the kinds of DBS serves that might be provided, the general consensus seems to be for a 625-line standard tv signal with the possibility of adding additional sound channels for stereo, sound tracks in different languages or separate radio services.

Financing such a service poses major problems and it is suggested that it may be operated by a separate body acting as a common carrier which leased the individual channels to the broadcasting bodies. The establishment of the system would require considerable initial capital outlay, and there is the continuing running cost. Licensing and subscription and advertising revenues are some of the possible sources.

Finally there are environmental aspects of DBS to be discussed. The receiving antennae are likely to have some visual impact on our skylines although a dish as small as 40 to 50cm in diameter might be possible under favourable conditions. A community reception centre with cable distribution to the individual household might be preferable. For transmission to the satellite only one transmission station would be needed compared with the 1,000 or so, currently in use for the terrestial service.

Component supplies

It is annoying to need a particular component and not to be able to find a supplier. We have received two catalogues from new suppliers and any new source is always welcome. Anglia Components originally started as a supplier of spare parts to retail radio and tv repair shops they have now expanded into a general component and tools supplier and still have some emphas (a whole separate section) on tv replacement parts. They have insalled a computer and offer to deliver all catalogued items by return of first class post. They can cater for low and high volume orders and can offer regular deliveries to high volume users. The newest issue of the catalogue describes in its 110 pages resistors, capacitors, semiconductors and industrial integrated circuits, opto-electronics, electromechanical components, tools, test equipment and linear i.cs. The catalogue is available from Anglia Components, Burdett Road, Wisbech, Cambs PE13 2PS.

Another catalogue, from M.S. Components, also emphasises that all catalogued parts are dispatched on the day that the order is received. The catalogue is of a similar size to that from Anglia; it contains some 2,500 separate items and it is promised that there will be a new edition soon which will be increased to over 3,000 items. Among the many products one particular service worthy of note is a transformer prototyping service. M.S. can supply, within 48 hours, transformers within the range 3 to 50VA with the secondary voltage and current specified by the customer, with a set price for each transformer of £5.99. Another notable point is that M.S. encourage the amateur constructor. You do not need to be an account holder and can buy components over the counter on a Saturday morning, if you can get to M.S. Components, Zephyr House, Waring Street, West Norwood, London SE27 9LH.

EBU proposes a world digital television standard

Western European broadcasters, through their organization the European Broadcasting Union, have proposed a set of parameters as a digital television standard for studio equipment. They hope it will be adopted throughout the world. It will in fact be submitted to the final meeting of CCIR study groups on this subject due to be held in September this year in Geneva. The need for such a standard has arisen because more and more television studio equipment is going digital and compatibility between different units is desirable. The EBU says that an agreed world standard would "mean less expensive equipment, because of the economies of scale, and benefit international programme exchange. It would have important financial advantages for users and manufacturers, lead to improvements in the technical quality of programmes shown in a country with a different television system from the originating country, and assist the international exchange of technical information on television production".

The EBU standard is based on coding of the separate components of the colour tv signal rather than the other possible approach, coding of the composite PAL, SECAM or NTSC colour signal. (Both of these methods have been studied by broadcasters for several years.) In the EBU proposal the luminance signal component is sampled at a frequency of 13.5MHz and the two colour-difference signal are each sampled at 6.75MHz. Thus the standard is called "13.5: 6.75: 6.75" in shortened form. The EBU hopes these parameters will be applicable to both 525-line and 625-line television systems and hence that the number of samples per television line will then be very similar. Because of the different field rates, of course, the number of samples per picture will be different.

The need for a worldwide standard in this field was the subject of a recommendation by all the unions at the 3rd World Conference of Broadcasting Unions held in Tokyo in 1980. In the USA the SMPTE has been studying the problem for some years, and the EBU has coordinated its work with the investigations of this society. There are now indications of support for the EBU proposal from several of the broadcasting unions. For example, the Organizacion de la Television Iberoamericana (OTI) has already given its support and this is particularly significant because both 525-line and 625-line countries exist in the OTI area. Encouraging reactions are also said to have come from the North American National Broadcasters Association and the Union of National Radio and Television Organizations of Africa.

● Another digital standard soon to be established in the field of television is for viewdata terminals – but in Europe only. Its purpose is to standardize television sets as far as public viewdata is concerned so that a common set of integrated circuits can be used with any of the different viewdata systems, such as Prestel in the UK, Bildschirmtext in West Germany and Teletel in France. At the time of writing the standard is expected to be ratified in June by the central organization of the European telecommunication authorities, the Conférence Européenne des Postes et des Télécommunications (CEPT) at Bern.

Technologists detained in USSR

Two professional workers in the field of electronics have been arrested in the USSR after unsuccessful attempts to obtain exit visas to enable them to emigrate from the country. Both are Jews. Kim Fridman, an electronics engineer, was head of the test department in the Kiev Radio Works. Viktor Brailovsky, a computer scientist, was a senior research fellow in the Insitute of Electronic Control Machines, Moscow.

Both men appear to have run foul of the Soviet authorities by holding cultural and scientific seminars in their homes, in spite of the fact that these meetings were conducted on strictly legal lines and had no political content. Kim Fridman's wife Henrietta, who visited these offices recently, told us it is common practice for "Refuseniks"* to hold such seminars, mainly to continue their scientific education and keep their professional knowledge up to date. The charge against Fridman is "parasitism"; that against Brailovsky "defaming the Soviet state and public order".

Kim Fridman voluntarily left his job in October 1969 in anticipation of a three-year wait before he would be allowed to submit his application to emigrate. The official reason for refusing him permission to leave the USSR is "secrecy" – presumably it was considered he had knowledge of Soviet radio technology which might be useful to an enemy of the state. Considering the date he left his job, *Wireless World* has expressed scepticism on the validity of this reason, which seems more like an excuse; and on the strength of our view the UK Foreign Office is arranging to have the Fridman case heard at the Madrid conference. Up to the time of his arrest in March 1981, Kim Fridman had been doing temporary, unskilled work but had been finding it more and more difficult to obtain employment.

Viktor Brailovsky asked for an exit visa in 1972. This was refused in 1973 and shortly afterwards he was dismissed from his post at the Institute of Electronic Control Machines. It is thought that his arrest, in December 1980, resulted from his editing of a cultural journal "Jews in the USSR", but the charge of defaming the Soviet state appears to be contrived because the journal, which ceased publication in June 1979, was not political. After his arrest, other scientists tried to go to his home for further seminars, at the invitation of his wife Irina, also a computer scientist, but were turned away by KGB officers. Some time in 1981 the IEEE expects to publish a paper by Brailovsky in their *Transactions on Pattern Analysis and Machine Intelligence*.

All professional workers in electronics will be distressed to hear of the way these colleagues in the USSR are being treated by the authorities and will hope for success in the efforts currently being made to help them.

*"Refuseniks" are Soviet Jews who, having been consistently refused permission to emigrate to Israel, are harassed by the KGB, usually dismissed from their work, and live in fear of arrest and trumped-up charges resulting in imprisonment.

New satellite earth station

British Telecom are to build a new satellite communications earth station in Wiltshire. An 87-acre site at Stert, near Devizes, has been purchased, and the first dish aerial is expected to be operating by early 1986. About six aerials should be working on the site by 1990. This is BT's third satellite tracking station, and has become necessary because capacity of Goonhilly Downs and Madley is limited. There will soon be further Intelsat satellites placed into geostationary orbits. Apart from these, Inmarsat, the international maritime satellite communication system, which the new station will also serve, is expected to grow rapidly in the next few years, becoming operational in early 1982.

At the time of writing Intelsat V-B, the second of a new series of nine international communications satellites, was scheduled to be launched on May 21 from Cape Canaveral. Like its predecessor, Intelsat V-B weighs 1,928 kg and has almost double the communications capability of early satellites in the Intelsat series – 12,000 voice circuits and two colour television channels. It will be positioned in geosynchronous orbit over the Atlantic Ocean as the main satellite to provide communications services between the Americas, Europe, the Middle East and Africa.

Dennis Baker has been awarded the Martlesham Medal for 1981. Given by British Telecom to present or former members of its staff, the medal is awarded for 'outstanding achievement in telecommunications science and engineering.' Mr Baker was responsible for introducing silicon transistors into submarine cable repeaters. He developed a system for bonding the extremely thin wires used in transistors onto the silicon chip. The repeater amplifiers used may be at depths of three miles with pressures of up to three tonnes per square inch. They need to have a guaranteed life of 25 years. The transistors developed by Mr Baker and his team have been in use in cables all round the world without failure for the past ten years. Mr Baker is also involved with integrated circuits and computer logic. He leads the team which is credited with coining the word 'microprocessor, and is currently working on small geometry circuits for the System X telephone exchanges, and on computer-aided design for large-scale integrated circuits. He is shown here holding microphotographs of the metal-to-silicon bonds used in the submarine amplifier transistors.

The twins paradox of relativity

A composite reply to correspondence arising from Professor Dingle's October article

from **Professor Ian McCausland**
Department of Electrial Engineering, University of Toronto

I am grateful for the opportunity to reply to various letters that have been sent to the Editor in response to Professor Herbert Dingle's article[1]. I shall start with Dr Tom Wilkie's letter (June issue), since it was in response to discussion with him that the article came to be written.

I am sorry if Dr Wilkie feels that he has been singled out in an undesirable way by Dingle's article. I understand that Dingle had planned to rewrite the article in more general terms, without specific reference to Dr Wilkie, but he did not live to do this. I did think of making such alterations myself, but I was reluctant to tamper with what Dingle had written.

Since Dr Wilkie describes his conviction that Dingle is wrong as being "unshakable", there is little that I can reply to him; but I would like to make some comments about his letter which may say something to others who may view the question as being still open.

In reply to Wilkie's comment that "most academic journals have for some years rightly viewed the matter as settled and regarded more discussion of it as a waste of paper", and his final plea to "let it rest", I would simply observe that he was the one who published the item entitled "The Twin Paradox revisited" in *Nature* in 1977, which led directly to the writing of Dingle's paper[1].

One of the interesting features of the responses to Herbert Dingle's criticisms of special relativity has been the variety of attempts to answer Dingle's question about the relative rates of the equatorial and polar clocks mentioned by Einstein in his original paper. Wilkie's answer is to say that it may be that there is an error or ambiguity in this example in Einstein's paper, and he later states that original papers may not be definitive because "second thoughts may change the author's mind". It is interesting to note that, in the very example mentioned, we do have Einstein's second thoughts available to us. If one studies that example in the generally-accepted English version of Einstein's first paper[2] (translated from the text in a German collection published in 1922), one finds a footnote which excludes the case of pendulum clocks, *but that footnote does not appear in the originally published version of the paper*. The later addition of the footnote seems to me to confirm that Einstein did mean exactly what he said, and also confirms that the statement about the slowing of the equatorial clock was intended to refer to a real slowing, not merely something that depended on the point of view of the observer.

According to Wilkie, Max Born answered in technical terms whose meanings were precise and well-defined. As an example of Born's precision, consider the following statement, referring to the special theory[3]: "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." Since the Lorentz transformation is contained in the special theory, but is not the whole theory, it is illogical to claim that any property of the Lorentz transformation is a sufficient condition for the whole theory to be free of logical contradiction.

With reference to Wilkie's statement that the language of relativity is geometry, not English or German, Dingle did not question the impeccability of the mathematics of special relativity. But the theory is based on postulates expressed in words, and the mathematics is not the whole theory; it was the theory as a whole that Dingle criticized, not its geometry.

I agree with Dr Wilkie that some of Dingle's critics have tripped themselves up by their use of words. However, this is not always because of the difficulty of expressing abstruse technical matters in words. Consider, for example, a case that I have documented elsewhere[4], in which, in *The Listener* in 1971, one scientist stated that the results of the Hafele-Keating experiment supported special relativity, and another stated that the experiment had no relevance whatever to the special theory. Now, a statement that the results of a certain experiment support a certain theory is a perfectly simple factual statement (however abstruse and technical may be the reasoning that led to that conclusion), and the same applies to the contrary statement. The fact that the two statements are contraries of one another (they cannot both be true, though they might both be false) shows that one or other of the scientists (or both) misunderstood either the theory or the experiment (or both). Or it might mean that there is a contradiction in the theory.

In the note mentioned above[4], I documented several other unsatisfactory statements that have been published by defenders of the theory. These cannot be dismissed as being merely poorly worded, since most of them were uttered by scientists who are prolific authors of books and who may therefore be reasonably expected to be able to write what they mean. I think we should keep in mind the words of the anonymous diplomat (quoted by Sir Bruce Fraser in his revision of Sir Ernest Gowers' *The Complete Plain Words*) who said: "What appears to be a sloppy or meaningless use of words may well be a completely correct use of words to express sloppy or meaningless idea."

Wilkie's paragraph about all the scientists who did not choose to seek fame by dethroning Einstein is very interesting, but totally devoid of scientific basis. The pursuit of scientific truth is not aided by statements such as: "That no young student over the last 20 years has seen the chance to make his name by developing Professor Dingle's ideas is eloquent testimony to the erroneousness of these ideas."

Several other letters were received by the Editor with varying degrees of relevance to the problem at hand. Before dealing with individual letters, examine the nature of the problem. According to Dingle[5] a paradox arises when, from the same premises P, two (or more) apparently contradictory conclusions X and Y seem inescapably to follow. It can be resolved only if one of the following four things can be shown: (1) the conclusions are not in fact contradictory; (2) conclusion X does not follow; (3) conclusion Y does not follow; (4) the premises P contain an internal contradiction.

Furthermore, if we start with a pair of contradictory premises, then, as Popper[6] has pointed out, we can infer any conclusion we like *using valid rules of inference*.

How does this apply to our problem? Suppose that we have a set of premises P, and suppose that one scientist (D) deduces from those premises a conclusion X, and that another (E) deduces from the same premises a conclusion Y, which is directly contradictory to X. Each scientist may believe that he has shown *by his own deduction* that the other's deduction is faulty, but in fact both deductions might be perfectly valid deductions from premises P which contain an internal contradiction. Furthermore, even if hundreds of supporters of E come forth, each with a different argument showing that Y does in fact follow from P, these do nothing whatever to show that D's deduction of X from P is faulty. To refute D's argument it is necessary to examine that argument itself and show that there is an error in it – in other words, to show that conclusion X does *not* follow from the premises P.

In reading the literature on the twin paradox, one finds many articles showing ingenuity, with varying degrees of originality, and picturesque detail, that asymmetrical ageing can be deduced from Einstein's theory. Many of these articles present the arguments in such a way as to imply that they refute the deduction of the opposite conclusion (symmetrical ageing), when in fact their results merely *contradict* the opposite result and, for the reasons discussed above, contradiction does not imply refutation unless it is first proved that the theory from which the contradictory results have been derived is itself free from contradiction.

For example, one of the correspondents, T. de Limelette, writes: "But I agree that the solutions to the paradox found in some texts are not all one could wish. I propose here my own. It is contained entirely within the special theory." I think it is clear from the foregoing that yet another presentation of the derivation of asymmetrical ageing, without showing what is wrong with the other argument, is not a solution to the problem that Dingle raised. T. de Limelette also comments on Dingle's article as follows: "I wonder where Professor Dingle picked up the strange idea that two different observable descriptions of the same events are not permissible. A description requires observers, apparatus and measurement procedures before it can be observed. These are not left unchanged by a change in the reference coordinate system. So why should the results of the measurements have to remain the same?" I am not quite sure that is the point of this comment, unless it is to suggest that the rather bizarre set of observations envisaged by Dingle are in fact feasible.

