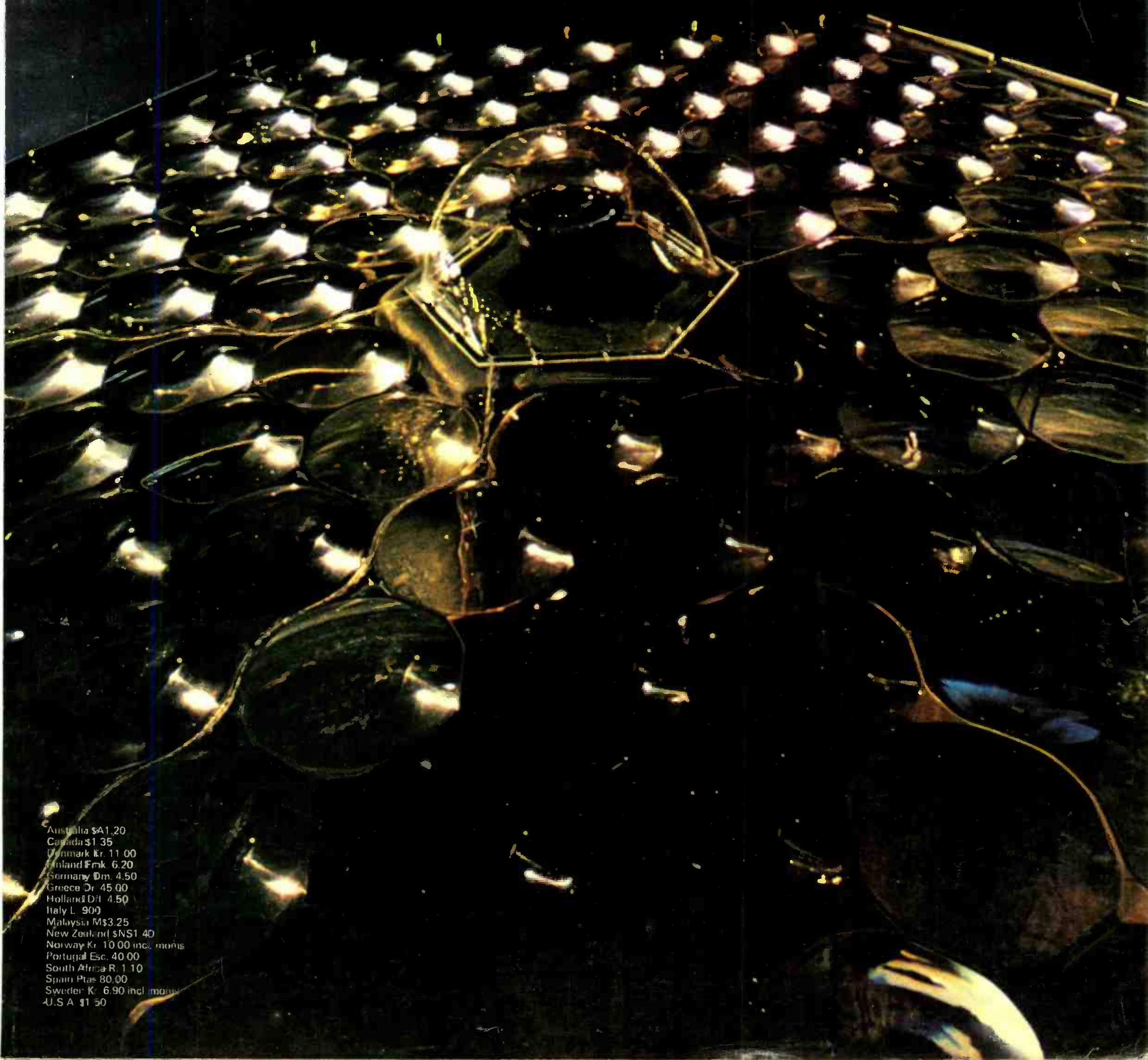
wireless world

CONSTRUCTIONAL DESIGN FOR A L.C.D. DIGITAL WATCH

OCTOBER 1976 35p

Power from the sun

Load lines



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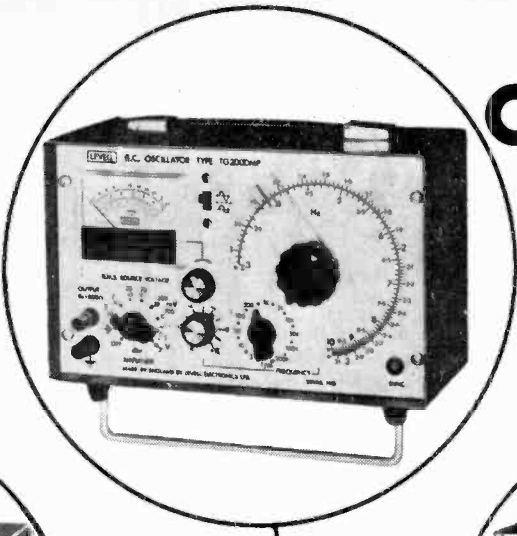
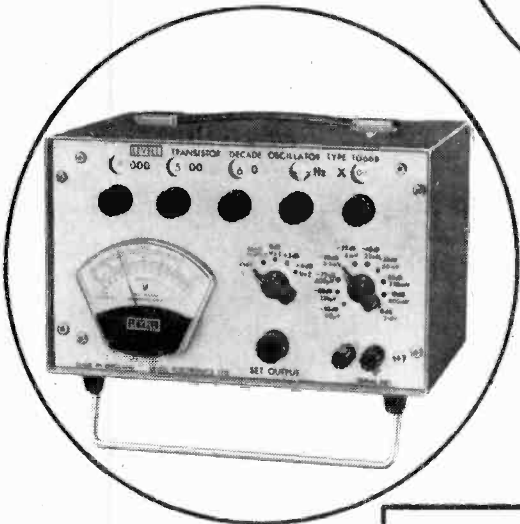
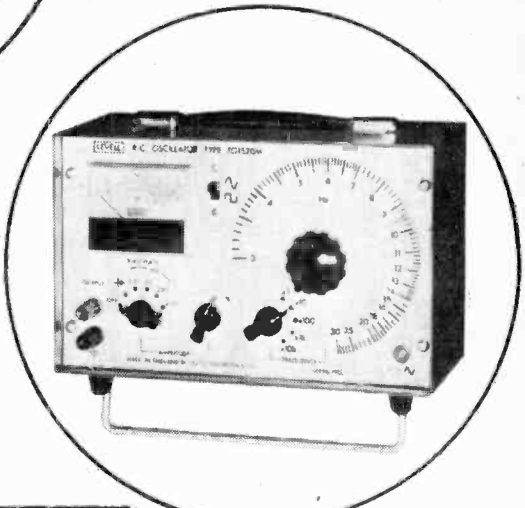






FREQUENCY	1Hz to 1MHz in 12 semi-decade ranges. 0 to 1% fine control included on TG200DMP.
ACCURACY	±2%±0.03Hz.
SINE OUTPUT	7V r.m.s. down to <200μV with Rs =600Ω.
DISTORTION	<0.1% to 5V, <0.2% at 7V from 10Hz to 100kHz.
SQUARE OUTPUT	TG200D, DM & DMP only. 7V peak down to <200μV. Rise time <150nS.
SYNC. 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	260mm x 130mm x 180mm. 4.3kg.

TG200	TG200D	TG200M	TG200DM	TG200DMP
£69	**£73**	**£84**	**£88**	**£92**

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 300 kHz. ±3% above 300 kHz.
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 &—2/+4dBm.
SIZE & WEIGHT	260mm x 190mm x 180mm. 5.6kg.

TG66B Battery model **£180**

TG66A Mains & battery model **£195**

FREQUENCY	3Hz to 300kHz in 5 decade ranges.
ACCURACY	±2% ±0.1 Hz up to 100kHz, increasing to ±3% at 300kHz.
SINE OUTPUT	2.5V r.m.s. down to <200μV.
DISTORTION	<0.2% from 50 Hz to 50kHz.
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	260mm x 130mm x 180mm. 3.4kg.