N. Thomas comes closer to dealing with Dingle's argument. The relevant paragraph of his letter is as follows:

> The situation according to Special Relativity is as follows (for instance, see Introduction to Relativity by L. Marder, Longmans 1968). According to Paul the outward and return journeys take 1½ days each, whilst according to Peter they take 15 years each. Thus Peter judges Paul's clock to be running slow by the factor 15x365/1.5 = 3650. According to Paul, Peter's clock runs slow by the same factor, and at the end of his outward journey Paul says that 35½ seconds have elapsed on Peter's clock whilst 1½ days have elapsed on his own clock. Now suppose that Peter had previously placed a stationary clock synchronized with his own at the point where Paul reverses his journey. Both Peter and Paul will say that this clock reads 15 years at the end of the outward journey, and this is how Peter assigns a duration of 15 years to the outward journey. However, be-

cause he is moving relative to Peter, Paul says that this additional clock is not synchronized with Peter's own clock but rather leads it by 15 years minus 35½ seconds: this is an example of the relativity of simultaneity. As soon as Paul reverses direction he judges that Peter's clock now leads the local clock (which reads 15 years) by 15 years minus 35½ seconds. Paul measures 1½ days on his own clock for the return journey (making a total of 3 days) whilst he judges that only a further 35½ seconds elapse on Peter's clock (making a total for the trip of 30 years). According to Paul, Peter's clock therefore races forward by 30 years minus 71 seconds during the reversal; as discussed by Einstein this can be explained using General Relativity. (Alternatively, since Paul changes inertial frames it can be attributed within Special Relativity to a change in his definition of simultaneity). Special Relativity does not therefore predict that Paul is rejuvenated at the beginning of the return journey, and Dingle's refutation of the theory on this basis is not valid.

It seems to me that his is not a satisfactory answer to Dingle's article. It should be recalled that Dingle was discussing Einstein's own resolution[7] of the twin paradox, and that this resolution required the use of general relativity. (Einstein's article[7] takes the form of a discussion between a relativist and a critic; the discussion of the paradox starts from special relativity but the critic asks for a resolution that satisfied the general theory, and it was that resolution that Dingle discussed in his article[1].) This seems to me to suggest that Dingle's argument must be met in terms of the general theory, not the special theory.

The other point to be noted about Einstein's resolution is that he agreed that it is perfectly valid to consider Paul to be fixed throughout the whole course of events, provided that the appropriate fields of force are invoked. This means that we could rephrase a passage in N. Thomas's letter as follows: "Now suppose that *Paul* had previously placed a stationary clock synchronized with his own at the point where *Peter* reverses his journey. Both Peter and Paul will say that this clock reads 15 years at the end of the outward journey, and this is how *Paul* assigns a duration of 15 years to the outward journey." (In case it may be argued that the fields of force associated with the initial parting of Peter and Paul might upset the synchronization of that clock, one can assume that Peter and Paul are moving uniformly relative to one another at the start of the process, so that no fields of force are needed at the original parting.)

W. James writes that "Dingle gives a wholly spurious symmetry to the problem by assuming that the Universe is empty but for the two clocks in his analysis (although in the statement of the problem he also refers to the earth.)" I can find no such assumption stated; in fact Dingle talks about the earth and a distant planet, whereas Einstein's statement of the same problem defines it wholly in terms of reference frames. Einstein's article[7] does not use *any* other objects except the travelling twins to resolve the paradox, except that later in his paper, when his supposed critic suggests that the gravitational fields are fictitious, he states that "all the stars in the firmament can be conceived as participating in the creation of the gravitation fields". I do not think that Dingle would have objected to this statement, and the fact that Dingle did not happen to mention all the stars in the firmament can scarcely be taken as equivalent to an assumption on his part that the universe is empty except for the two clocks.

W. James also states: "The clock paradox of special relativity is stated in McCausland's article 'if there are two clocks in *uniform* relative motion the special theory of relativity requires each clock to run faster than the other'. . . ". In fact my article[8] does not even mention the clock paradox, much less *state* it. In the relevant context I quoted a passage from Davies[9], and then suggested that passage provided strong support for Dingle's claim that "if there are two clocks in uniform relative motion, the special theory requires *each* clock to run (not merely *seem* to run) faster than the other." If the passage I quoted from Davies does *not* support that claim of Dingle's, then I think that someone should state clearly what it *does* mean.

I. M. Crann states that Dingle tacitly assumes some form of universal time, and that this assumption of "absolute" time guarantees that contradictory results will be obtained. I do not think that Dingle makes such an assumption, any more than Einstein did. Einstein stated quite clearly, in the passage Dingle quoted, that retardation of a clock during one phase of the experiment was over-compensated by faster working during another phase, and that a clock works faster if located at a point of higher gravitational potential. I think that Dingle merely followed Einstein's argument to its inevitable conclusion.

K. Burnett (May letters) asks "Am I the only reader of *Wireless World* with an interest in physics who finds the long series of articles on special relativity somewhat boring?" After making some interesting comments about theories of modern physics, he ends his letter by writing: "When a new more inclusive theory arises, which will embrace quantum mechanics and general relativity, I suspect that few 'anti-relativists' will like the result. But boring it won't be."

I do not know the grounds on which Burnett bases his suspicion that few anti-relativists would like such a result. There seems to me to be a suggestion here that those who criticize relativity are like Luddites longing for a retreat to pre-Einstein physics, whereas in fact they are trying to suggest that it is time for the scientific world to consider the possibility of moving on to post-Einstein physics.

Some correspondents, such as W. James, M.H. de la Rica, R. V. Harvey, and A. B. Starks-Field, present alternative resolutions, or partial resolutions, of the clock paradox. For the reasons given in my earlier comments, I believe that they do not meet Dingle's argument, because they do not identify a fault in his reasoning. M.M. Albahari (February letters) suggests a new experiment to test the validity of relativity by a test of the constancy of the velocity of light, using time intervals four orders of magnitude greater than those in the Michelson-Morley experiment. A.H. Winterflood states that Dingle is wrong in believing that the mathematics of special relativity is impeccable; he states that the mathematics of the theory is wrong, and refers to his recently-published book "Einstein's Error". Other correspondents, such as C.L. Thomson, W.T. Morris, J. de-Pière, F. Allen and J.A. MacHarg, contributed interesting comments and suggestions, and V. Halsall contributed a discussion relating to Dr Essen's article in *Wireless World* dated October 1979.

There is another letter which I think requires comment, namely a letter by J.H. Fremlin, which appeared in *New Scientist* last year[10]. Some of the comments below were made in a letter that I sent to the editor of *New Scientist* in October 1980, but to the best of my knowledge my letter has not been published.

Professor Fremlin stated that he would "like very much to refute the suggestion that opponents of the theory of relativity find it difficult to get a proper hearing". He might *like* to refute the suggestion, but his letter certainly does not do so. The only evidence he presents in support of his "refutation" is about things that were published, whereas the suggestion that he claims to refute is related to the fact that papers have been denied publication. There is no contradiction between the fact that some papers have been published and the fact that others have been denied publication. Unfortunately few people, except those who have direct experience, are aware of the difficulty of having *any* paper published if it is critical of relativity. Part of the problem is that almost all the evidence about papers that have been rejected is hidden from public view.

To take a specific example, Professor Dingle's paper[1] was rejected by another journal before his death. I have in my possession a copy of the relevant correspondence (which spanned a period of several months) between Dingle and the journal, but the journal has refused my request for permission to publish its part of the correspondence.

Professor Fremlin's letter also dealt with his own personal correspondence with Dingle, and his (Fremlin's) demonstration of the difference to be expected between the ages of the pair of twins in the twin paradox. Although it is difficult to comment on this without seeing all of the relevant correspondence, I suspect that Dingle considered the finding of an error in Fremlin's analysis to be a non-existent problem. He was convinced that the special theory contained an internal contradiction, and he knew that meant that it was possible, using valid rules of inference, to deduce from the theory any conclusion that one wished.

Dr Wilkie did not think it was wise to publish Professor Dingle's article, because Dingle is unable to defend himself. As I pointed out in my note accompanying the article, Professor Dingle sent the article to me in the hope that it would eventually be published. I am conscious of the inferiority of my qualifications as a defender of Herbert Dingle, but perhaps I amy excuse my attempts by quoting a sentence from his last book, *The Mind of Emily Bronte*: "To disinter from a mass of diverse writing a common substratum demands penetration of a far higher order, and the only ground on which I claim justification for attempting the task is the absence of competitors."

In fact there is a significant number of scientists dissatisfied with the special theory of relativity. Anyone who doubts this should read the August 1979 and October 1980 issues of the journal *Speculations in Science and Technology*. I happen to believe that Herbert Dingle was right in his thesis that the special theory is untenable, but I would not be so rash as to claim that I have an "unshakable conviction" on this. I am, however, firmly convinced that the problems raised by Professor Dingle have not been satisfactorily solved.

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7. Einstein, A. Dialog über Einwände gegen die Relativitätstheorie. *Naturwissenchaften*, vol.6, 1918, pp. 697–702.
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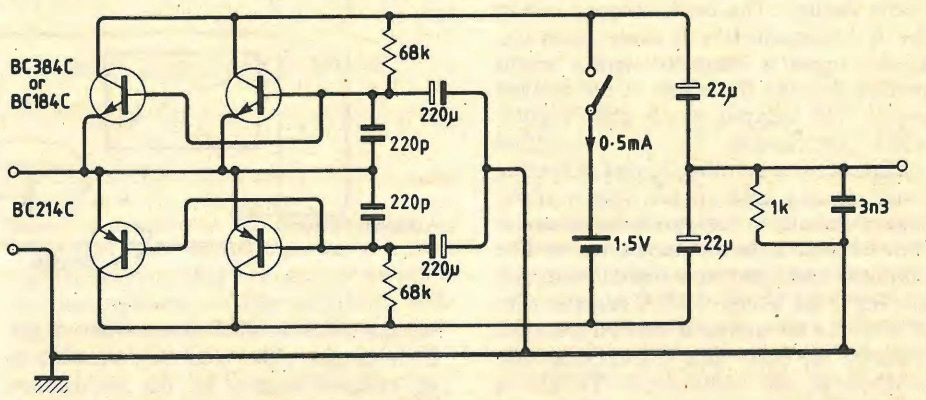
CIRCUIT IDEAS

Low noise moving-coil preamp



Noise performance of this design is about 3dB below many similar commercial units, and the high-frequency response is −1dB at 150kHz without the 3n3 output capacitor. The output clips at about 500mV and, below 150mV, distortion is caused solely by the push-pull input stage. Cartridges with high impedances will give lower distortion. High quality components must be used throughout and the circuit layout should be neat with no long connections. The circuit shown has been optimised for an Ortofon moving-coil cartridge, but other types should also be suitable.

Performance

Voltage gain	35dB
Input impedance	20Ω

Output harmonic distortion (mainly 3rd)

	3Ω	R_s	6Ω
400mV			0.32%
150mV	0.13%		0.1%
100mV	0.1%		0.056%
50mV	0.05%		

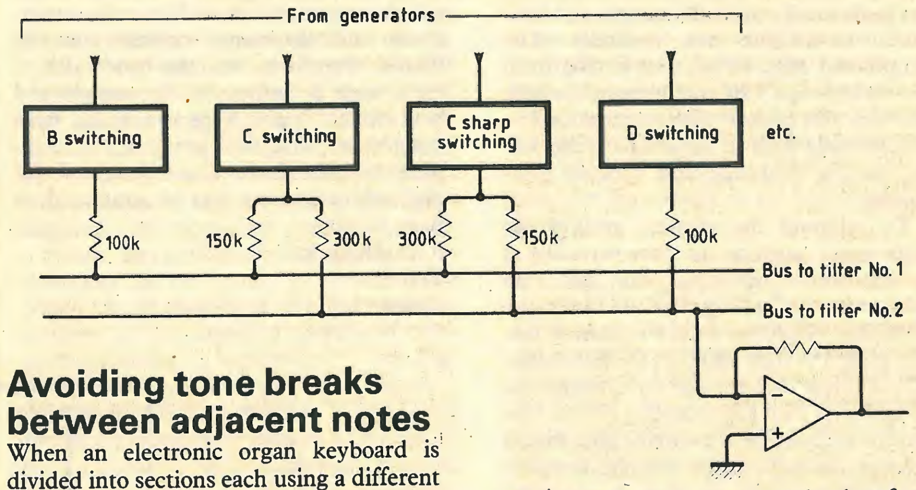
Noise (unweighted 10Hz to 15.7kHz) referred to input (includes hum)

o.c	74nV
s.c.	52nV 4 transistors as shown
	74nV 2 transistors only

Frequency response
−1dB at 15Hz
−3dB at 50kHz (see text)

R. Lee
Bradford

Avoiding tone breaks between adjacent notes



When an electronic organ keyboard is divided into sections each using a different filter, as described by Dr Pykett, there is a noticeable change in tone when a single-note step is made from one filter to the next. This can be overcome very effectively by grading the change. In the diagram, note B drives filter no. 1, note C drives 66% filter 1 and 33% filter 2, note C sharp drives 66% filter 2 and 33% filter 1, and note D drives only filter 2. The change from one filter to the next is therefore spread between four notes and the abrupt change of tone is eliminated. Mixing from the notes driving one filter should be at a low impedance input to avoid signals being fed back.

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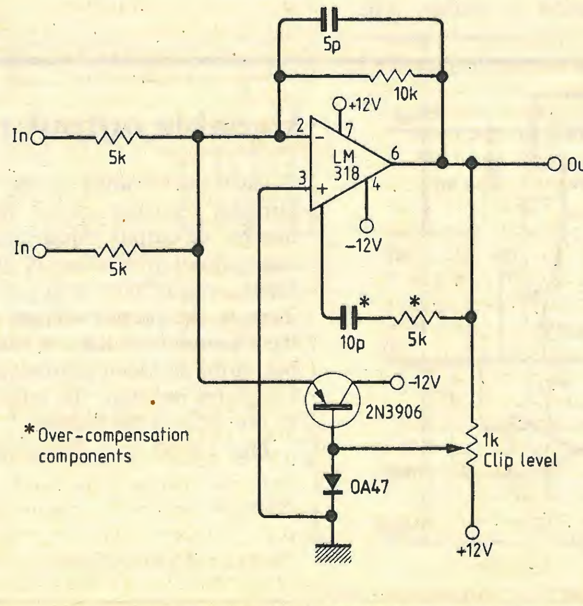
Wembley
Middx.

Video summing amplifier

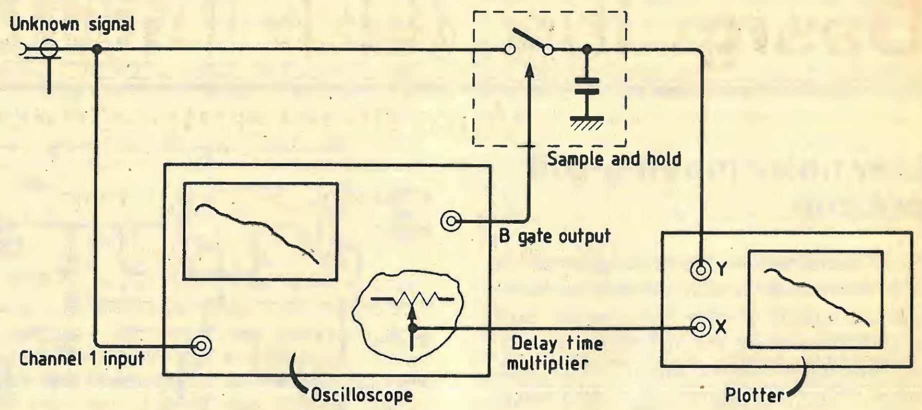
A simple video summing amplifier and limiter with an adequate bandwidth for modest c.c.tv applications can be built using one LM318 op-amp. Because a sharp cut-off is required, to avoid overloading the monitor, the emitter-base junction of a transistor is used as a limit sensing element. Emitter current is (β+1)×base current provided by the clip-level potentiometer, which reduces the limiting slope by the factor β.

The circuit can be assembled on Veroboard provided that tracks to the op-amp are kept short. It is recommended that the 10kΩ feedback resistor is mounted across the top of the i.c. and the 5pF capacitor mounted underneath the board. The LM318 can drive directly into a 75Ω load.

P. Newman
Glasgow



Plotting oscilloscope waveforms



This system enables a display to be plotted from an oscilloscope which has a delayed sweep facility. The oscilloscope is set in the A – intensified-by-B mode so an unknown signal is displayed with a bright portion showing the extent of the delayed sweep. The delayed sweep gate, a pulse which corresponds to the intensified portion of the waveform, is used to operate a sample and hold circuit whose output voltage is equal to the waveform voltage at the end of the delayed sweep interval. The output is measured by a digital voltmeter and fed to the Y axis of a X/Y recorder. An X drive for the plotter is derived from the wiper of the delay-time multiplier potentiometer in the oscilloscope. To plot a waveform, the potentiometer is rotated through its full range, which drives the pen horizontally while the sample and hold circuit drives the pen vertically. The sample and hold circuit can be fed from the oscilloscope ChI out terminal, which provides the plotter with vertical deflection features such as adjustable scale factor, ac/0/dc coupling, and variable positioning.

To calibrate the plotter, ground the scope input, position the trace vertically at an appropriate reference point and scan horizontally using the delay-time multiplier control to write a reference line. The plotter is then adjusted for full deflection, i.e. one inch for one c.r.t. horizontal division. As with any sampling system, the waveform must be repetitive, and trigger jitter on the oscilloscope will blur the plotter waveform.

This arrangement can form the basis of a powerful computer controlled waveform acquisition system. In this case, the position of the B gate pulse is set by a control voltage from the computer.

As the waveform samples are digitized by the computer, the control voltage is increased and the sampling position is scanned across the waveform. Although this is a slow data acquisition system, the progress of digitization is visible. The voltage which controls the position of the B sweep gate pulse must be derived from an external source, so the oscilloscope needs to be slightly modified.

The computer can determine many waveform parameters such as peak, mean, r.m.s. and harmonic content via the Fourier transform, but the bandwidth of the system is limited by the sample and hold circuit. A prototype system has been constructed using two ports in a PET computer to control the converters, and the digitization process was programmed in Basic.

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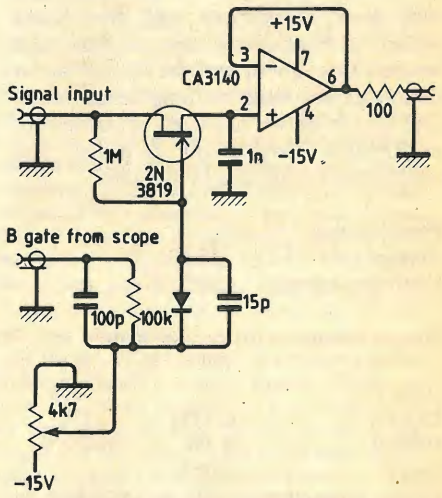
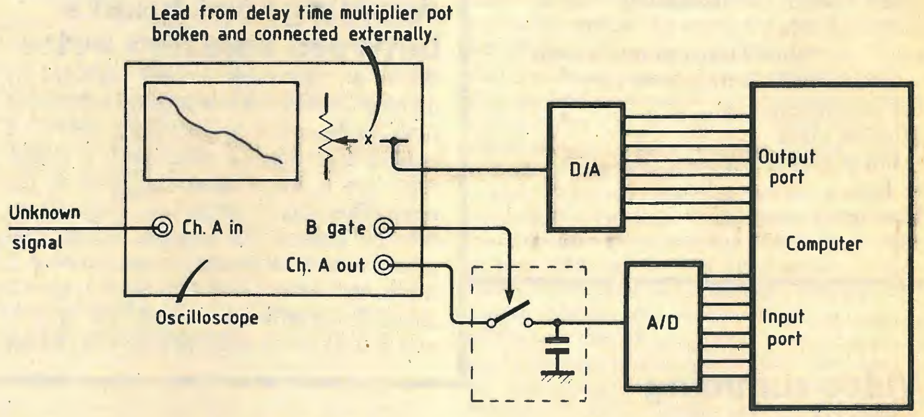
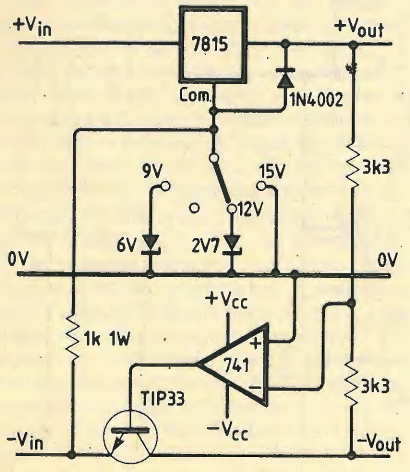




Variable output regulator



A small modification to the normal three terminal regulator circuit will provide a number of output voltages and retain the short-circuit protection of the regulator. Many designs have been published which increase the output voltage by returning the common terminal to a positive pedestal but, if the common terminal is returned to a negative pedestal, the output is reduced by the value of the pedestal.

This circuit uses Zener diodes to provide switched outputs below 15V, however, the diodes could be replaced by an adjustable low power regulator. A 1N4002 protects the regulator from reverse voltage if the output is shorted. Dual supplies can be provided by adding the op-amp and transistor shown, but the negative rail is not protected.

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Designing with microprocessors

9 – More on interrupt-driven circuits

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Procedures for the step-by-step design and implementation of interfaces in interrupt-driven microprocessor-based systems are described in this article. The authors show that the interface hardware is the same for both vectored and non-vectored interrupts, and that it is almost independent of the microprocessor chip used. Fully-worked out examples, using the Intel 8080 and the Motorola 6800 chips are used to demonstrate these statements.

As explained in the first article on this subject (June issue), interrupt-driven circuits are used when sensitivity to the environment is needed. This would be the case with equipment and/or processes which, when they malfunction, require fast corrective action to avoid catastrophies that may result in damaging equipment, shutting down systems and so on.

The concepts we used to develop such systems are straightforward, involving basically the equipment or the process signalling the micro-processor when it wishes to communicate with it, and waiting for the microprocessor to respond. This resulted in the development of an uncomplicated interrupt configuration, whose block diagram is shown in Fig. 7 in the June article. For ease of reference this diagram is reproduced here as Fig. 1.

The function of the interrupt controller in Fig. 1 is to generate the interrupt request signal, IRQ, when one or more flags are present, and to provide the microprocessor, when it responds to the interrupt request, with some meaningful information which allows it to vector to the appropriate service routine. The meaningful information is denoted variable i. The design and implementation of interrupt controllers and a review of support chips implementing their function will be considered in a later article.

Interface hardware

Although at first sight the design and implementation of the interface hardware might appear complex (particularly to the uninitiated), in practice it turns out to be a straightforward process, as we shall demonstrate next. Our starting point is Fig. 1, which clearly indicates that the interface hardware is a logic circuit whose function is to monitor the status signals of the peripheral (which may be either equipment or a process) and generate flag f_n when the status signals indicate to it that the peripheral wishes to communicate with the microprocessor. The interface then simply waits for the microprocessor to respond electronically.

Note that the flag simply requests a response from the microprocessor, which may well be ignored, if masked by the programmer. To avoid blocking microprocessor responses to emergencies, an interrupt pin, which cannot be disabled by software, is also provided in most cases. The interrupt signal using this pin is referred to as a **non-maskable interrupt,** to discriminate it from **maskable interrupts,** which represent requests rather than commands for microprocessor responses.

When the microprocessor responds, it generates the electronic 'go ahead' signal which, as explained in the June article, consists of i/o signal(s) associated with predetermined i/o address(es) – see Fig. 1. The nature of the 'go ahead' signal is described in detail in article 5, published in the October 1980 issue. On receipt of the i/o signal(s), the interface generates the command signals that drive the peripheral. In order to prevent the flag from continuously interrupting the microprocessor, the interface must clear the flag.

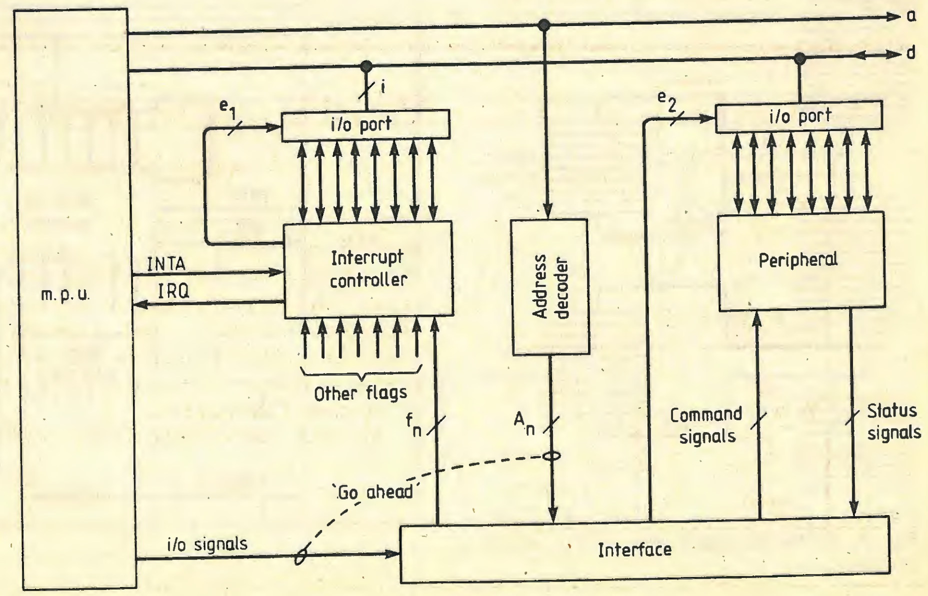
Since the interrupt controller does not send a signal back to the interface, it follows that interrupt interfaces are independent of the nature of the interrupt controllers. *That is, the interface hardware in interrupt systems depends only on the peripheral and not on whether vectored or non-vectored interrupts are being used. Furthermore, because the microprocessor response consists of i/o signals, whose nature does not vary greatly from microprocessor to microprocessor, the interface hardware is almost identical for all types of microprocessors.*

Interrupt interfaces, in common with all other interfaces, are designed and implemented using well-established procedures that always work[1]. We shall demonstrate the simplicity of the design procedures and lack of complexity of their implementation by means of a design problem, after we describe the nature of the interrupt software.

Interface software

As in the case of the interface hardware, the interrupt software is relatively uncomplicated and should present no difficulty to the reader who possesses some knowledge of programming. In the author's experience, the primary cause of misoperation in practice is lack of proper initialization procedures, which results in unwanted signal spikes (glitches) that are generated on interrupt lines during hardware and/or software initialization of interrupt in-

Fig. 1. Basic configuration of an interrupt system (a repeat of Fig. 7 in the June issue).



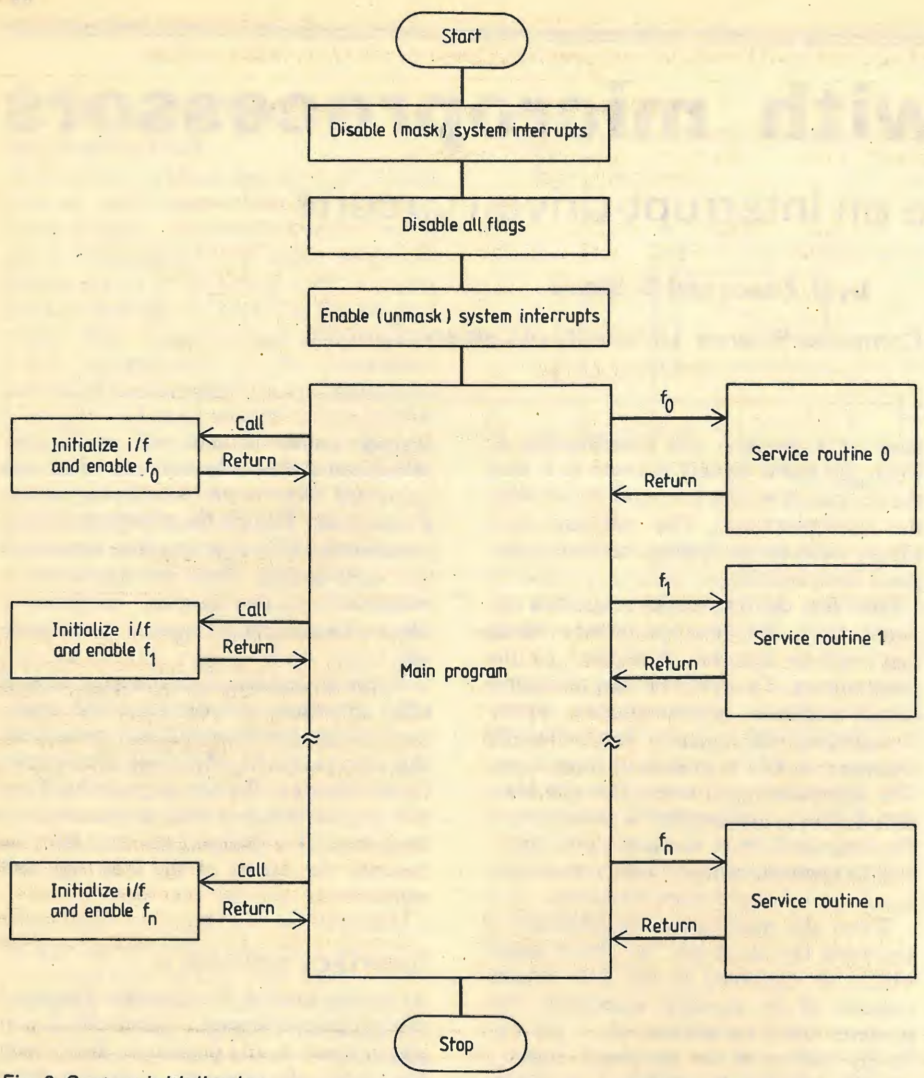


Fig. 2. System initialization.