TG152D Without meter **£55**

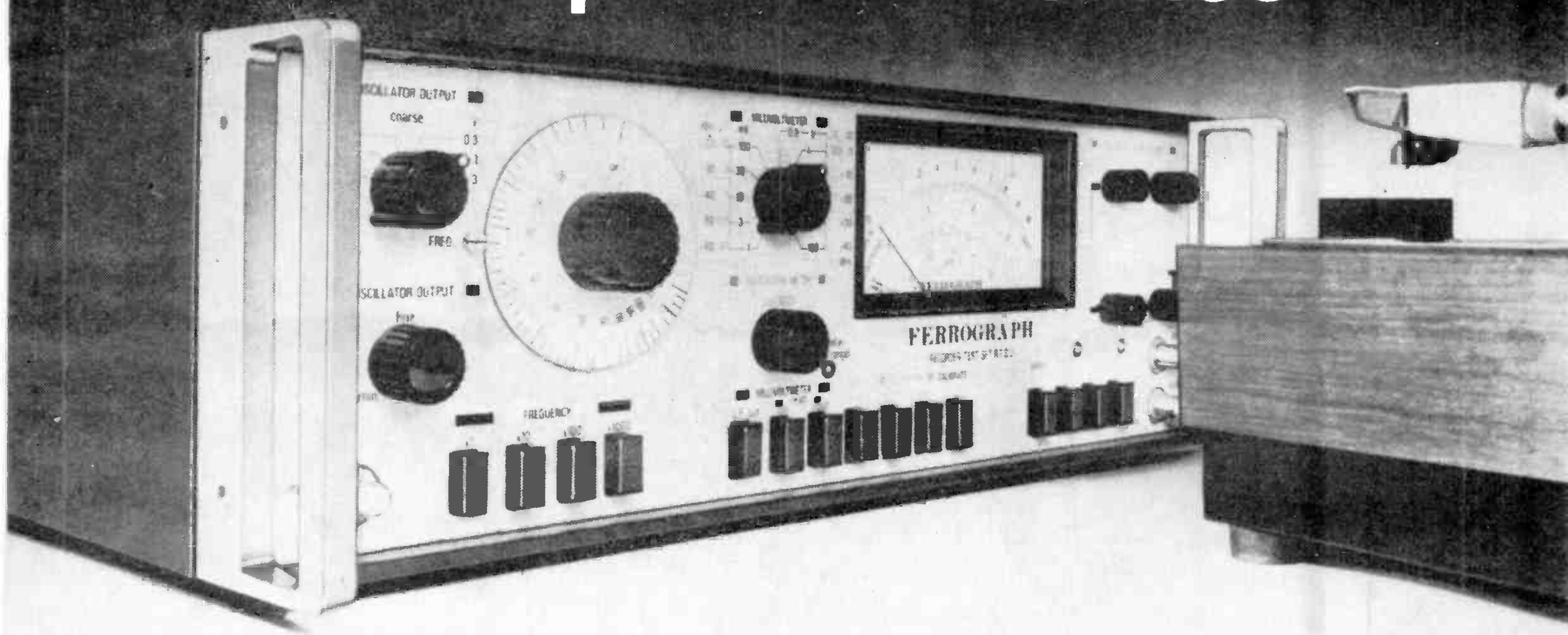
TG152DM With meter **£69**

LEVELL ELECTRONICS LTD.
Moxon Street, High Barnet, Herts. EN5 5SD
Tel. 01-449 5028/440 8686

Prices include batteries and U.K. delivery. VAT extra. Optional extras are leather cases and mains power units. Send for data covering our range of portable instruments.

WW—016 FOR FURTHER DETAILS

How every hi-fi dealer can increase his sales and improve his service



The Ferrograph RTS 2 is a complete, single-unit audio analyzer. Used by leading manufacturers and dealers throughout the world, it is the only single equipment available that can run exhaustive checks on hi-fi – including amplifiers, tape recorders, equalisers and mixers – making it an invaluable aid to sales and service.

Increase your sales!

By using the RTS 2 in your hi-fi store, your salesman can quickly *prove* to customers that the hi-fi system he is demonstrating is as good as it sounds. In a matter of seconds, *up to ten different tests* can be carried out, using just one pair of leads. (The push-button operation is so simple, even unskilled staff can make accurate measurements.)

Result? The customer is reassured, confident he is getting value for money. So you sell more, more easily.

Improve your service!

But the RTS 2 is much more than a cost-effective sales aid. Used in your service department, it quickly identifies faults, making your after-sales back-up more efficient. And more profitable. You don't need a variety of incompatible test gear – so there are fewer connections, no hum-loops, no time-consuming frustrations. All of which means you save money.

The RTS 2 is an unbeatable demonstrator. It's so simple! And as test equipment, there's nothing faster.

Photograph by courtesy of Sewards in Reading.

Ferrograph RTS 2

the complete, single-unit audio test set.

Wilmot Breeden Electronics

Ferrograph Rendar Wayne Kerr

☐ Send me more information about the RTS 2 audio test set.
☐ I would like a demonstration. Phone me to arrange an appointment.

Name ____________ Address ____________

Company ____________

Tel. No. ____________ WW

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Durban Road, South Bersted,
Bognor Regis, West Sussex, PO22 9RL.
Telephone: Bognor Regis 25811
(STD Code 02433)

Ask us for a demonstration of the Ferrograph RTS 2 before your customers ask you. Send off the coupon today!

DECADE BOXES

"Junior" Series—Resistance—1%

	Decades	Ohms Range	Ohms Resolution	£
J1	5	0–1,111,100	10	**30.90**
J2	5	0–111,110	1	**30.50**
J3	4	0–111,100	10	**25.10**
J4	4	0–11,110	1	**24.80**
J5	3	0–11,100	10	**20.60**
J6	3	0–1,110	1	**20.50**
J60	6	0–1,111,110	1	**37.20**
J70	7	0–11,111,110	1	**43.70**

"Junior" Series—Capacitance—1%

	Decades	pF Range	pF Resolution	£
JC1	3	100–111,000	100	**22.20**
JC2	2 +var	30–11,140	"Infinite"	**23.20**

"Point One" Series—Resistance—0.1%

	Decades	Ohms Range	Ohms Resolution	£
R3	4	0–1,111	0.1	**50.85**
R4	4	0–11,110		**50.53**
R5	4	0–111,110	10	**49.67**
R7	5	0–1,111,100	10	**61.71**
R9	5	0–111,110	1	**62.35**
R10	5	0–11,111	0.1	**62.89**
R11	5	0–11,111,000	100	**71.81**
R20	6	0–1,111,110	1	**74.71**
R21	6	0–111,111	0.1	**75.68**
R22	6	0–11,111	0.01	**82.24**
R30	7	0–11,111,110	1	**94.39**
R31	7	0–1,111,111	0.1	**87.72**
R32	7	0–111,111.1	0.01	**88.37**
R41	8	0–11,111,111	0.1	**107.07**
R42	8	0–1,111,111.1	0.01	**102.88**

"Hundred" Series—Resistance—0.03%

	Decades	Ohms Range	Ohms Resolution	£
R400	4	0–111,100	10	**87.20**
R401	4	0–11,110	1	**91.40**
R402	4	0–1,111	0.1	**92.40**
R403	4	0–111.1	0.1	**98.70**
R600	6	0–11,111,100	10	**118.70**
R601	6	0–1,111,110	1	**120.80**
R602	6	0–111,111	0.1	**122.90**
R603	6	0–11,111.1	0.01	**128.70**
R701	7	0–11,111,110	1	**140.70**
R702	7	0–1,111,111	0.1	**142.80**
R703	7	0–111,111.1	0.01	**148.10**
R802	8	0–11,111,111	0.1	**160.20**

DECADE BOXES continued

	Decades	Ohms Range	Ohms Resolution	£
R803	8	0–1,111,111.1	0.01	**162.80**

High Dissipation—Resistance—1%

	Decades	Ohms Range	Ohms Resolution	£
HD1	5	0–1,111,100	10	**104.70**
HD1/L	5	0–111,110	0.2 Approx.	**110.30**

"Point One" Series—Inductance—5%

	Decades	mH Range	mH Resolution	£
L1	3	0–1,110	1	**95.60**
L2	2	0–110	1	**67.10**
L3	2	0–1,100	10	**74.50**

"Hundred" Series—Inductance—0.3%

	Decades	mH Range	mH Resolution	£
L300	3	0–1,110	1	**277.00**
L400	4	0–11,110	1	**360.00**

CAPACITANCE BOXES

Decades

	Decades	pF Range	pF Resolution	Accuracy	£
C3	3	100–111,000	100	1%	**48.30**
PC3	3	100–111,000	100	0.5%	**66.70**
C4	4	100–1,111,000	100	1%	**73.60**
PC4	4	100–1,111,000	100	0.5%	**103.80**

Decade plus Variables

	Decades	pF Range	pF Resolution	Accuracy	£
VC4	3	50–111,150	INFINITE	1%	**61.00**
VC5	4	50–1,111,150	,,	1%	**86.30**
PVC5	4	50–1,111,150	,,	0.5%	**128.80**
SVC5	4	50–1,111,150	,,	0.05%	**574.20**
C500	4	50–1,111,150		0.2%	**238.50†**

SVC5 special. Details on application

Variables

	pF Range	Accuracy	£
PVC1 Mk 2	5–200	0.5%	**111.32**
PVC2 Mk 2	20–1,120	0.5%	**101.20**
VC2	20–1,130	1%	**42.60**
PVC4	0–10	1%	**77.22**
PVC1/S	20–120	0.5%	**67.10**

Switched

	uF Range	uF Resolution	Accuracy	£
C140	0–140	1.0	5%	**156.00†**
C100	0–100	1.0	5%	**132.00†**
C60	0–61	0.1	5%	**117.60†**
C60P	0–61	0.1	1%	**239.00†**