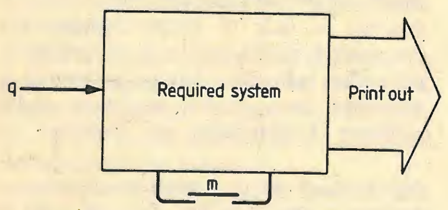


Fig. 3. Block diagram of the event counter.

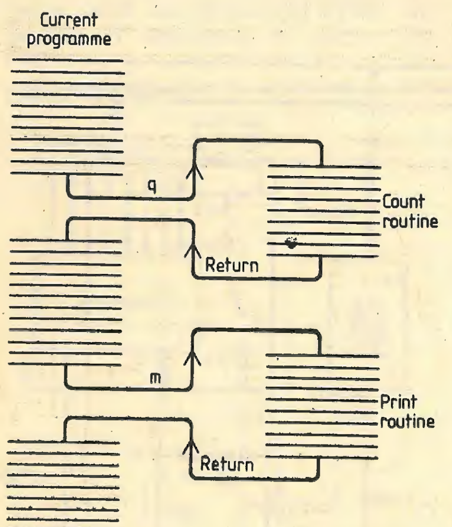


Fig. 4. Software responses of the event counter.

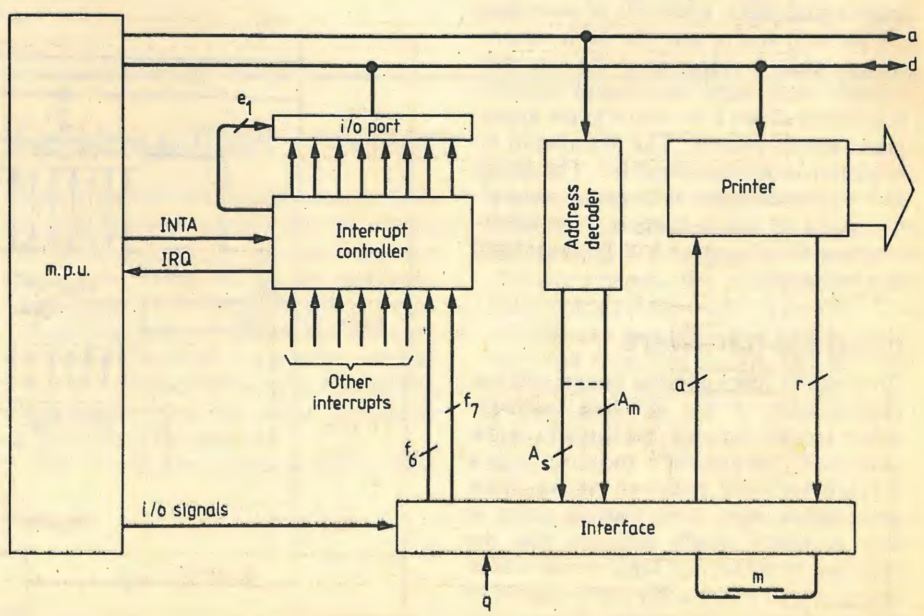


Fig. 5. Block diagram of our solution of the event counter.

terfaces. **An initialization procedure** that avoids this problem is flowcharted in Fig. 2. As an additional precaution, all interfaces that are not being used should be disabled.

We mentioned earlier that during a program interruption, the re-entry point, consisting of

1. The return address;
2. The condition flags, and;
3. The working registers;

must be preserved during program interruption. In practice this information is stored in **stack,** which is a block of consecutive locations in r.a.m. that can be accessed from one end on a last-in-first-out (lifo) basis. A stack is established in r.a.m. by loading a **base address** into the stack pointer. Every time a new item is put on stack the stack pointer is 'advanced' (decremented) and everytime an item is removed the stack pointer is 'retarded' (incremented)[2]. This means that the base address points to the highest location in stack.

PUSH, POP and RETURN instructions, explained earlier, refer to explicit operations in which information is transferred between the microprocessor chip and locations in stack specified by the stack pointer.

In summary, for the purpose of writing the interface software the only system feature that one has to know, is the vectoring address associated with each of the interrupt flags one is generating.

We shall now give an example to demonstrate the steps used to design and implement interrupt-driven microprocessor systems.

Design example – an event counter

Pulses representing events arrive randomly on line q in Fig. 3. Our problem is to design an interrupt-driven system that would allow a print-out of the event-count to be produced each time switch m is activated. Activation of the switch, which can be assumed to be infrequent, resets the count.

Table 1: Mnemonic and hex listings of the count and print routines used in the event counter

INTEL 8080 Mnemonics Code	Operands	Machine code Opcode	Operands	MOTOROLA 6800 Mnemonics Code	Operands	Machine code Opcode	Operands	COMMENTS
		COUNT ROUTINE				COUNT ROUTINE		
PUSH	PSW	F5						Save program status
INR	C	0C		INC	COUNT	7C	06 50	Increment count
OUT	62	D3	62	STA	A F002	B7	F0 02	Clear count flag
POP	PSW	F1						Restore program status
EI		FB		CLI		0E		Enable interrupts
RET		C9		RTI		3B		Return to interrupted program
		PRINT ROUTINE				PRINT ROUTINE		
PUSH	PSW	F5						Save program status
MOV	A C	79		LDA	A COUNT	B6	06 50	Copy word count into A
OUT	63	D3	63	STA	A F003	B7	F0 03	Print and clear flag
MVI	C 00	0E	00	CLR	COUNT	7F	06 50	Clear count
POP	PSW	F1						Restore program status
EI		FB		CLI		0E		Enable interrupts
RET		C9		RTI		3B		Return to interrupted program

We will implement the design using an action/status printer, and either the Intel 8080 or the Motorola 6800.

Solution

Step 1: aim of the design. To demonstrate the steps used in designing and implementing interrupt interfaces.

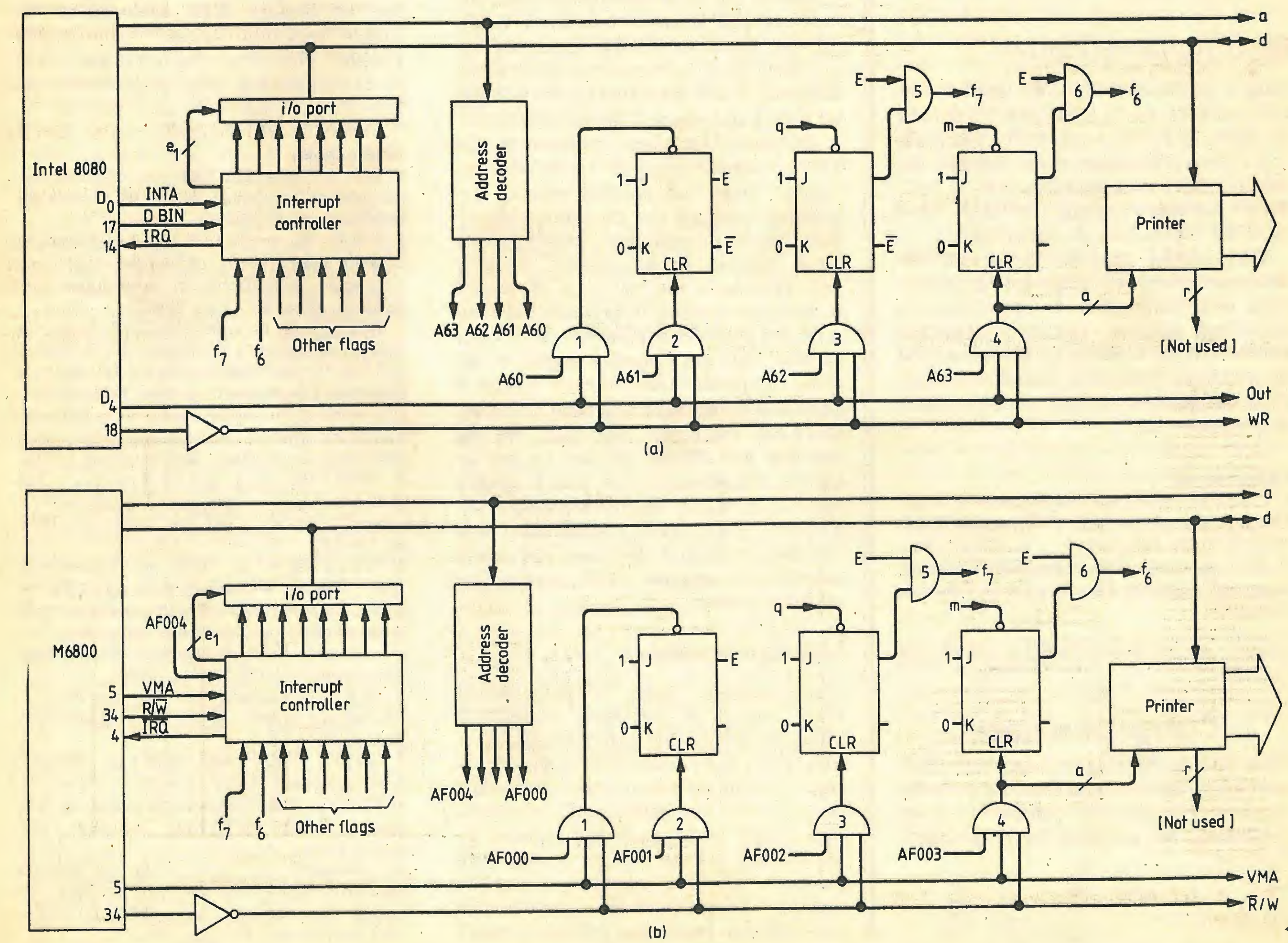
Step 2: resources. A microprocessor-based system and an action/status character printer.

Step 3: our solution. Our solution consists of evoking a COUNT routine when an event is detected, and a PRINT routine each time switch m is activated, as shown in Fig. 4. The COUNT routine will be given a higher priority than the PRINT routine should signals q and m be both present before the program is interrupted. The block diagram of our solution is shown in Fig. 5.

8080 implementation

Step 4: hardware design. Reference to Fig. 5 shows that the basic functions of the interface hardware is to generate interrupt flag f_6 when switch m is activated and signal f_7 when a pulse is received on terminal q, and allow them to be cleared under program control. The most straightforward method of implementing these two functions is to use two JK flip-flops, as

Fig. 6. (a) Interface hardware of the event counter problem using the Intel 8080 microprocessor; (b) interface hardware of the event counter using the Motorola 6800. Note that the two interfaces are almost identical.



shown in Fig. 6(a). Switch *m* is connected directly to the clock terminal of flip-flop 6, allowing it to be set each time switch *m* is pushed and released. Similarly the output of the sensor is connected directly to the clock terminal of flip-flop 7, which also allows it to set each time the sensor generates a pulse.

We can allow the programmer to reset the two flip-flops by simply routing software-generated i/o pulses to their clear terminal. For this purpose, we can use two AND gates, 3 and 4, as shown in Fig. 6(a). The i/o addresses 63 and 62 are used for this purpose. That is, flip-flop 6 is reset by executing an OUT instruction with address 63 and flip-flop 7 by executing also an OUT instruction with address 62.

To allow the programmer to enable or disable the interface, we can introduce a third JK flip-flop which is set by executing an OUT instruction with address 60, and reset by executing an OUT instruction with address 61, as shown in Fig. 6(a). We use the output E of this flip-flop to AND flags f_6 and f_7.

The final function of the interface is to activate the printer. We can either use a separate OUT instruction for this purpose or simply connect the output of gate 4 to the action terminal of the printer. This causes execution of OUT 63 both to clear f_6 and activate the printer at the same time. This, in addition to saving an extra gate, also avoids using an extra i/o instruction.

Step 5: software design. The COUNT and PRINT routines are shown in Table 1.

6800 implementation

Step 4: hardware design. We use the same procedures to derive the interface hardware of the Motorola 6800. The reader's attention is drawn to the fact that the two interfaces are almost identical.

Step 5: software design. The PRINT and COUNT routines are shown in Table 1.

Well-defined steps for the design and implementation of interrupt interfaces have been demonstrated. Specifically, it has been shown that the interface hardware is the same for both vectored and non-vectored interrupts and that it is almost independent of the microprocessor chip used.

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The next article in the series will deal with interrupt controllers.

Correction note

Data store by running average, May 1981, contained three incorrect hex bytes in the machine-code list. The correct values are underlined. We apologise for these errors.

Address		
02E4	B5 (underlined)	28
036D	B0	E5 (underlined)
03D0	A6 (underlined)	26

Which way h.f. broadcast receivers

continued from page 67

The prescaler and prom devices used in the first system approach design are quite expensive at present. A 'direct entry without calculation' method could be used to replace the prom devices, but the cost reduction would be balanced out by adding twelve different crystal oscillators due to the fact that no simple arithmetic relation exists among the shortwave broadcasting bands. An alternative approach is, however, to ask whether a rearranged frequency allocation plan could end up with a cheaper system design. Fig. 2 shows the system functional block diagram. The suggested frequency allocation proposal is listed in Table 3. The amount of spectrum allocated is the same; but the band edge starting frequencies are slightly offset from the current and proposed WARC frequencies.

TABLE 3. Suggested proposal

rf (MHz)	osc (MHz)	offset (MHz)
3.900 to 4.390	48.900 to 49.390	48.895
4.600 to 4.945	49.600 to 49.945	48.895 + 0.700
4.950 to 5.440	49.950 to 50.440	48.895 + 1.050
6.000 to 6.490	51.000 to 51.490	48.895 + 2.100
8.100 to 8.590	53.100 to 53.590	48.895 + 4.200
10.200 to 10.690	55.200 to 55.690	48.895 + 6.300
12.300 to 12.790	57.300 to 57.790	48.895 + 8.400
14.400 to 14.890	59.400 to 59.890	48.895 + 10.500
16.500 to 16.990	61.500 to 61.990	48.895 + 12.600
20.700 to 21.190	65.700 to 66.190	48.895 + 16.800
24.900 to 25.390	69.900 to 70.390	48.895 + 21.000

Prior to the programmable divider, the v.c.o. output is converted down twice, first by a fixed 48.895MHz frequency signal, then by a correspondent band offset frequency signal generated from a one signal source and selected through multiplier or dividers. After these conversions, the v.c.o. frequency is equal to the channel number times and channel spacing frequency; therefore the programmable divider can be programmed directly by the b.c.d. number in the channel memory unit. Because of the low v.c.o. frequency at the input terminal of programmable divider, no prescaler is required. After comparison with the reference signal in the phase comparator unit, an error voltage is generated through the loop filter to correct the v.c.o. frequency. The fact that the prescaler and PROM devices are not required, the whole system cost is greatly reduced *because of the frequency allocation*. The r.f., i.f. signal amplification and selection, sideband detection and audio amplification are the same as the first system approach.

Microprocessors

Microprocessors have invaded almost every branch of electronic technology which includes radio communications as well. There is no doubt about some advantages of using microprocessors in product design, such as: "intelligent" products, easy design modification and reduced assembly and testing cost, is a long-term prospect. To see whether a popular shortwave broadcast receiver could benefit from this new technology or not, we check the necessity of using microprocessors against the basic requirement of the majority shortwave broadcast listeners.

(1) Easy operating: microprocessors could be used to replace Ch/Band switching unit, memory unit and prom unit.

(2) Good performance: no improvement after using microprocessors unless a sophisticated self-adaptive receiver[6] design is implemented.