† Packing and Handling extra. Prices do not include VAT

INSTRUMENTS

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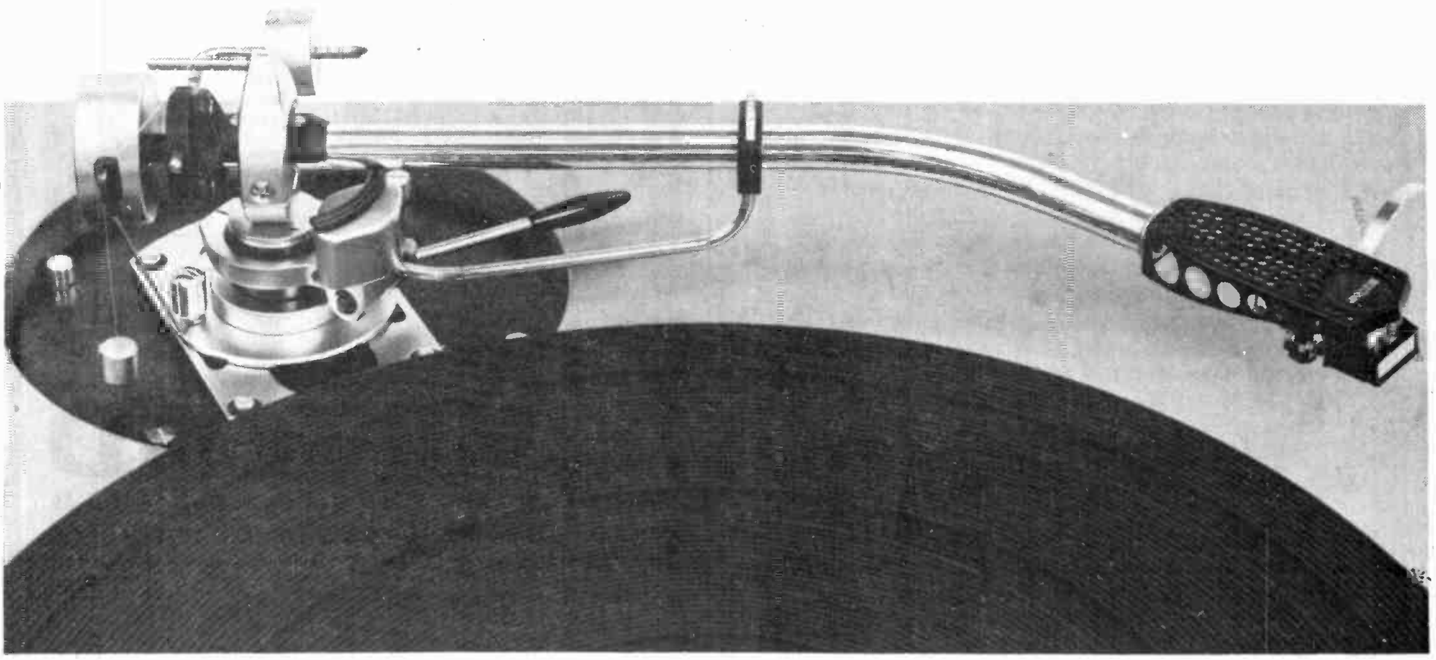

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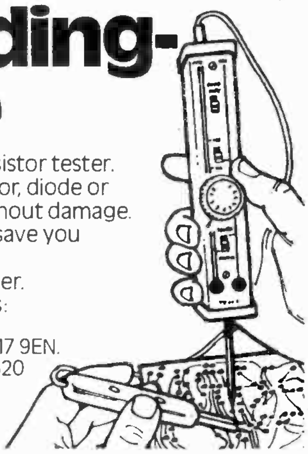
fault finding-no fiddle



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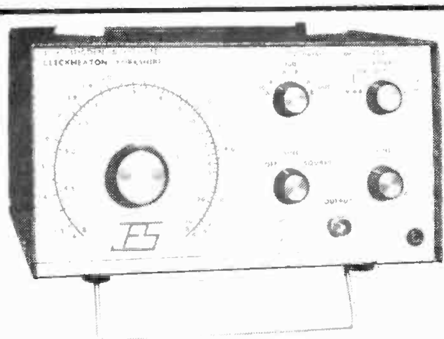

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★ very low distortion content—less than 0.03%
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Si452 Distortion Measuring Unit
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These modules are fully assembled, tested and guaranteed units, as featured in our tuner designed by experts in integrated circuit technology and applications, they represent the finest available modules, ideal for incorporation into top quality home built systems.

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including ten turn manual tuning pot

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including L.E.D. indicator

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six channel & provision for manual tune

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20v, 100mA output, 240v input

M5 TOUCH TUNE PRE-SELECT UNIT — **£17.54**
A touch switched replacement for M3

All items (except M5) are available in kit form, or as individual J.C.s, P.C.B.s, etc.

Full metalwork and teak cabinet is also available to complete the finest tuner on the market today.

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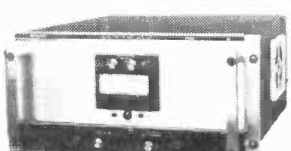

	M600	DC 300A	D150A
RMS power out	750 watts into 8 ohms 1,350 watts into 4 ohms	500 watts rms into 2.5 ohms (1 chan)	200 watts into 2.5 ohms (1 chan)
Power bandwidth	DC to 20 kHz + 1 db — 0 db	DC-20kHz + 1 db — 0 db	DC-20 kHz + 1 db, — 0 db
Phase response	+ 0′ — 15′ DC — 20 kHz	+0, — 15′ DC to 20kHz	+ 0′, — 15′ DC to 20 kHz
Slew rate	16 V/μsecond	8 volts per microsecond	6 volts per microsecond
Hum & noise	120 db below 600 Watts	At least 110db below 150 watts	At least 115 db below 90 watts
Dimensions	19″ std rack, 8¾″ H, 16½″ Deep	19″ Rackmount, 7″ High, 9¾″ Deep	19″ Rackmount, 5¼″ H, 8¾″ D.

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It can be seen and heard at our demo studio. Pembroke House, Campsbourne Road, Hornsey, London N8.

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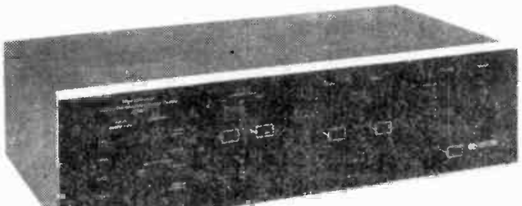

ZD22 Stereo Pre-amplifier Control Unit
A stereo pre-amplifier of virtually zero distortion. Inputs for disc, tuner, and two tape machines, providing comprehensive recording and reproducing facilities. Sensitivities: Disc 1mV, and Auxilliaries 50mV., for 1V output. Exceptional signal/noise ratio. Output at clip level 18V r.m.s.

ZD50 Power Amplifier
A stereo power amplifier of all aluminium construction. Output of 110 watts per channel into 4 ohms and 70 watts into 4 ohms at typically less than 0.002% distortion.

ZD100 Power Amplifier
A stereo power amplifier of all aluminium construction with high thermal mass and designed for continuous operation at high output level. Provides 150 watts per channel into 4 ohms and 90 watts per channel into 8 ohms at virtually zero distortion.

ZD200 Power Amplifier
Characteristics as ZD100 amplifier but provides an output of 250 watts per channel into 4 ohms and 150 watts per channel into 8 ohms.

HD250 Stereo Integrated Amplifier
Uses ZD22 pre-amplifier with a power amplifier having a power output in excess of 50W per channel into 4-8 ohms. Distortion: less than 0.02% at rated power, typically less than 0.01%. True complementary symmetry output. Headphone output. Inputs: Disc, tuner, and two tape machines. Sensitivities: Disc 1mV. Auxilliaries 50mV for 20W output.

Full descriptive leaflets available from:
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FREQUENCY COUNTERS

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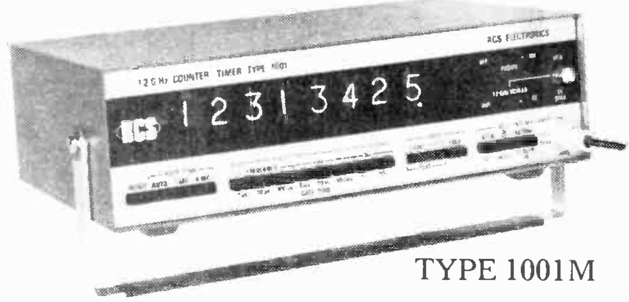

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TWO TONE BLUE CASE

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Sensitivity 10mV. Stability 5 parts 10^{10}

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wireless world

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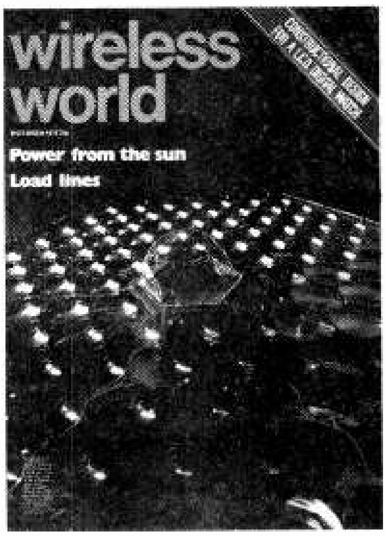

Front cover shows a modular solar energy unit developed and photographed by the RCA Corporation in their Princeton, New Jersey laboratories.

IN OUR NEXT ISSUE

Advanced preamplifier design with noise gating, undetectable distortion, high overload margin and accurate equalization.

Optical fibre communication. Part one of this two-part article covers the status of fibre systems and gives design considerations for a large-scale field demonstration. Part two will describe equipment requirements.

Mobile radio systems in the v.h.f. and u.h.f. bands are surveyed, with particular attention to equipment for land mobile use. Problems of frequency selection, interference and noise are discussed, modulation modes are compared and reliability is examined.

wireless world

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GORDON HENDERSON

Business is business

To the ordinary observer it seems that in business anything goes as long as both parties agree about a transaction and are satisfied with it. It is even possible to have fair trading in an illegal commodity. But when the transaction crosses a national frontier other interests are affected, notably the economic and perhaps the military security of the countries concerned. Hence the recent calls in Britain for import controls on consumer electronics goods (reported in the August and September issues). Referring to Japanese competition in colour television sets, Mr Edward Lyon, the M.P. for Bradford West, said in the House of Commons recently "It is quite clear that we are facing unethical business practices with the long-range objective of destroying sectors of Western European industry."