(3) Low cost: one of the disadvantages of using microprocessors is the requirement of reinvestment for new tools and resources and possible re-training in production engineering. Although the unit cost of the microprocessor is low, the overall unit receiver cost could be the same as when a specially developed l.s.i. device is produced for a large number receiver market[9].

Today, due to the advanced integration technique, most parts of the system block diagram could be integrated as a few l.s.i. modules, and consequently the assembly and testing cost could also be reduced. Therefore, unless a multi-functional receiver is demanded[6,7], we do not see a desire to use microprocessors in popular shortwave broadcast receiver design.

Conclusion

Two system approaches have been described for a popular shortwave broadcast receiver design. Both demonstrate the simple "tuning by channel" operating philosophy. They also bring out realization of an easy-operating, good performance and low-cost shortwave broadcast receiver.

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Electrical and mechanical units – are they the same?

by **D. A. Bell**, F.Inst.P., F.I.E.E.

SI units, with L,M,T,Q dimensions, provide a single consistent set for both mechanical and electrical applications. The presence of the Q dimension distinguishes electrical from purely mechanical phenomena.

"Units of the world unite: you have nothing to lose but your dimensions!" If scientists used slogans as politicians do, this might have been the call for the introduction of SI (Système International) units which unify electrical and mechanical units. As far as electrical units are concerned, they appear to involve little change from MKS units, though there is a change in the status of those odd but essential constants, ϵ_0 and μ_0. The change is more drastic in mechanical units, which might be said to have been brought into line with electrical practice. In particular, it is now recognised that heat and mechanical energy are within limits interchangeable, something which was demonstrated by Rumford in 1798 and first quantified by Joule in 1842. The result is that heat energy is in future to be measured in joules* instead of in calories. The equivalence is 'within limits' because the experiments of Rumford and Joule were concerned with the transformation of mechanical energy into heat; but the converse transformation is subject to Carnot's law, that the proportion of heat which can be transformed to mechanical energy cannot exceed $(T_1 - T_2)/T_1$ where T_1 and T_2 are the upper and lower temperatures, e.g. temperatures of boiler and condenser of steam plant. It is this limitation which gives rise to the allegation that electric power stations have an "efficiency" of only about one-third.

To return to electrical units, we now have only one set of units instead of three: for example current is now measured only in amperes, discarding the c.g.s. electromagnetic unit of current which was equal to ten amperes and the c.g.s. electrostatic unit which was equal to one-third of a nanoampere. (The reason for the ratio between electromagnetic and electrostatic c.g.s. units being numerically equal to the velocity of light will appear later.) A separate idea which has been absorbed via MKS into the SI system is that of *rationalised* units. This idea is that a factor involving π can reasonably be expected in circumstances involving spherical or circular geometry, e.g. the electric field around a charged sphere or the capacitance between concentric cylinders, but not where the geometry is planar, e.g. the capacitance between two parallel plane electrodes. (C.g.s. formulae are exactly the reverse of this.) The simplest electrical formula is that for the potential V at distance r from a point charge q:

$$V = \frac{q}{4\pi\epsilon_0 r} \qquad (1)$$

4π is the rationalising factor, since the system has spherical symmetry; and if q is in coulombs and r in metres, then V is in volts. How does this happy coincidence of units come about?

Through choice of a suitable value of ϵ_0 of course! So the first function of ϵ_0 is to be of the right size as a unit-forming constant. Mechanical units also are brought in through the formula for the force F between two charges:

$$F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2} \qquad (2)$$

The force F will be in Newtons. It is convenient also to introduce the idea of an *electric field* E such that $F = qE$ and E in volts per metre is given by

$$E = \frac{q}{4\pi\epsilon_0 r^2} \qquad (3)$$

So far it has been assumed that nothing else is present apart from the charges represented in the formulae, i.e. that the charges are in a vacuum. (The results are very nearly the same if they are in air.) Now suppose the charges are immersed in a fluid having a property described as relative permittivity ϵ_r (relative to a vacuum) which is none other than what we have long known as "dielectric constant": its value is usually dependent on frequency and temperature, but is around 2.3 for benzene, 7 for porcelain and 80 for water at low frequency and room temperature. It is an experimental fact that equation (2) now becomes

$$F = \frac{q_1 q_2}{4\pi\epsilon_r\epsilon_0 r^2} \qquad (2a)$$

and so (3) is changed to

$$E = q/4\pi\epsilon_r\epsilon_0 r^2 \qquad (3a)$$

In order to obtain a quantity which depends only on q and r, not on the surrounding medium, (3a) is transposed into the form

$$\epsilon_r\epsilon_0 E = q/4\pi r^2 = D \qquad (3b)$$

The new quantity D was originally called the flux of electric induction. It has the useful property that the integral of D over any closed surface is equal to the charge enclosed (Gauss's theorem in rationalised units): this is obvious in (3b) if the charge is imagined to be surrounded by a sphere of radius r and therefore surface $4\pi r^2$. D is measured in coulombs per square metre in SI units. Note that ϵ_0, as well as ϵ_r, has been transferred to the left-hand side of (3b); and ϵ_0, which we originally introduced as a constant serving to give the right size of unit, is commonly called "the permittivity of free space", which is where the controversy begins. Some physicists argue that permittivity is a property of matter, and therefore free space cannot have a permittivity. Accordingly, they claim that the c.g.s. system of units is inherently correct in putting $\epsilon_0 = 1$, because in free space D must then be the **same** as E, not merely numerically equal to it. Engineers find it convenient to distinguish between D and E because engineering is concerned with the behaviour of material objects.† (It is also a link with displacement current, but that is another story.) However, there is also a conceptual argument that D is a causal property of charge and that E is an effect which may be modified by the interposition of a material medium having the property described by the constant ϵ_r; and ϵ_0 is not necessarily a pure number but is the constant factor relating effect E to cause D. This makes D appear to be more fundamental than E, though in practice it may be difficult to say which is the hen and which is the egg!

It is now known that magnetic phenomena are manifestations of *currents*, which can usually be identified with charges in motion. The relevant formulae look more complicated because a current, unlike a static charge, has direction as well as magnitude; and the equations therefore have to be in vector form. Most of them, however, can be obtained from the analogous

* For large quantities of heat energy, which have often been expressed in tonnes of coal equivalent or tonnes of oil equivalent, the unit much bigger than a megajoule is the *exajoule* (EJ) which is 10^{18} joules.

† Perhaps one should qualify this as "old-fashioned engineering", since there is now talk of "software engineering".

electrostatic equations by the rule-of-thumb procedure "replace scalars and scalar operations by vectors and vector operations and replace $1/\epsilon_0$ by μ_0." Thus the magnetic equation analogous to (3) is

$$\mathbf{dB}=\mu_0 \mathbf{idl}\times \mathbf{a}_r/4\pi r^2 \qquad (4)$$

and the analogue of (2) is

$$\mathbf{dF}=\mu_0 \mathbf{idl}\times \mathbf{i'dl'}\times \mathbf{a}_r/4\pi r^2 \qquad (5)$$

Because the different parts of the current (circuit) may be at different distances from the point of observation, equation (4) gives only the contribution **dB** to the total magnetic effect **B** at a given point, the contribution being that due to a short element **idl** of the current, which is at distance *r* from the point. The quantities in bold type are vectors, the symbol × here represents vector multiplication and $\mathbf{a}_r$ is a unit vector in the direction of *r*. Equation (4) means that the direction of **dB** is at right-angles to both the direction of current flow and the direction of *r*. (This is part of the definition of 'vector multiplication'.) Note that an equation for **B** has been offered as analagous to the one for **E**, a consequence of replacing $1/\epsilon_0$ by μ_0. In fact **H** is the property of current which is independent of surrounding medium (the analogue of Gauss's theorem for **D** is that the line integral of **H** round a closed circuit is equal to the current enclosed) and therefore analogous to **D**. This time we are accustomed to regarding **H** as a cause and **B** as its effect. Initially μ_0 also can be regarded as a unit-forming constant, the function of which is to ensure that the force between two currents comes out in Newtons.

So much for units; but what of "dimensions"? It is familiar that all mechanical units can be related back to the fundamentals of length, mass and time: for example, force = mass × acceleration leads to a dimensional relation $[F]=[MLT^{-2}]$. Some quantity additional to *L*,*M* and *T* may be needed for electrical phenomena and in the c.g.s. system this was taken as *either* ϵ *or* μ so that every quantity had two sets of dimensions as well as two sizes of unit. What can be demonstrated experimentally, by giving a capacitor a charge which is measured in c.g.s. electrostatic units and discharging it through a meter which measures the current in c.g.s. electromagnetic units, is that the ratio of numerical values in the two sets of units is equal to the numerical value of the speed of light. It is, moreover, implicit in Maxwell's equations that the velocity of propagation of electromagnetic radiation is $1/(\mu\epsilon)^{1/2}$ from which it is deduced that the inverse of the product of μ and ϵ has the dimensions of the square of velocity.

There is no certain method of dividing the dimensions $L^{-2}T^2$ between μ and ϵ. But it seemed a *plausible conjecture* (no more) that since magnetic effects are due to charges in motion the dimensions of velocity squared should be associated with equation (5). Since current = charge/time, the current-length product **idl** is equivalent to a charge-velocity product; and if μ_0 has dimensions which differ from those of ϵ_0 by $L^{-2}T^2$ then μ_0 will cancel out the velocities in **idl** and **i'dl'** and we shall have force related to charge²/distance² in both (5) and (2). It is tempting to suggest that if μ_0 has *only* the dimensions of velocity^{-2} and ϵ_0 is purely numeric, then the dimensions of charge can be expressed in terms of *L*,*M*,*T* through either equation. But this could be a trap for the unwary. It is equally possible that there is an electrical dimension which appears equally in μ_0 and $1/\epsilon_0$ and therefore cancels out in the product $\mu\epsilon$. It is equally plausible, however, the *electrical* phenomena must involve more than the purely *mechanical* dimensions of length, mass and time. In SI units, therefore, one takes the reasonable step of taking *Q* as a further dimension to add to *L*, *M*, *T*. On this basis it is found from equations (2) and (5) that ϵ_0 and μ_0 have dimensions $L^{-3}M^{-1}T^2Q^2$ and LMQ^{-2} respectively. *M* and *Q* cancel out in the product $\mu_0\epsilon_0$, leaving the dimensions $L^{-2}T^2$ of velocity^{-2}. One might wonder how this squares with the specification of ϵ_0 and μ_0 in units of farads per metre and henries per metre respectively. The fact is that both farads and henries involve all four *L*,*M*,*T*,*Q* dimensions (as can be seen from the fact that $\frac{1}{2}CV^2$ and $\frac{1}{2}Li^2$ are energies) so that these specifications are still valid in the self-consistent system of SI units. The important difference between the MKS and SI systems is the SI postulate that *Q* should be taken as the electrical 'dimension', in contrast to both the c.g.s. and MKSμ systems, though the MKSA system (A for ampere) was half-way there. But incidentally, ϵ_0 and μ_0 now have dimensions which is contrary to the c.g.s.-based argument that *D* and *E* are identical in free space. I wonder how long the matter will be allowed to rest there. □

Literature received

Engineering Bulletin 3539A from Sprague describes a range of Tanite chip **capacitors** with conformal plated terminations. The capacitors are of the solid-electrolyte type, for use in hybrid circuits. The bulletin can be obtained from the UK distributor, Hy-Comp Ltd, 7 Shield Road, Ashford Industrial Estate, Ashford, Middlesex TW15 1AV. WW401

Catalogue of **components** and **instruments** is available from HRS Components, Ltd, Brasshouse Passage, Birmingham B1 2HR WW402

Short catalogue describing a range of plastic-film **capacitors** with values in the range 100pF to 20μF can be obtained from Ashcroft Electronics Ltd, 28 Somerford Road, Cirencester GL7 1TW. WW403

Leaflet on the 3M Videodata **communication system** for installation in buildings is available. This is nothing to do with a videotext system, but is concerned with the use of coaxial cables instead of multicore types to carry video and data throughout a building. The system is broadband, which allows the connexion of new equipment relatively cheaply. Copies from Mike Bellamy, Interactive Systems Group, 3M (UK) Ltd., 3M House, PO Box 1, Bracknell, Berkshire RG12 1JU. WW404

Sound synthesis using Walsh functions

continued from page 64

l.s.i. implementation, interested readers may like to consider the application of computer-generated Walsh functions. Clearly a microprocessor-based system could be realised enabling the software implementation of fully polyphonic musical sounds.

Effects of relative phase of harmonics

If a sinewave oscillator is set to a frequency of 220Hz and its output summed after passing through a variable phase shift network with that of a second sinewave oscillator of frequency 440Hz, the resulting waveshape, displayed on an oscilloscope, alters as the relative phase of the two components is varied. If the waveform is also listened to however no apparent change in sound is perceived by the ear, regardless of the phase relationship. Therefore as far as steady-state sounds are concerned, the relative phase of the individual partials in direct Fourier synthesis is irrelevant.

With regard to Walsh harmonics, B. A. Hutchins, whose work first prompted my interest in Walsh synthesis, has conducted synthesis experiments using different Walsh/Fourier series for the same waveform and has demonstrated differences in tone colour which are directly attributable to the use of different phase relationships. The effect is connected with the problem of monaural phase.[4] Interested readers may like to generate the triangular wave mentioned earlier using the Walsh/Fourier series than quoted, and compare the sound perceived when the alternative Walsh/Fourier series +0.5wal1, −0.25wal5, −0.125wal13, −0.063wal29 is used.

Acknowledgment. The concept of using Walsh functions for musical synthesis was first suggested by Dr C. Frederick of the Centre for Radiophysics and Space Research, Cornell University. □

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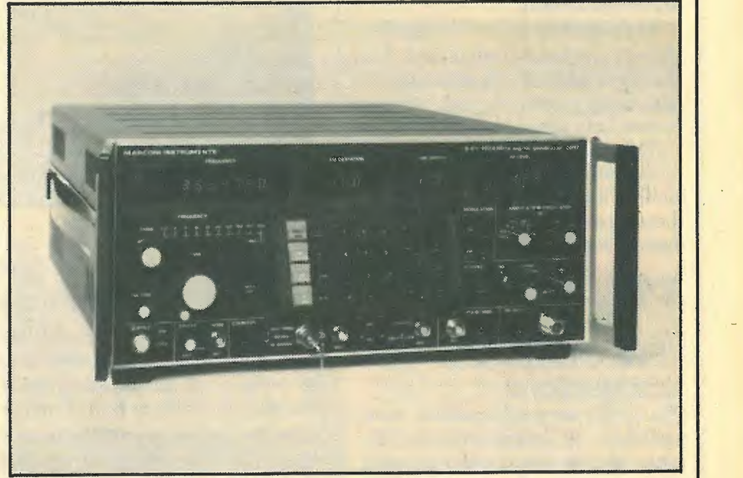
4 V. Lozhkin, Monaural phase effects, *Soviet Physics Acoustics*, vol. 17, no. 1, July-Sept 1971.