Unfortunately there are no real ethics in business, beyond the basic agreement mentioned above, and the practice of knocking out a sector of somebody else's industry, whether at home or abroad, is an accepted part of business activity. As for the accusations of dumping, made against the Japanese now and the Americans earlier (on integrated circuits), it must be remembered that there are people in one's own country who are buying the dumped goods and that they are just as much to blame, for conniving in the practice, as the sellers in another country.

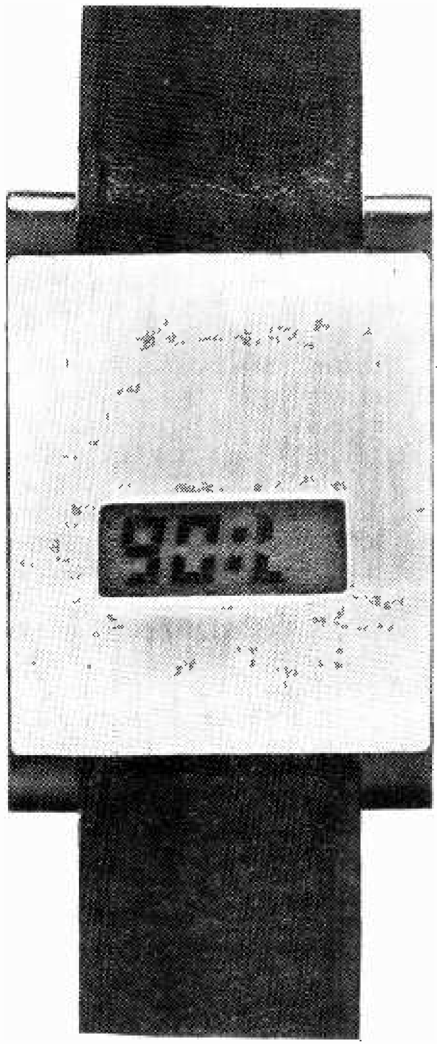
Leaving aside questions of right or wrong, it seems inevitable that protectionism must be applied, as it is, indeed, by nations all over the world. In itself it has become a part of business. There seems to be several types of protectionism in use. First of all there is the direct process of controlling imports to keep them at levels which are safe for one's own industry. Secondly there is export protectionism, such as the Americans are thinking of applying to "mechanisms that transfer key know-how" of strategic value to the Soviet Union. Thirdly there is a protectionism directed against foreign technological systems, for example in the discrimination applied in America against the Decca Navigator system to protect US electronics industry interests.

In Britain protectionism alone is not enough to get us out of trouble. If the government is to be called in to intervene in business affairs it should also be to support particular sectors of industry which are worth supporting because they have considerable export potential. This must be done selectively because, as a small nation, we have insufficient resources to be experts at making and selling everything. It is good to see that certain types of electronic products have been chosen for long-term economic planning by the National Economic Development Council as part of the government's "new industrial strategy" introduced last year.

Digital wristwatch

Single i.c. design using a liquid crystal display — 1

by P. A. Birnie



This design allows a 3½-digit watch to be built for under £25 by using a minimum of components. The use of a p.c.b. and conductive plastic sockets eliminates much of the tedious wiring normally associated with d.i.y. watches. If the module is housed in the case detailed the result is a slim and compact timepiece measuring 40 x 28 x 8mm.

A dramatic increase in the availability of digital wrist watches over the past year has not been reflected in the build-it-yourself market, and only one well known (l.e.d. display) kit is currently available. This design uses one i.c. and, as shown in Fig. 1, represents a minimum component design as used in mass-produced devices. The watch uses a 3½-digit liquid crystal display (l.c.d.) operating in a 12 hour mode. A 32,768Hz quartz crystal offers a stability, after initial ageing of about four weeks, of better than a minute per year and, with careful adjustment, a few seconds per year. Power is supplied by mercury cells which give at least a year of continuous operation.

In the functional diagram of Fig. 2 the crystal uses an amplifier and integral feedback resistor in the i.c. to form, in conjunction with the fixed capacitor and trimmer, a stable frequency source for the watch. A field-effect l.c.d. is connected to 22-segment outputs and one back-plane or common output. Setting of the time is achieved by two single-pole switches. The terminal marked test-in allows high-speed operation of the device. Another terminal marked DDC is designed to drive a d.c. to d.c. converter for generating up to 6V. for the display. In this design two cells are used instead of the last-mentioned output because it is more economical in space and cost. Those wishing to experiment with the converter can use a circuit similar to Fig. 3 which is designed to generate a 6V d.c. supply across the 20nF capacitor. This voltage must not exceed the 6V maximum for any input on the TA6478.

Multiplexing of the display is not possible because all of the segments have one common back plane connection. The l.c.d. consists of two pieces of glass sandwiching a thin chemical layer as shown in Fig. 4(a). This layer can be made opaque when an electric field is applied across it. Digit segments are deposited on the inner face of the front piece of glass using a virtually transparent conducting material. The inner face of the rear piece of glass has an overall back plane covering of the same material. A piece of highly reflective tape is fixed to the rear of the device which is less than 2mm thick. To reduce degradation of the cell an alternating voltage is used to drive the segments as shown in Fig. 4(b). A square wave of about 30Hz is directly applied to the back plane and the segments are connected to the outputs of exclusive-OR gates. Fig. 5 shows the square wave applied to the back plane, the 180° out-of-phase waveform applied to segment a, which turns it on, and the in phase waveform applied to segment b, which turns it off. The actual waveforms applied to the display are shown in Fig. 6. Note that the alternating voltage effectively doubles the supply which greatly increases the contrast ratio. Current consumption of the display is about 3000nA under normal operating conditions.

Operation of the oscillator can be explained by reference to Fig. 7. Within the TA6478 a pair of complementary m.o.s. transistors form a simple inverter, and the trimmer capacitor allows a frequency change as shown in Fig. 8. The crystal is designed specifically for miniature time keeping applications and operates in the length-width mode of vibration. Mechanical characteristics of the crystal are carefully optimized to reduce ageing effects but, as Fig. 9 shows, a certain amount of drift occurs predominantly over the first six to eight weeks.

The batteries used in this design are not conventional watch types. Instead, two RM312H mercury cells are used which are cheaper and more readily available. As the voltage drops at the end of the cell life the oscillator will cease driving the colon correctly. At this point the cells should be replaced immediately because a direct voltage is being applied to the display.

Mounting and interconnections

Overall size of the TA6478 necessitates the use of a printed circuit board and an enlarged layout is shown in Fig. 10. Three large areas on the right of the board allow supply connections, and an additional V_{DD} pad on the left terminates the earth sides of the two capacitors. This pad also provides an earth screen for the oscillator terminals. Two small rectangular pads from S_1 and S_2 allow flying leads to be connected to the

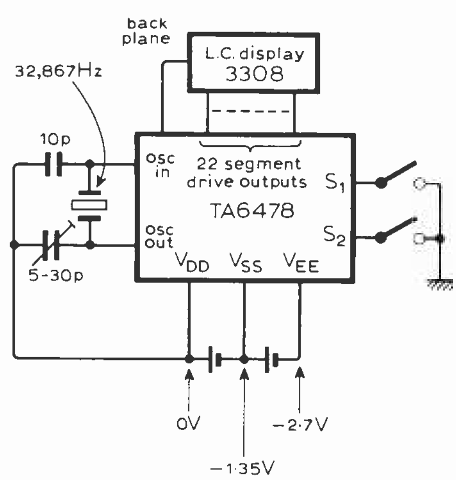


Fig. 1. Block diagram of circuit using two conventional mercury cells.

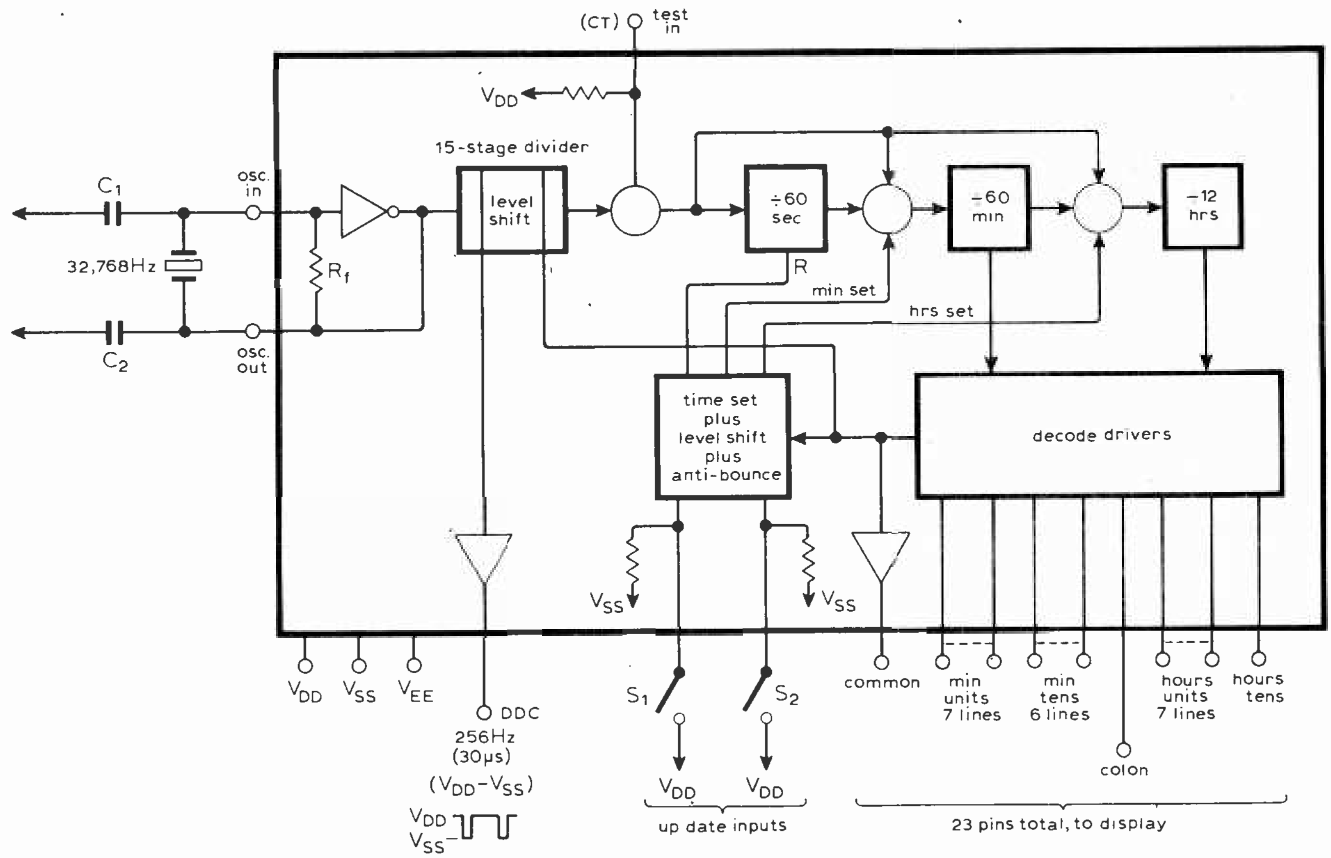


Fig. 2. Functional diagram of the TA6478. The DDC output can be used to generate up to 6V for the display.

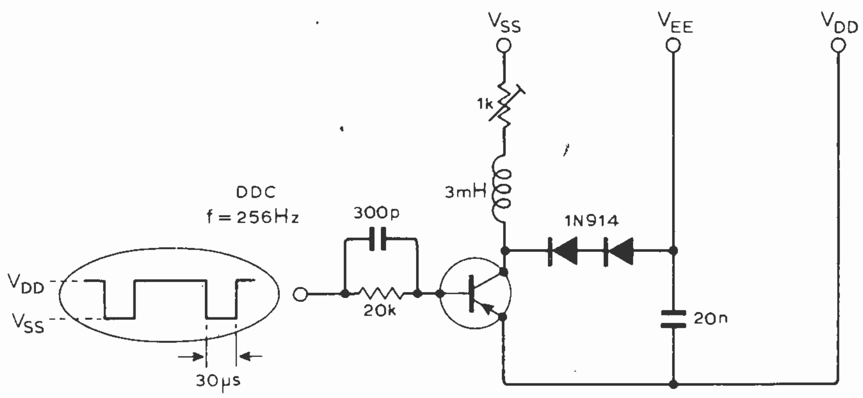


Fig. 3. Converter suitable for use with the DDC output.

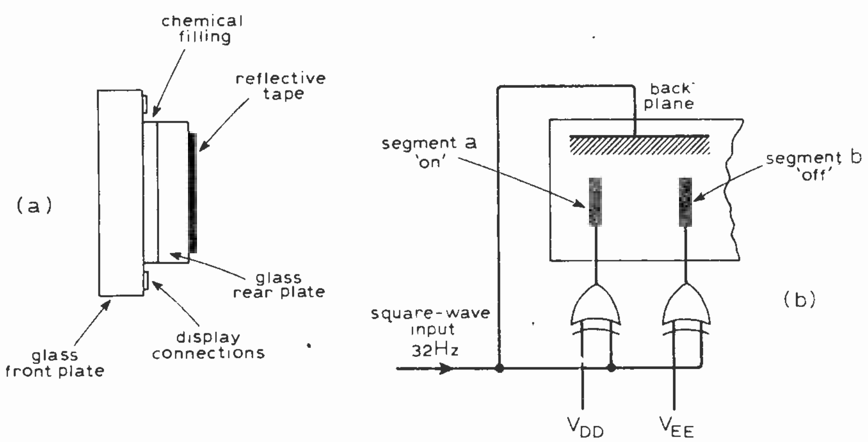


Fig. 4(a). Cross section of a l.c.d. cell; (b) method of producing the in and out of phase signals for the segments.

setting switches. Two pads on the left of the board connect to the oscillator terminals and allow mounting of the crystal, and ends of the capacitors. Attachment of the TA6478 to the board is made relatively easy by using the following method.

Spread a thin layer of Multicore Solders type XM27330 cream over the i.c. pads and place the i.c. in position. Secure a piece of aluminium at least 6in square in the horizontal position and place the board in the middle. Precisely line up the i.c. on the board and then heat the underside of the metal plate with a gas blow torch. At 179°C the paste becomes liquid and at this point raise the temperature very slowly until the liquid turns to solder which will flow over the tinned pads. After a few seconds remove the heat and leave the board to cool. If all of the pins have not been soldered correctly, the process can be repeated. Remove surplus flux and paste using cellulose thinners. Normal c.m.o.s. handling practice should still be adopted even with the i.c. mounted on the board.

The crystal is mounted as shown in Fig. 10, taking care to insulate it from the board and the i.c. Crop the trimmer capacitor leads and mount it in place making sure that the lead which is electrically connected to the adjusting screw is soldered to the V_{DD} pad. Finally mount the fixed capacitor in place.

Initial testing

Testing can be carried out by using fine flexible wires. Make connections to the

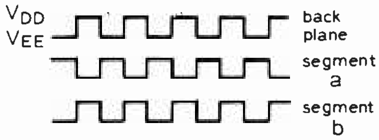


Fig. 5. Signal applied to the backplane with the in and out of phase signals for turning segments on and off.

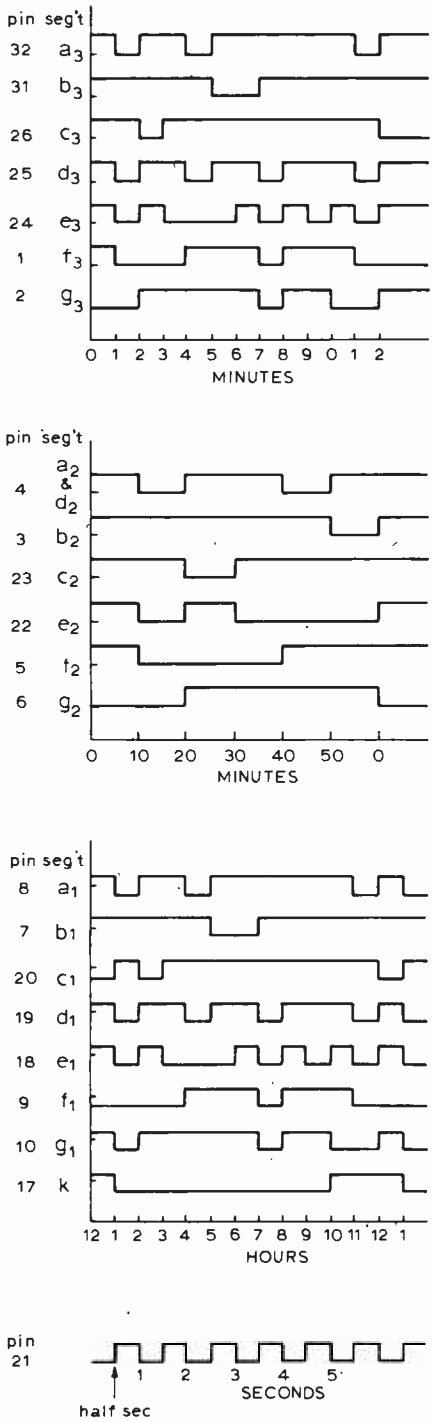


Fig. 6. Actual signals applied to the display.

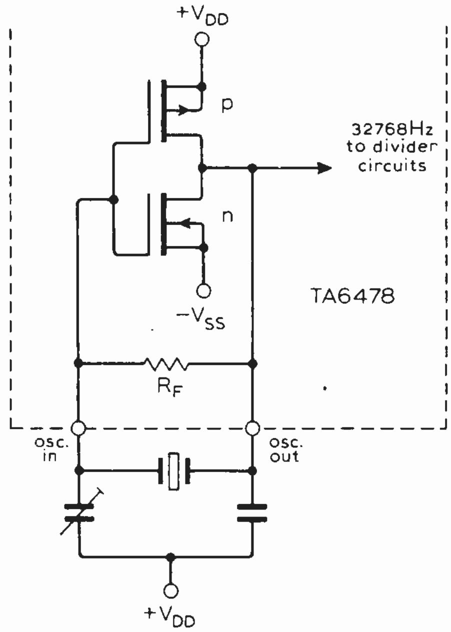


Fig. 7. Integral m.o.s. transistor inverter of the TA6478.

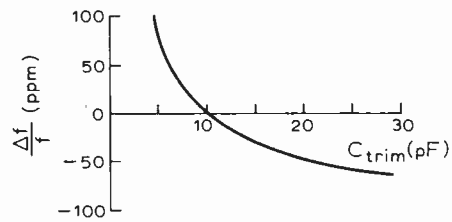


Fig. 8. Change in frequency for change in trimmer capacitor value.