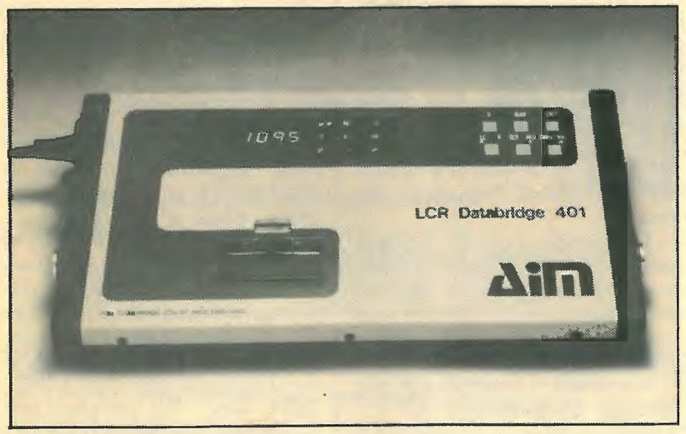
NEW PRODUCTS

LCR bridge

Combined inductance/capacitance, resistance and Q are the LCR Databridge 410's three manually selectable function ranges. On the LC range the bridge distinguishes between inductors and capacitors and gives the value and the appropriate units automatically. All four functions have overridable auto-ranging through eight decades. Measuring frequencies of 100Hz and 1kHz are selected manually, but an indication is given when the component under test can be measured more accurately using the frequency not selected. A similar indication is given for series and parallel measurement modes when the best mode for a given component is not selected. Range limits are 1mΩ to 100MΩ, 0.1μH to 9999H, 0.1pF to 9999μF and 0.1 to 99 for Q measurements, all with a basic accuracy of 0.25%, ±1 digit. Six push-buttons are the only controls and the reading, obtained within one second of insertion of the component, is given on a 4-digit l.e.d. display. The unit of measurement is indicated by one of nine l.e.ds, except in the case of the Q range when all range l.e.ds are extinguished. Input protection, a switchable polarizing voltage for electrolytics and a socket for external test leads or fixtures are also provided. Internally, a Z80 microprocessor carries out the control functions. An option is available with digital outputs for use with limits comparators, and the standard version costs £495. AIM Cambridge Ltd, Burrel Rd, Indust. Est., St Ives, Huntingdon, Cambs PE17 4LF.

WW301





A.m./f.m. signal generator

A fully programmable microprocessor-controlled signal generator covering the range 10kHz to 1024MHz has been introduced to the market by Marconi Instruments Ltd. The manufacturers claim that the 2017 gives signals that are completely free from non-harmonic spurious additions from 4 to 1024MHz, ±1dB level accuracy, 4V output across the complete frequency range and a sideband noise figure better than −136dB/Hz at 20kHz offset in the range 256 to 512MHz. A slow-sweep facility provides an analogue sweep between any two frequencies on one of nine carrier ranges so that spurious responses within a receiver can easily be found. The carrier frequency can be stepped up or down in steps of any size and the total shift at any point indicated on depression of a key. Two methods of manual control are used: one digital using a keyboard, and one analogue using rotary controls. Programming via a general purpose interface bus (IEEE-488) extends the range of applications to include a.t.e. systems. The 2017 is said to be simple to use and a memory facility is provided so that up to ten frequencies can be stored for later use. Marconi Instruments Ltd, Longacres, St Albans, Herts AL4 0JN.

WW302

Video editing interface

Trigger Happy is designed to help organisations who have a U-matic edit pair of video recorders but who want to use material shot on low-gauge cassette or open-reel format. Built to a Fantasy Factory specification, it "bridged the editing gap between consumer and U-matic formats", allowing fast editing from ½in feed decks (VHS, Beta, Sony 3670, National 3150) direct onto a ¾in U-matic edit deck via a normal edit controller.

Trigger Happy obviates the need for a transfer first onto U-matic with a resulting loss of quality, or for tedious stop-watch editing. It contains two counter-displays, one which counts control track pulses from the feed deck, the other which is preset to a number specific to the edit controller being used. A start pulse causes the U-matic edit deck to roll down to the edit point at precisely the right time.

According to its designer, Richard Monkhouse of Costronics, Trigger Happy Mk2 is easy to interface as modification data and kits are provided (state feed deck and controller), no mechanical modifications being needed except for fitting sockets. Price is £440 from sole distributors Fantasy Factory Video Ltd (a registered charity company), at 42 Theobalds Road, London WC1 8NW.

WW303

High-temperature thermistors

The range of thermistors available from Electrautom has been expanded by the inclusion of the Mid-Temp series for temperatures from 200 to 600°C. These devices can be used as temperature sensing elements in cookers, soldering irons and photo-copier fuser rollers. Electrautom Ltd, Etom House, Queens Rd, Maidstone, Kent ME16 0JG.

WW304

Microcomputer

Both a microcomputer for business and personal use and applications software are avaiable from LSI Computers Ltd. The standard M Three computer, manufactured in Great Britain, is based on the Z80 microprocessor with 64K r.a.m., two double-density 51/4in floppy disc drives, v.d.u. and keyboard with 109 keys, fourteen of which are programmable.

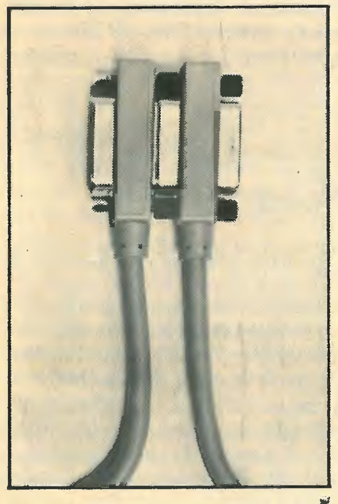
Versions with the two 51/4in disc drives replaced with two 8in double-density drives and Centronix matrix printers for use with the system can also be supplied. A CP/M operating system is included as standard. The basic system costs under £3000, excluding v.a.t. LSI Computers Ltd, Copse Rd, St Johns, Woking, Surrey GU21 15X.

WW305

WW305

IEEE data bus connectors

Up to fifteen programmable measurement or instrumentation devices can be interconnected using the Amphenol terminated cable assemblies to IEEE 488 interface standards. Each assembly comprises a 24-core screened cable and two rack and panel type connectors, i.e. connectors with combined plug and socket, which can be mounted upon each other in 'piggy-back' fashion. Of the 24 conductors, 16 are used for signal lines and eight for logic ground returns and shielding. Celdis Ltd, 37 Loverock Rd, Reading, Berks RG3 1ED.



WW306

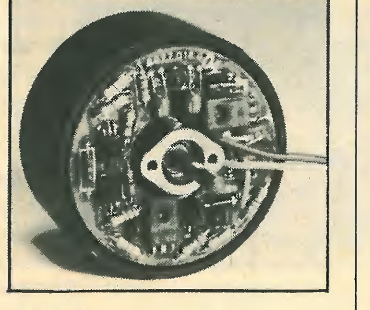
Power supplies

Voltage stabilized, current limited power supplies ranging from 2.5A, 10-15V internally adjustable units to '19in' laboratory types capable of deliverying more than 15A from 0 to 65V are available in the UK through Big Ears (seriously). EA-Produktion, the German manufacturers, claim that the complete range consists of more than 150 models, each of which has a two year guarantee. The latter type mentioned above has fine and coarse controls for both current and voltage, 40mV maximum output variation from 0 to 100% mains variation, an output temperature coefficient of 0.01%/°K and resistor or voltage programmable output voltage and current. All laboratory types have s.c.r. pre-regulation for low dissipation and can be supplied with either l.c.d. or analogue meters. Plug-in supplies for covering 5-24V and 0.5-10A, converters for 12V d.c. to 220V a.c. and combined variable a.c. and d.c. supplies are included in the range. As far as we know, all these supplies are designed for 220V±10% mains operation. Four 'low-price' units were tested by us using a 240V mains supply, and found to perform well under all loads. Two weeks delivery is quoted for units that cannot be supplied from stock. Big Ears, 68 Narborough Rd, Leicester.

WW307

Brushless d.c. motor

Drive electronics of the GAE 43.14 brushless Hall effect controlled d.c. motor are mounted on the stator for compactness. This unit, measuring 56×30mm, can produce up to 2Ncm torque and has a nominal running speed of 2000 r.p.m. which can be varied using an external control circuit. Supply voltages range from 18 to 30V; for a 24-volt version the supply current is 200mA. Ball bearings are used on the 4mm diameter drive shaft for the dynamically balanced high inertia rotor. Papst Motors Ltd, Parnell Court, East Portway, Andover, Hamps SP10 3LX.



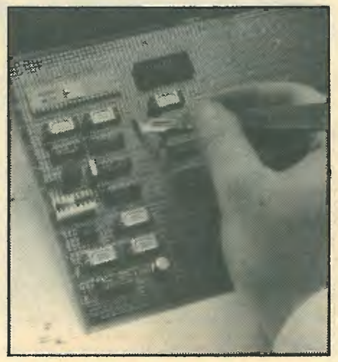
WW308

Four-layer p.t.h. board for prototypes

A four-layer plated-through printed circuit board suitable for prototypes or small production runs has been introduced by Logiclayer, a subsidiary of ICL. The p.c.b., known as Multiboard, is arranged as a matrix of 60 × 88 drilled pads spaced at 0.1in. The component side, or X tracking, has pads connected at regular intervals in columns, and the underside, or Y tracking, has different pads connected at regular intervals in rows. Sandwiched between the X and Y layers are a ground or 0V layer, and a power supply layer which provides two interleaved supply rails. The ground and supply rails are connected to three sets of pads regularly spaced throughout the board.

To assemble a circuit, the components are placed in their optimum positions and they are then interconnected by linking and cutting tracks on pads using isolated pads where necessary.

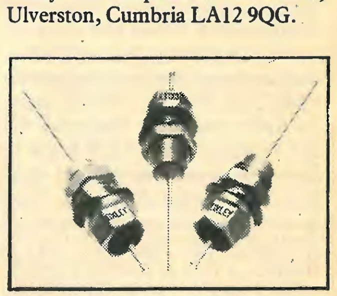
Multiboard is manufactured in a standard Eurocard size, 233.4 × 160mm, and will accept DIN connectors at the front or rear. The board has a characteristic impedance of 50Ω which is maintained after customising. When a completed board has been tested, Logiclayer can produce a production run of customised boards from layout drawings or cut and link information supplied with pad addresses. Logiclayer, Plymouth Grove, Manchester M13 9LN.



WW309

R.f.i. suppression filters

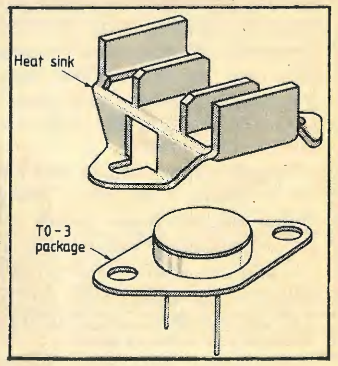
Negligible d.c. and low frequency voltage drop coupled with high insertion loss for a wide range of frequencies are features quoted for the 1.5 and 5nF radio-frequency interference filters from Oxley Developments Co. Ltd. Minimum insertion losses from 200MHz to 1GHz are 45dB for the 1.5nF type and 50dB for the 5nF type. Maximum limits of these pi-section ceramic devices are 350V d.c., 10A d.c. or low-frequency a.c. and −55 to 85°C operating temperature. Both the FLTM/P/1500 (1.5nF) and FLTM/P/5000 (5nF) types have stud mounting packages with M5 threads. Versions with 12UNEF threads are also available. Oxley Developments Co. Ltd, Ulverston, Cumbria LA12 9QG.



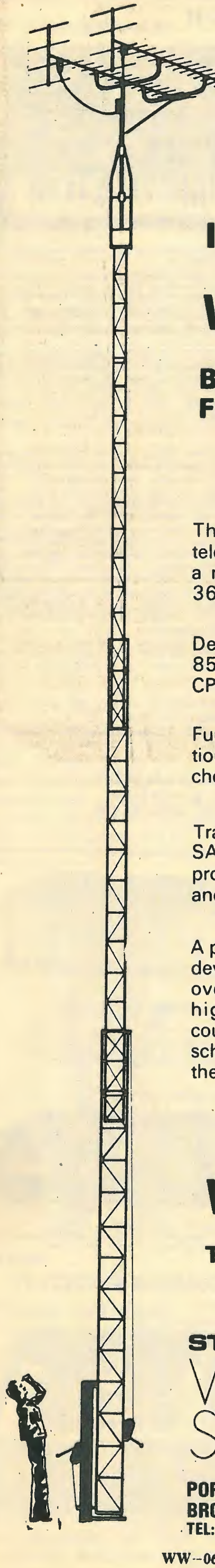
WW310

Silicone-free thermal grease

In applications where silicone contamination from thermal grease causes problems, Thermalcote II could provide an alternative. This grease, which at 36°C provides a minimum thermal conductivity of 16.7×10^{-4} cal/s cm°C, is said not to dry out, melt or give migration problems. A high-lubricity oil base is used which permits the compound to flow into small gaps and the working temperature is 165°C (200°C max). The manufacturers, Thermalloy, have also introduced a ½in high heat sink, for mounting on top of T03 transistor packages, which can be used on its own or combined with existing p.c.b. mounting heat-sinks for additional cooling. MCP Electronics Ltd, 38 Rosemont Road, Alperton, Wembley, Middx HA0 4PE.



WW311



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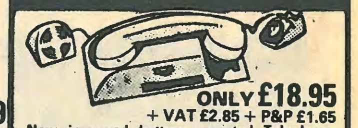

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Wednesday, 8th July, 1981, 9.30 a.m.