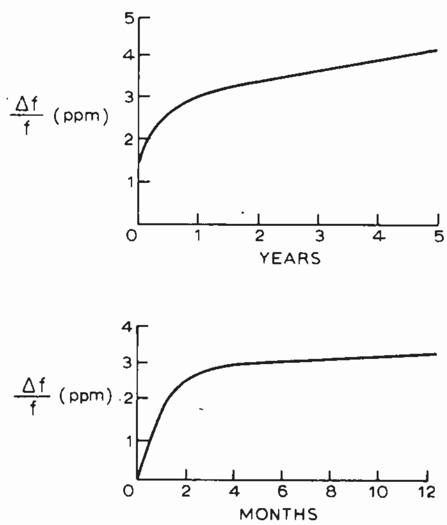


Fig. 9. Ageing effects of the crystal. Most of the drifting occurs within the first 6 weeks of operation.

battery terminals V_{DD}, V_{SS}, V_{EE}, the display common and colon, and also the DDC point if an oscilloscope is to be used. Connect two 1.5V dry cells as shown in Fig. 1, with a 0-50μA ammeter in series with the V_{DD}-V_{SS} supply. This cell should supply between 3 and 5μA, readings outside this range indicate a circuit fault. If an oscilloscope is available check the DDC waveform shown in Fig. 3. If an accurate method of measuring frequency is available adjust the trimmer to give exactly 256Hz.

Testing without an oscilloscope is performed by using the display to indicate correct outputs at display common and colon terminals. Fig. 11 shows the display connections from the front of the device. Using two flying leads from common and colon, a display of a segment should occur when the wires are lightly touched onto the display contacts. Because each segment has a resistance of several hundred megohms, it is virtually impossible to electrically damage either display or driver, but it is easy to physically damage the contact areas on the display. If a weak display appears, the oscillator is not running and a direct voltage is being applied to the terminals. This can be checked with a voltmeter which will give no d.c. reading when the basic module is functional and about 3V if it is faulty.

A further test uses a pulse generator to inject a 32kHz square wave of 1.4V pk-pk (reference to V_{DD}) into osc in, after removing the quartz crystal. If, on repeating the previous tests, correct results are obtained then it is almost certain that the crystal is faulty or has been incorrectly connected. If the tests still do not result in the correct display conditions, the i.c. has been incorrectly connected or damaged during assembly.

Display mount

When the display is on top of the p.c.b. module, the i.c. output directly aligns with the display inputs. Connection is made by two small printed wiring boards and a conductive rubber material. The rubber is necessary because the contact material of liquid crystal displays is not suitable for soldering, and it allows easy replacement of the display. An end view of the basic module and display mount is shown in Fig. 12. The two display mounts are small printed wiring boards with twelve tracks 29 "thou" wide and spaced 29 "thou" apart. The two small boards are aligned with the basic module so that twelve tracks on each are directly aligned with the corresponding tracks on the module.

After ensuring that the display fits into the mount, the boards are glued, using Araldite, onto the module. Interconnection is achieved by soldering fine wires between the relevant pads. To

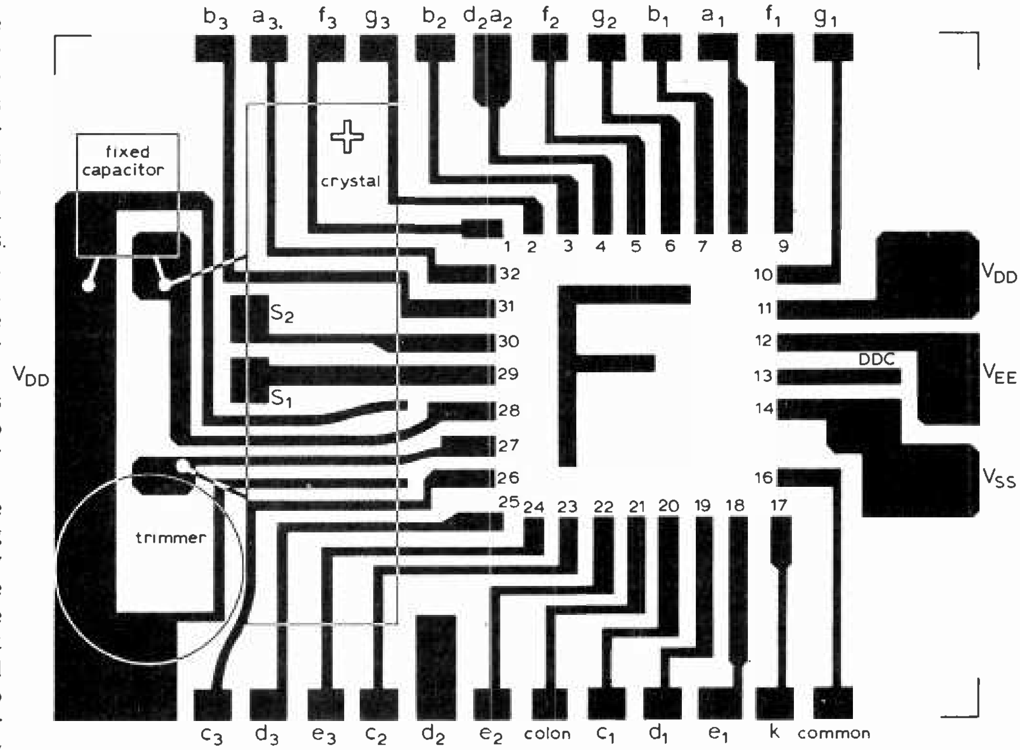


Fig. 10. Enlarged layout of the printed circuit board.

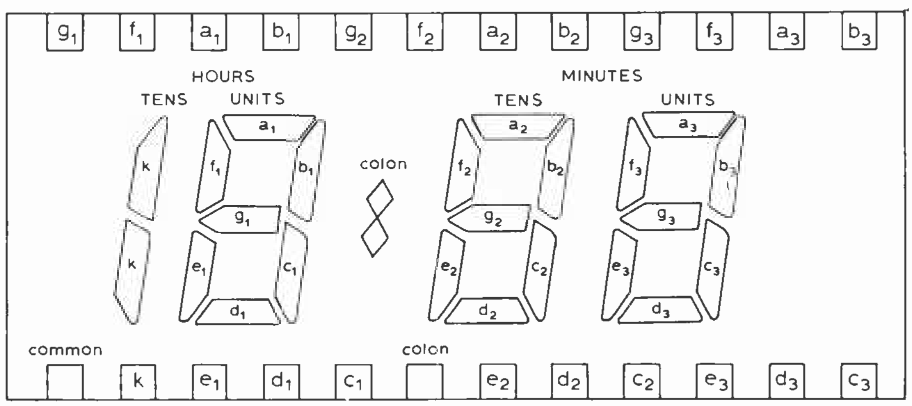


Fig. 11. Display connections from the front of the device. Normally the display is blank; if it is breathed on and examined under a strong light, the segments can be identified.

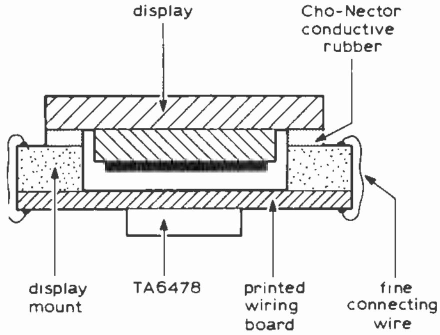


Fig. 12. End view of printed circuit module and display. The display-mounts are small p.c.bs as shown in Fig. 13

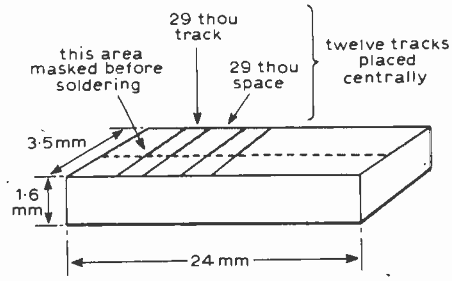


Fig. 13. Dimensions and masking details for the display-mounts. These boards are glued to the main p.c.b., and connected using fine tinned wire.

avoid solder spreading onto the display contacts, it is essential to mask these areas with adhesive tape before soldering. Fig. 13 shows how this is done and also gives dimensions for the two mounts. It is also essential to use tinned copper wire of very small diameter such as 0.1mm. All connections are straightforward except the one labelled d_2a_2 in Fig. 10 which drives two display segments rather than one. From the d_2a_2 output on the module a wire connects directly up the side of the display mount to segment a_2 and another wire is taken over the surface of the integrated circuit, using the spare pad between outputs c_2 and e_2, and then up the side of the display mount to segment d_2. If this wire is kept taut there is no danger of a short to other pads. Although it is possible to connect the display by placing it on top of the display mount pads, conductive rubber is necessary to take up irregularities. Small pieces of conductive foam, as used to protect c.m.o.s. devices, may be glued to the solder connection on each display-mount pad using contact adhesive. The adhesive must be kept away from the display contacts. A better solution, however, is to use a material called Cho-Nector which is designed for this application and has unique conductive properties best explained by reference to Fig. 14. The material contains carefully controlled conductive areas which have a maximum dimension of not greater than 60% of the material thickness. When contacts are placed on opposite surfaces the overlap of conductive areas forms a connection. Provided the contact separation across the surface of the material is greater than the specified minimum, resistance between contacts on the same surface is greater than 10^9 ohms. In practice, material of 10 "thou" is used which permits contact spacings down to 12 "thou" and a minimum area of 12 "thou" square. Two strips 3 × 24mm are secured to the display mount by a spot of adhesive. The Cho-Nector should not be contaminated with grease or sweat. The pads can be cleaned but should not be treated with an abrasive substance. The Cho-Nector can also be treated with an alcohol based cleaner but petroleum or chlorinated solvents will damage the material.