For auction:
Flow soldering plant with immersion bath, **armament lines**, ceiling circular conveyor, **paint spray stations**, drying kilns, **ultrasonic degreasing plant**, assembly lines, **modern electroplating equipment**, winding machines, de-insulating presses, **bending and cutting automatic machines**, testing compartments, **transformers**, hydraulic and pneumatic punches and presses, (Lifetestwagen) **spot welding machines**, rotary heat kiln, aerosol recovery plant, freon **degreasing** plant, mixer, **Wolfram welding equipment**, continuous heating kiln, hydrogen hatch kiln, **eight and ten head lock and seal machines** for 90° and 110° colour tubes as well as shelves, **canteen equipment, machine tools**, fork lift truck and over **1,000 items** measuring and testing equipment for many more items.
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Model	Output Power RMS	Distortion Typical at 1KHz	Slew Rate	Rise Time	Signal/Noise Ratio DIN AUDIO	Price & VAT
MOS120	60W into 4-8Ω	0.005%	20V/μs	3μs	100dB	£25.88 + £3.88
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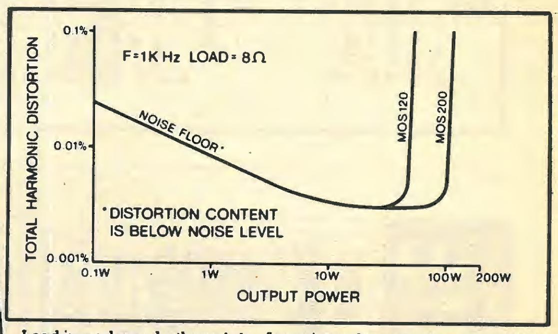

Load impedance both models 4Ω-∞ Input sensitivity both models 500mV. Input impedance both models 100KΩ. Frequency response both models 15Hz-100KHz - 3dB

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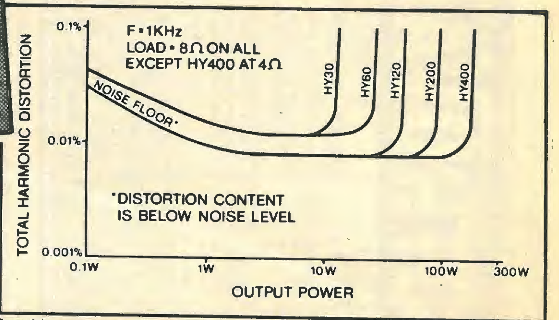
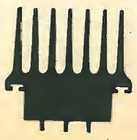
HY60	30W into 4-8Ω	0.015%	15V/μs	5μs	100dB	£8.33 + £1.25
HY120	60W into 4-8Ω	0.01%	15V/μs	5μs	100dB	£17.48 + £2.62
HY200	120W into 4-8Ω	0.01%	15V/μs	5μs	100dB	£21.21 + £3.18
HY400	240W into 4Ω	0.01%	15V/μs	5μs	100dB	£31.83 + £4.77



Load impedance all models 4Ω-∞ Input sensitivity all models 500mV. Input impedance all models 100KΩ. Frequency response all models 15Hz-50KHz - 3dB



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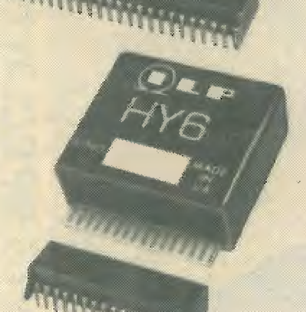

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HY6 mono £6.44 + 97p VAT Connectors included
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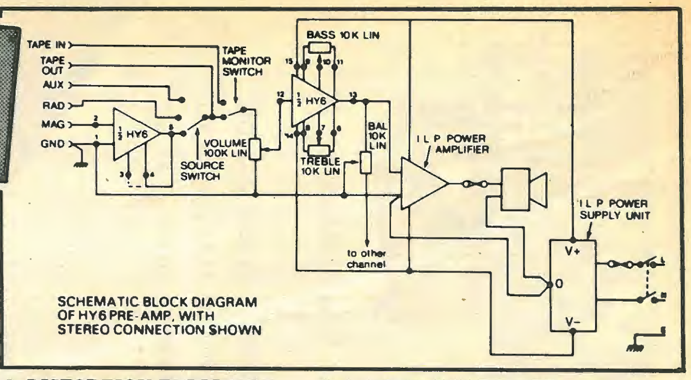
B6 Mounting Board for one HY6 78p + 12p VAT
B66 Mounting Board for one HY66 99p + 15p VAT



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WW – 074 FOR FURTHER DETAILS

VALVES

Minimum Order £1 — VALVES VAT IS INCLUDED

Valve	£
A1065	1.40
A2293	8.80
A2900	9.20
AR8	0.75
ARP3	0.70
ATP4	0.60
B12H	3.90
CY31	1.40
DAF96	0.70
DET22	26.95
DF96	0.70
DK96	1.20
DH76	0.75
DL92	0.60
DY86/87	0.65
DY802	0.70
E55L	14.90
E88CC	1.60
E88CC/01	3.10
E92CC	1.20
E180CC	2.80
E180F	6.30
E182CC	4.95
EA76	2.25
EABC80	0.60
EB91	0.60
EBC33	1.15
EBC90	0.90
EBF80	0.60
EBF83	0.60
EBF89	0.80
EC52	0.65
EC91	3.40
EC92	0.85
ECC81	0.65
ECC82	0.60
ECC83	0.65
ECC84	0.60
ECC85	0.60
ECC86	1.70
ECC88	0.80
ECC189	0.95
ECC804	0.90
ECF80	0.85
ECF82	0.65
ECF801	1.05
ECH34	2.25
ECH35	1.70
ECH42	1.20
ECH81	0.70
ECH84	0.80
ECL80	0.70
ECL82	0.75
ECL83	1.40
ECL85	0.80
ECL86	0.90
EF37A	2.15
EF39	1.80
EF80	0.65
EF83	1.75
EF85	0.60
EF86	0.75
EF89	1.05
EF91	1.50
EF92	2.90
EF95	0.65
EF96	0.60
EF183	0.80
EF184	0.80
EF804	4.95
EF812	0.75
EFL200	1.85
EH90	0.85
EL32	1.10
EL34	1.80 / 2.90*
EL37	4.40
EL81	2.45
EL82	0.70
EL84	0.80
EL86	0.95
EL90	1.00
EL91	4.20
EL95	0.80
EL504	1.70
EL803	5.90

Valve	£
EL509	2.70
EL802	1.70
EL821	8.20
EL822	9.95
EM31	1.60
EM80	0.85
EM81	0.85
EM84	0.85
EM87	1.30
EY51	0.95
EY81	0.65
EY86/87	0.60
EY88	0.65
EZ80	0.70
EZ81	0.70
GM4	5.90
GY501	1.30
GZ32	1.05
GZ33	4.20
GZ34	2.75
GZ37	3.95
KT66	6.30 / 9.20*
KT88	8.95 / 13.80*
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ML6	2.50
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N78	9.90
OA2	0.70
OB2	0.80
PABC80	0.60
PC85	0.75
PC86	0.95
PC88	0.95
PC97	1.50
PC900	1.15
PCC84	0.50
PCC89	0.85
PCC189	1.05
PCF80	0.80
PCF82	0.70
PCF84	0.75
PCF86	1.50
PCF87	0.50
PCF200	1.60
PCF201	1.65
PCF800	0.50
PCF801	1.75
PCF802	0.85
PCF805	2.45
PCF806	1.20
PCF808	2.75
PCH200	1.35
PCL81	0.75
PCL82	0.95
PCL84	0.90
PCL86	1.05
PCL805/85	1.25
PD500/510	4.30
PFL200	1.10
	2.80
PL36	1.25
PL81	0.85
PL82	0.70
PL83	0.60
PL84	0.95
PL504	1.45
PL508	1.95
PL509	2.90
PL519	3.20
PL802	3.20
PY33	0.70
PY80	0.70
PY81/800	0.85
PY82	0.65
PY83	0.80
PY88	0.85
PY500	1.70
PY809	6.45
PY801	0.80
QQV03/10	2.85
QQV03-20A	14.40
QQV03-25A	21.20

Valve	£
QQV06/40A	16.10
QV03-12	4.20
SC1/400	4.50
SC1/600	4.50
SP61	1.80
TT21	16.50
U25	1.15
U26	1.15
U27	1.15
U191	0.85
U281	0.70
U301	0.65
U600	11.50
U801	0.90
UBC41	1.20
UABC80	0.75
UAF42	1.20
UBF80	0.70
UBF89	0.70
UBL21	1.75
UCC84	0.85
UCC85	0.70
UCF80	1.30
UCH42	1.65
UCH81	0.75
UCL82	0.95
UF41	1.35
UF80	0.95
UF85	0.95
UL41	2.30
UL84	0.95
UM80	0.90
UM84	0.70
UY82	0.70
UY85	0.85
VR105/30	1.25
VR150/30	1.35
X66	0.95
X61M	1.70
XR1-6400A	82.90
Z759	19.00
Z749	0.75
Z800U	3.45
Z801U	3.75
Z803U	16.00
Z900T	2.45
1A3	0.85
1L4	0.50
1R5	0.60
1S4	0.45
1S5	0.45
1T4	0.45
1U4	0.80
1X2B	1.40
2D21	1.10 / 1.85*
2K25	11.90
2X2	1.15
3A4	0.70
3AT2	2.40
3D6	0.50
3D22	23.00
3E29	19.00
3S4	0.60
4B32	18.25
5B/254M	16.90
5B/255M	14.50
5B/258M	12.50
5C22	29.90
5R4GY	1.80
5U4G	0.75
5V4G	0.75
5Y3GT	0.80
5Z3	1.50
5Z4G	0.75
5Z4GT	1.05
6/30L2	0.90
6AB7	0.70
6AC7	1.15
6AG5	0.60
6AH6	1.15
6AK5	0.65
6AK8	0.60

Valve	£
6AL5	0.60
6AL5W	0.85
6AM5	4.20
6AM6	1.50
6AN8A	2.50
6AQ4	3.40
6AQ5	1.00
6AQ5W	1.80
6AS6	1.15
6AT6	0.90
6AU6	0.60
6AV6	0.85
6AX4GT	1.30
6AX5GT	1.30
6BA6	0.55
6BE6	0.60
6BG6G	1.60
6BJ6	1.30
6BQ7A	0.85
6BR7	4.80
6BW6	6.20
6BW7	0.90
6C4	0.50
6C6	0.55
6CH6	8.20
6CL6	1.70
6CX8	3.80
6CY5	1.15
6D6	0.70
6EA8	3.20
6F6	1.60
6F6GB	1.10
6F7	2.80
6F8G	0.85
6F12	1.50
6F14	1.15
6F15	1.30
6F17	1.15
6F23	0.75
6F24	1.75
6F33	10.50
6FH8	4.20
6GA8	0.90
6GH8A	0.95
6H6	1.60
6J4	1.35
6J4WA	2.00
6J5	2.30
6J5GT	0.90
6J6	0.65
6J6W	0.90
6JE6C	2.95
6JS6C	2.95
6K7	0.80
6L6M	2.80
6L6G	2.50
6L6GC	2.10
6L6GT	1.25
6L7G	0.65
6L18	0.70
6LQ6	2.95
6LD20	0.70
6KG6A	2.70
6Q7G	1.30
6SA7	1.00
6SG7	1.15
6SJ7	1.05
6SK7	0.95
6SL7GT	0.85
6SN7GT	0.80
6SR7	1.10
6SQ7	0.95
6V6G	1.50
6V6GT	0.95
6X4	0.75
6X4WA	2.10
6X5GT	0.65
6Y6G	0.90
6Z4	0.70
7B7	1.75
7Y4	1.25
9D2	0.70
9D6	2.90
10C2	0.85
10F18	0.70
10P13	1.50

Valve	£
11E2	19.50
12A6	0.70
12AT6	0.70
12AT7	0.65
12AU7	0.60
12AV6	0.95
12AX7	0.65
12BA6	0.90
12BE6	1.25
12BH7	1.10
12C8	0.65
12E1	18.95
12J5GT	0.55
12K7GT	0.70
12K8GT	0.80
12Q7GT	0.60
12SC7	0.65
12SH7	0.65
12SJ7	0.70
12SQ7	1.45
12SQ7GT	0.85
12Y4	0.70
13D3	0.70
13D5	0.90
13D6	0.80
14S7	1.15
19AQ5	0.85
19G3	11.50
19G6	8.50
19H5	39.55
20D1	0.80
20F2	0.85
20E1	1.30
20P1	0.65
20P3	0.75
20P4	1.25
20P5	1.35
25L6GT	0.95
25Z4G	0.75
30C15	0.50
30C17	0.50
30C18	2.45
30F5	1.15
30FL2	1.40
30FL12	1.25
30FL14	2.15
30L15	1.10
30L17	1.10
30P12	1.15
30PL13	1.25
30PL14	2.45
35L6GT	1.40
35W4	0.80
35Z4GT	0.80
40KD6	3.15
50C5	1.15
50CD6G	1.35
75B1	1.25
75C1	1.70
76	0.95
78	0.95
80	1.70
85A2	1.40 / 2.55*
723A/B	11.90
807	1.25
813	14.80
829B	14.00
832A	8.90
866A	3.80
866E	6.25
931A	13.80
954	0.60
955	0.70
956	0.60
957	1.05
1625	1.80
1629	1.85
2051	2.90
5763	4.20
5842	7.50
5881	3.40
5933	6.90
6057	2.20
6060	1.95

Valve	£
6064	2.30
6065	3.20
6067	2.30
6080	5.30
6146	4.95
6146B	5.20
6360	2.85
6550	6.60
6870	14.00
8552	8.20
6973	3.30
7199	2.85
3BP1	11.00
5FP7	18.00
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88L	14.00
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DG7-32	34.80
DG7-36	36.00
DPM9-11	38.40
D13-33GM	41.80

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BM 25L
BW 153
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BR 179
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GMU 2
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BK485/5552A
MIL 5948/1754

IC

IC	£
SN5402N	0.28
SN5410F	0.32
SN5470F	0.48
SN54196J	1.20
SN7407N	0.29
SN7408N	0.18
SN7445P	0.85
SN74453P	1.10
SN7453N	0.18
SN74L73N	0.38
SN7474N	0.30
SN7485N	0.95
SN74L85N	1.10
SN7491AN	0.32
SN74123N	0.42
DM74123N	0.38
SN15836N	0.26
SN76013N	1.80
SN76003N	1.60
SN76033N	1.95
MC6800P	8.20
MC68B00P	9.80
MC14511BA1	2.95
B1702AL	4.30
MM6300-1J	3.80
MCM6810AP	3.40
6340-1J	3.60
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WW – 069 FOR FURTHER DETAILS

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- COMPLETE WITH BRIDGE SUPPLY
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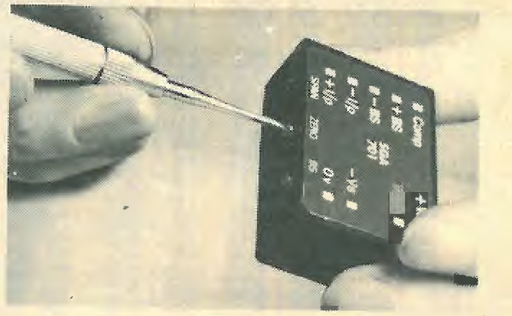
- **COMPLETE** (NO EXTERNAL COMPONENTS NEEDED)



The series SGA 700 provides the complete solution to Strain Gauge Amplification. Simply connect the bridge, connect the power supplies and the SGA 700 does the rest. It also offers high stability. Miniature size, good supply rejection — in fact a specification as good as many instruments many times the price and size.

CIL electronics ltd

CIL Electronics Ltd
14 Willowbrook Road,
Worthing, Sussex BN14 8NA.
Tel: Worthing (0903) 204646
Telex: 87515 WISCO G ATT CIL

WW – 052 FOR FURTHER DETAILS

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ULTRASONIC TRANSMITTER Complete unit (uncased requires 1.5V) £3.25.

FOSTER DYNAMIC MICROPHONES 200 ohm impedence Moving coil. £1.75 pair Complete on chassis

STEREO CASSETTE TAPE HEADS Quality replacement for most recorders with mounting plate. Record/Replay. £2.80.