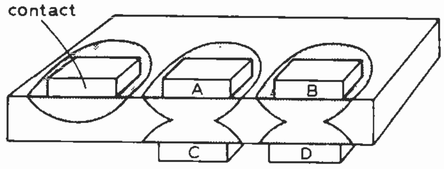


Fig. 14. Operation of the Cho-Nector. Conductive areas in the rubber make contacts through the thickness of the material but not across the surface provided the contacts are far enough apart.

Testing the assembled module

The completed module should be tested to ensure that all segments operate correctly, and trimmed for initial adjustment. Connect flexible wires to the two V_{DD} pads, V_{SS}, V_{EE} and S_1, S_2 pads. Using two 1.5V cells connect the supplies. Connect wires from S_1 and S_2 via single pole switches to V_{DD}. Place the display in the mount, ensuring correct orientation. If the viewing surface is breathed on and examined under a strong light the orientation can be checked. If a correct display is not obtained two possibilities exist. Either the display is not aligned with the mount in which case move it from side to side until the display is correct, or the integrated circuit is in an incorrect display condition. This can be remedied by carrying out a time-setting sequence as in the table. When a correct display is achieved, two scraps of perspex should be glued in the mount to prevent side movement of the display. Using scraps of plastic or perspex, construct a temporary clamp to hold the module together for a few days while the trimmer is adjusted with the help of the GPO clock.

To be continued

Time setting sequence

Colon state before switch closure	S_1	S_2	Function after switch closure
Flashing	open	open	normal operation
Flashing	open	closed	hours change at 1Hz rate while S_2 closed
Flashing	momentarily closed	open	seconds reset, S_2 now controls minutes-set
Continuously on	open	closed	minutes change at 1Hz rate while S_2 closed, hours not affected
Continuously on	open	open	set time held
Continuously on	momentarily closed	open	normal operation

Parts list

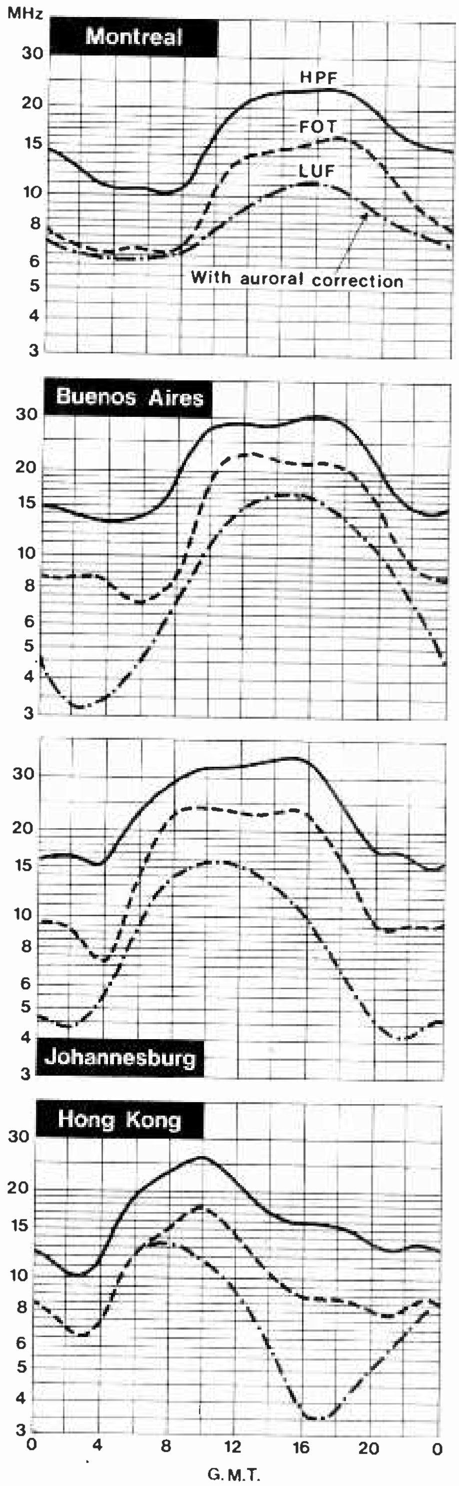
Integrated circuit TA6478 (RCA)
Display 3308 (Hamlin Electronics Ltd)
Crystal 32,768Hz subminiature type (Sintel, 53 Aston Street, Oxford)
Trimmer CT-5, 5-30pF (Pulsar Developments Ltd,
Fixed capacitor 10pF
Mercury cells RM312H (two off)
Three p.c.b.s (see text)
Display connector two off 3 × 24mm pieces of 12 thou thick
Cho-Nector conducting sheet (Steatite Insulations, Hagley House, Hagley Road, Birmingham B16 8QW)

We understand that Pulsar Developments Ltd, Spracklen House, Dukes Place, Marlow, Bucks, are organizing a kit of parts for a digital watch based on the published design.

HF predictions

Ionospheric, as distinct from solar, indices are used for predicting characteristics of the ionosphere which determine path MUF. Most important of these are the monthly median values of vertical-incidence critical frequency of the E and F layers and the MUF/distance factor of the F layer.

Variations of any index with time shows three components, a regular component of about eleven year period, a component with a period of about a year which appears over the few years of a maximum in the eleven year cycle and an erratic fluctuation component due to rapid changes in solar activity which cannot be resolved by a monthly mean index.



News of the Month

Dolby and Capital, at last

The IBA and the Home Office have authorised Capital and BRMB commercial radio stations to go ahead with experimental broadcasts using Dolby and variable pre-emphasis, but even if the tests are overwhelmingly successful the use of the techniques may never become permanent.

It emerged during a press conference held at Capital's headquarters in Euston Tower, London, on July 29 to announce the experiment that the IBA were keen to tell the public that the experiments would be held and to encourage the public to write to them at the engineering information service at Crawley Court, Winchester to say whether the techniques were effective and whether there were any ill-effects. Tests carried out in other countries, notably Germany, had been carried out unannounced, and both the IBA and Capital, after two years of private tests, had intended earlier in the year to carry out unannounced broadcast tests in the UK. Capital chief engineer Gerry O'Reilly had approached the IBA with the proposal for lengthy announced and unannounced tests.

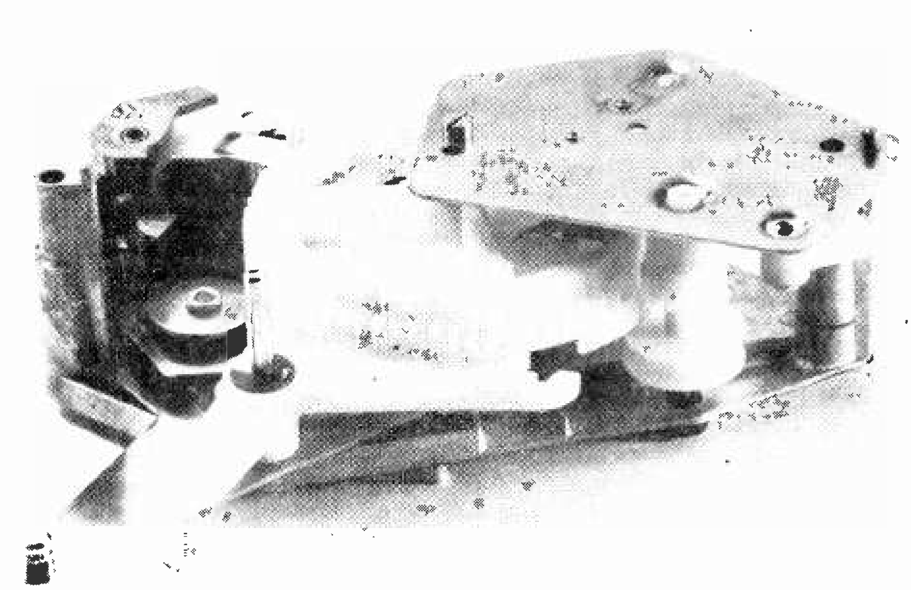
After discussions between the IBA and the Home Office, however, the present proposal emerged: from October 1 to 14 all Capital transmissions will be Dolby B encoded, and from October 19 to November 1 they will be passed through a prototype variable pre-emphasis system made by Audio and Design Ltd. Other stations were also invited by the IBA to participate in the experiment and BRMB, the Birmingham commercial station, responded. The BRMB experiment will take place on the same dates but the variable pre-emphasis broadcasts will come first.

Answering questions from journalists as to why there would be no unannounced "control" experiment, Mr James Slater of the IBA said: "We don't really know what a satisfactory response would be. We just want to get the information in. The experiment is regulated by the Home Office, and it is not even guaranteed that if it proved successful that we would use it."

Although the IBA are not admitting to having wanted unannounced tests, it is clear that they had to change their minds. No-one would say who had decided that Capital should accept "a modified form of tests", or to whom the information obtained from them would have to be submitted for a final decision. No-one from the Home Office was present to answer questions, but the IBA's statement says the IBA would have to seek Home Office approval for the permanent use of either system.

Both the Dolby and the A&D system will allow a 2dB improvement in signal to noise ratio on conventional receivers, say the IBA, more if the Dolby signal is decoded on reception. The increased high frequency content of broadcast material since the 50μs time constant was adopted 20 years ago has meant a compression of the rest of the spectrum. Both systems modify the pre-emphasis characteristics to improve matching with programme material, reducing the need for the 2dB guard band currently allowed when lining up the transmitters.

The Dolby B system has frequently been described elsewhere, but the Audio & Design system (see article in this issue) is so new that only one unit is available for the experiments, hence the alternate dates between Capital and BRMB.