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(5082-7650) high efficiency and very bright.
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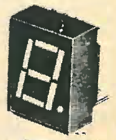

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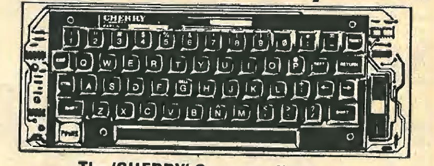

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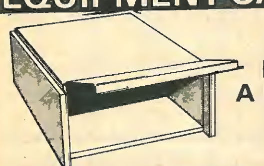

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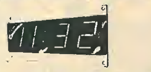
★ ALARM
★ 50/60 HZ



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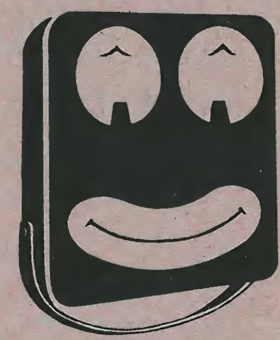

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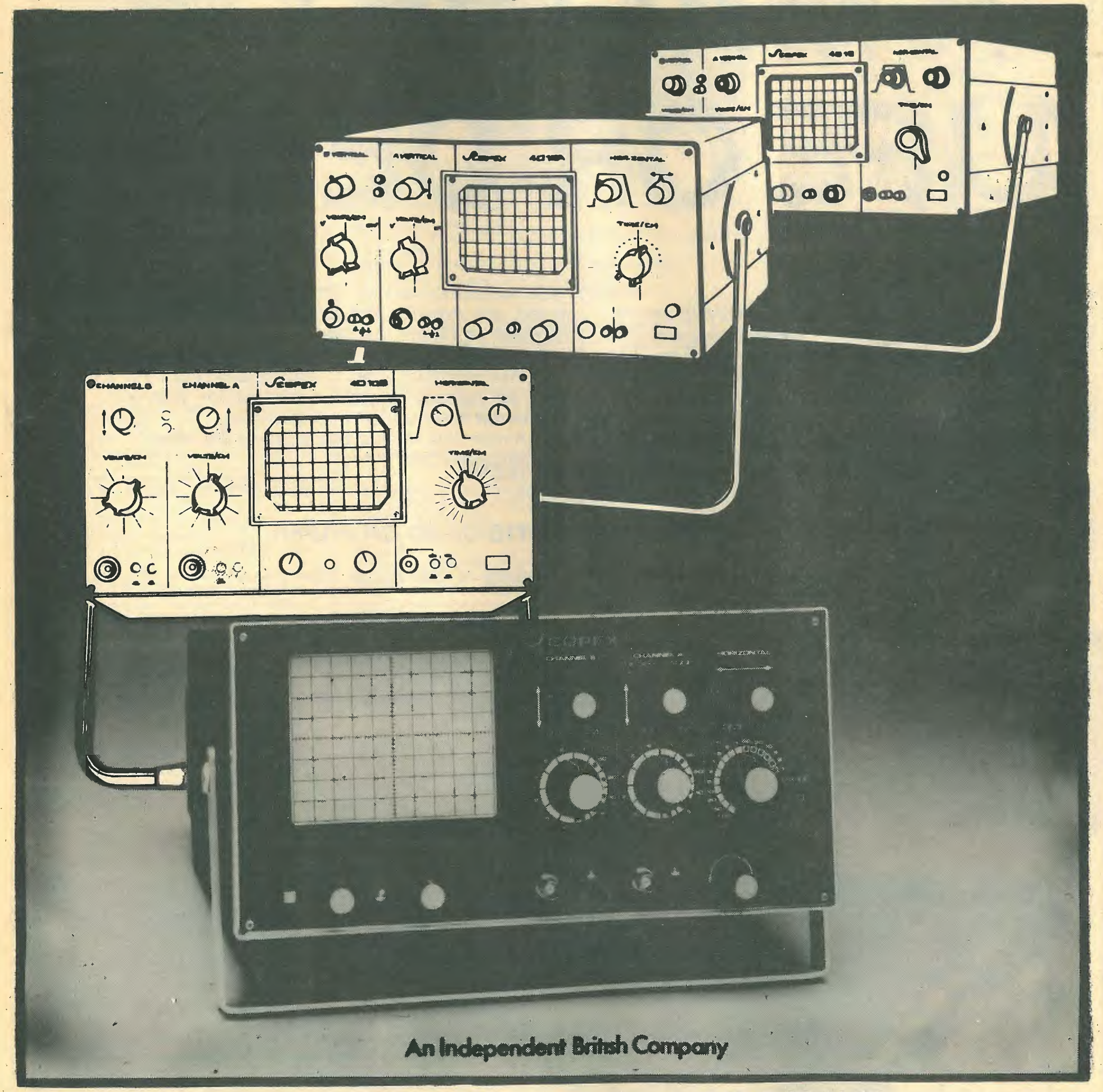

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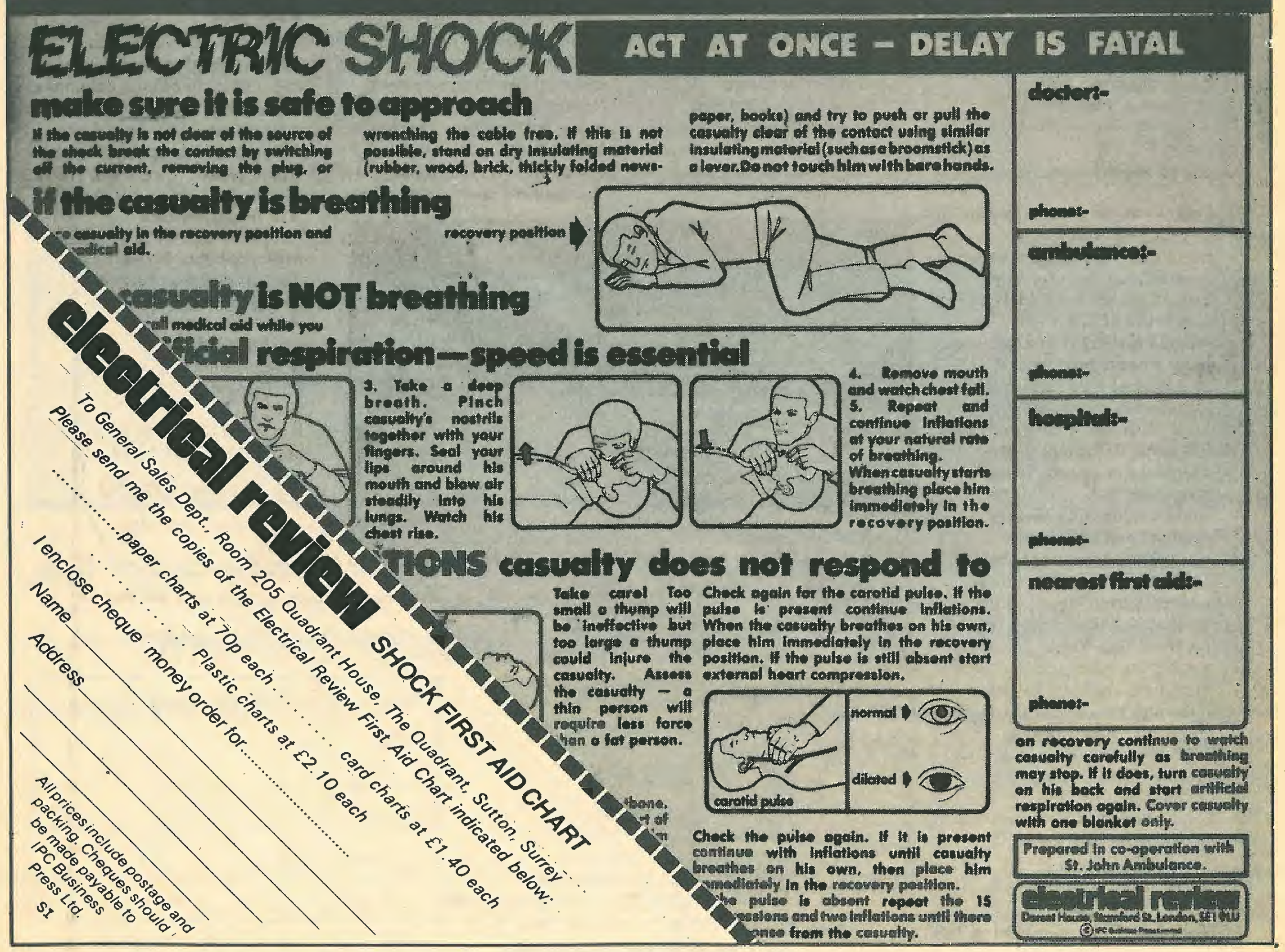

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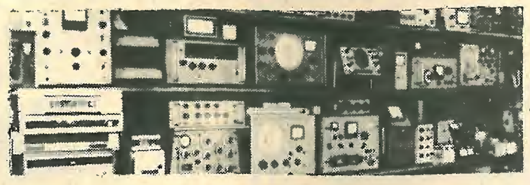

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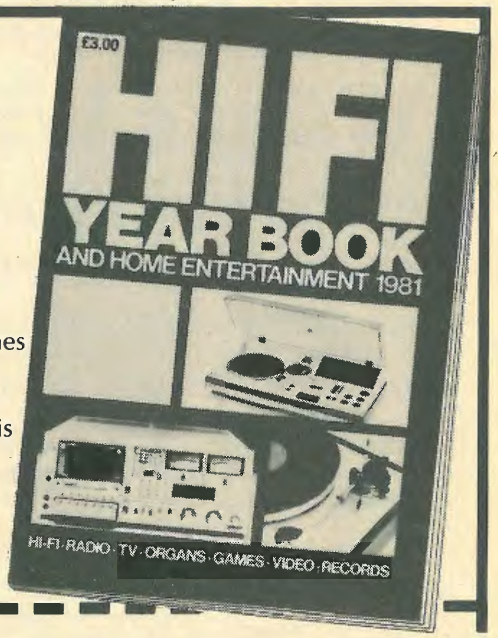

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15MHz, 8 BIT

By Micro Consultants Ltd. 50Ω cable drive op. Linearity 0.25%, max. 0.125% typ. Settling time: 2V step 70nS typ. 2MV step 50nS colour television transmission standard. Diff. gain 0.5% diff. phase shift 0.5° types rad 802 and MC2208/8. Unused. Ex-maker's pack.

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Type	Stock	Each	Type	Stock	Each
7401	12,400	.08	74LS76	7,000	.20
7402	4,400	.08	74LS138	13,900	.36
7405	5,400	.10	74LS157	3,800	.34
7420	1,200	.10	74LS175	4,800	.68
7425	4,500	.20	74LS192	29,200	.50
7473	1,500	.20	74LS193	6,650	.65
7475	10,000	.25	74LS221	30,800	.65
7486	6,200	.25	74LS251	600	.65
7489	7,200	1.55	74LS273	10,000	.75
74123	15,150	.45	74LS290	40,300	.45
74125	2,000	.26	74LS293	35,000	.45
74154	1,900	.60	74LS390	2,100	.65
75452	19,700	.40	UA709	25,400	.25
74LS00	39,600	.10	UA709A	18,600	.25
74LS01	11,200	.10	*TMS1000	9,555	1.00
74LS02	2,650	.10	TMS4036	3,400	1.00
74LS10	14,500	.10	DS8889	12,100	1.00
74LS11	53,300	.20	MC3491	6,000	1.00
74LS30	9,600	.12	40085BPC	23,000	POA
74LS73	18,600	.20			
74LS75	4,750	.25			

* 4-bit Comparator

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Type	Stock	Each	Type	Stock	Each
2N1306	10,400	POA	BC184L	248,000	.08
2N1307	c 2,000	POA	BFR86	68,400	POA
2N3055	12,500	.45	BD240C	16,200	.22
FRB876	7,400	POA	BCY70	51,800	POA
FRB877	17,600	POA	ZTX342K	149,000	.08
R1076	7,350	POA	ZTX542K	128,000	.08

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HEAVY DUTY KEYSWITCHES
2P 12A 600V AC **£1.50**
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49mm ☐ Fascia.

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Good range stocked. Please phone your requirements. Large stocks of the following:
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CANNON 15w sockets, D type or Souvrian/McMurdo Daiss **60p** ea. Also Cannon 9w plug, brand new, **60p** ea.

WELWYN STRAIN GAUGE. (Precision micro-measurements). Romulus Michegan type MA-09-500B4-350. Our price **£1.25** ea. List price £3.85. Large quantities available.
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REDPOINT HEATSINK, Type TV4 **15p** ea. 1 off price. Discount on quantity.
We have the following **Welwyn .1% Resistors** available, 2K, 3K, 10K, 20K, 30K, 1 Meg. Price **25p** ea. Type 4802.

BURROWS CONNECTOR (LH) 1701, 41c, **20p;** Burrows Connector (RH) 1201, 4LC **25p.** Large quantities available.

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BUZZERS, 6v and 12v, **50p** ea.

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PCB mounting 16mmø
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10A 250V AC ILLUMINATED ROCKER SWITCH
Red, DP ST 26x30mm rect. Snap-in type **75p**

16A 250V AC ILLUMINATED ROCKER SWITCH
(Amber). 14x30mm rectangular snap-in type. SPST **30p**

WIREWOUND POTS
10R-100K by A.B., Colvern, etc. 1½W **40p,** 3W **60p,** 5W **80p.**

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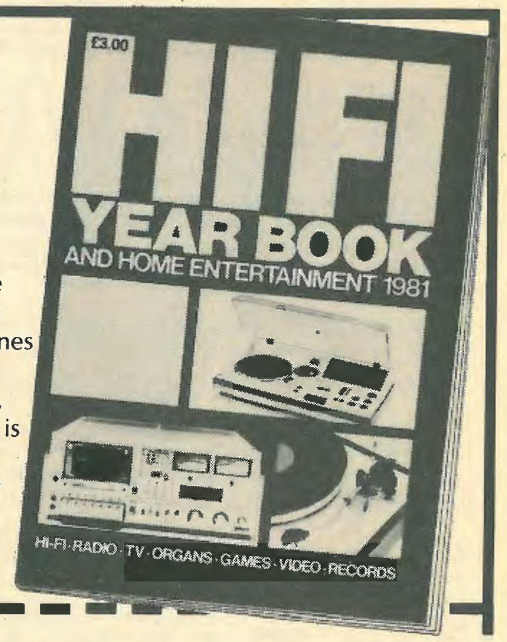

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75452	19,700	.40	UA709	25,400	.25
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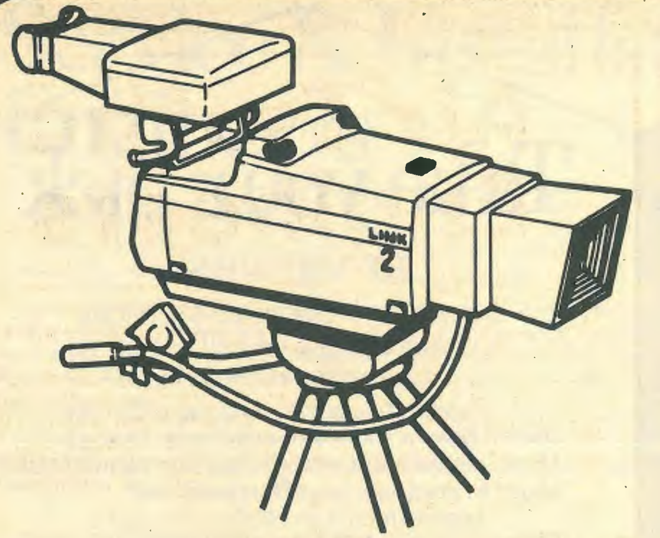

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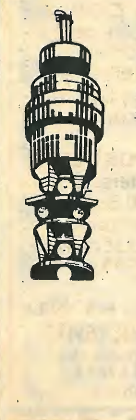

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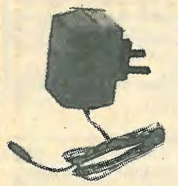

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