Garrard have designed and patented this cyclical turntable mechanism, used in the new GT55 series, to provide an integrated unit independent of the drive assembly. It is driven by a flexible belt connected to the turntable and is capable of functions from the fully automatic playing of one record (six on American models) to manual over-ride for individual record track selection. The moulded plastics mechanism is highly durable, needs little maintenance and is quieter than earlier ones, say Garrard.

Electronics industry progress

At 613,000, deliveries of British and foreign colour TV sets for the six months to the end of June have fallen by a quarter compared with last year, according to figures issued by the British Radio Equipment Manufacturers' Association, but exports of colour tvs in the same period were up £8.8 million to £20.4 million. Monochrome deliveries were up 10% to 490,000. Deliveries of audio stereo systems fell 24% during the six months to 259,000, and radio sets fell 18% to 1,853,00.

Mr Jack Akerman, managing director of Mullard has at last said, in an interview with *The Times*, that he wants government aid for the British electronics industry. In a previous encounter with *Wireless World* he had said that earlier remarks he had made about wanting government money as well as import controls had been mistaken, but he told *The Times* at the beginning of August that the industry should have £100 million each year for the next ten years. Akerman now seems to be turning his undoubted gifts for proselytising to the whole of the electronics industry rather than just that small sector of it involved in television manufacture. Though unavailable for comment, Mr Akerman is said to be taking his example from other governments, notably those in Germany and Japan, who are assisting their industries. At a meeting on August 10 between management and unions in the industry and Mr Edmund Dell, Secretary of State for Trade, the industry was assured by Mr Dell that the Japanese had assured him there would be no sudden increase in colour tv imports for the rest of the year. The importing of monochrome sets, a more sensitive issue, was still being discussed.

In March, when manufacturers first became seriously concerned about the importing of colour tv tubes and sets, Whitehall also expressed an interest in the audio industry, and the manufacturers were asked to submit a report. The civil servants take the view that British audio is in much the same state as the motor cycle industry was before it was destroyed by foreign competition. The industry's report was not submitted until the end of July, however, and more delays may be expected before the Department of Industry takes any action since not all the information Whitehall needed had been submitted.

After a BBC TV news story on the representations by the British manufacturers, Lasky's managing director Derek Smith issued a statement in which he said that Japanese products "sell principally because of their high quality, reliability and technical leadership." Many products they wanted to sell were no longer made in the UK, such as cassette recorders and decks. On the call for import controls he said that if the government were to reconsider their opposition to import controls he would strongly argue that controls should only be on specific products and not just a blanket attack on anything Japanese "..... We have no evidence that the hi fi we buy from Japan is being sold to us at dumped prices."

Cabled sound

After the generally admitted failure of the cable television experiment the Home Office has said it is prepared to licence up to six experimental local cable radio stations in the period to July 31, 1979. In reply to a question from Mr Eric Moonman, Labour MP for Basildon, Mr Brynmor John, Minister of State at the Home Office, said that the issue of the experimental licences would be conditional on the form and content of the programmes, the need to pay a licence fee to the Home Office to cover expenses in setting up and supervising the experiments, and the need for applicants to consult the local community in the area to be served about the operation of the service. The Home Office said in a statement that the Annan Committee, which will report next spring, had been consulted and had said it would welcome the experiments.

Experimental cable television stations were licensed in January 1972, and five were set up at Bristol, Greenwich, Sheffield, Swindon and Wellingborough. Only the Greenwich and Swindon experiments are operating, though another experiment is due to start in Milton Keynes later this year.

Advertising was allowed on the stations from February last year after a recommendation by the Annan Committee, but Bristol, opened in May 1973 and the largest of the five, closed in March last year. Wellingborough shut around the same time and Sheffield, potentially the largest station, closed on December 31, having started to take ads from September 1.

At a meeting held on July 21, Swindon Viewpoint, who operate the Swindon cable tv experiment, said their service could continue definitely for three more years until the licence expired in July 1979. "Though the target has not yet been fully reached," they said in a statement, "it was felt that some applications still outstanding and more local contributions would soon close the gap."

Swindon Viewpoint needs £60,000 a year to continue the service. The local authority provides £2,000, the Arts Council £3,000, but local industry £15,730. EMI is providing £15,000 in the first three months of the year as well as offering equipment, vehicles and tape stock worth £72,000 as a gift if Swindon can raise the rest of the money. EMI acquired the cable television equipment interests of Thorn Automation in June, 1973. A proposed increase in Home Office licence fees of £1,500 was scrapped after intervention of Swindon's MP, Mr David Stoddart.

Commenting on the Home Office decision to allow cable radio experiments the assistant secretary of the Cable Television Association, Mr Anthony Brittain, told Wireless World: "Naturally the cable companies welcome any move capable of extending what can be done on cable and showing its capabilities." Any further commitment to cable radio, however, would have to be made by individual companies and it was not for the Association to comment, he said. We understand that Swindon Viewpoint and others have already applied for licences.

High-level compiler for microprocessors

GEC Semiconductors claim to have developed the first commercially available high-level language compiler to run resident on a microprocessor. The RCC80 which compiles Coral 66, the first major government and defence approved real-time computing language, was developed for Intel's 8080A microprocessors and may be run on an MDS800 development system. In addition to the standard features of the Coral 66 language, the compiler includes functions necessary for microprocessor work and options such as recursion and bit manipulation that are not always available on much larger machines. The compiler package is available ex-stock for £1,500 and consists of a 2002-block floppy disc, a programming manual and an operator's manual. Hardware required includes a micro-computer development system, 48k of r.a.m., a floppy disc system and console and output devices. GEC claim that the Post Office, which already runs a Coral switching system, is among several prospective customers who have shown interest in the compiler.

Depolarising investigation

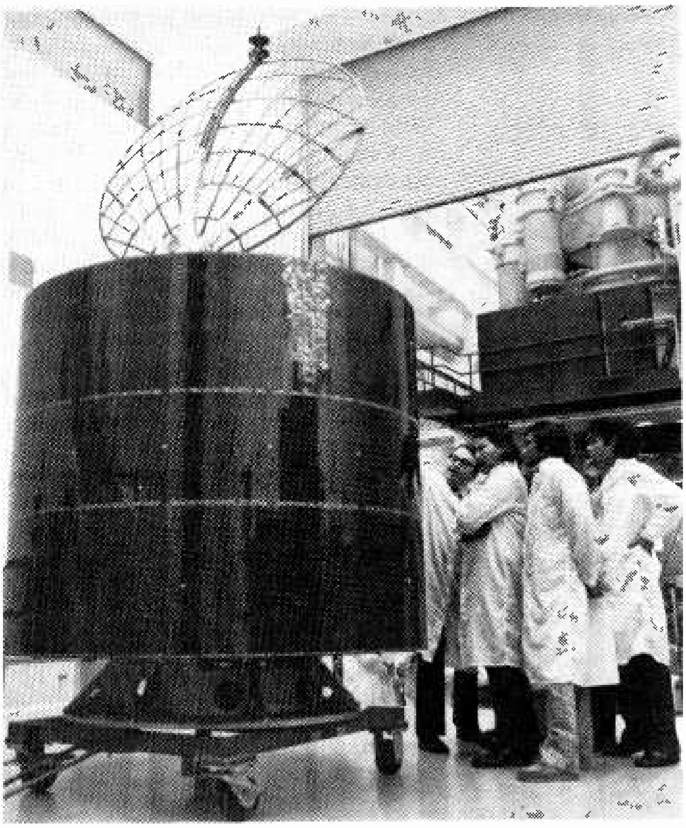
Intelsat will begin a 12-month investigation into the depolarising effects of rainfall on communications satellites this winter. They have awarded a $34,284 dollar contract to Canadian telecommunications carrier Teleglobe Canada. Heavy rainfall causes a reduction in polarisation purity between orthogonally polarized microwave signals and impairs the ability of a communications system to re-use frequencies. The object is to design systems which minimise the effect, and to measure it on the 4GHz down link and the 6GHz up link and the correlation between the two at the Mill Village 1 earth station, Nova Scotia. Intelsat are sponsoring a series of projects on depolarisation around the world.

PO waveguide network

A new waveguide system capable of carrying up to half a million simultaneous two-way telephone conversations or 150 television circuits may be installed between Britain's principal towns and cities. The Post Office estimate that the system, in the form of two inch pipes buried four feet underground, would be £25 million cheaper than alternatives using existing techniques or fibre optics. The Post Office has already spent £3 million in developing the system and, with BICC Research & Engineering, has set up a waveguide manufacturing unit in Alperton, Middlesex. BICC have installed a trial length of 14.2 km between Martlesham and Wickham Market in Suffolk.

The waveguide consists of a hollow tube 50 mm in diameter of helically wound fine copper wire encased in a glass fibre reinforced jacket incorporating a dielectric. The whole is then wrapped in aluminium foil to exclude oil or water and coated in a protective finish.

The use of a lightweight waveguide instead of the more conventional steel types was recommended in a report by Plessey and BICC commissioned by the Post Office in 1970 to survey various waveguide designs, their performance and economics. In the early 60s British Telecommunications Ltd, jointly owned by the two companies, had made a test length of a waveguide developed by Bell Laboratories, but the BPO's interest was stimulated by the improvement in high frequency solid state devices and the need to plan for future growth in telecommunications traffic.



Indonesian engineers look at solar cells to power the "Palapa" communications satelite at El Segundo, California, where the satellite was built by Hughes Aircraft. Palapa began its telephone, television, radio and data service to 130 million Indonesians on August 17 after being launched from Cape Canaveral during the US bicentenary week. It is in synchronous orbit 35,000 km above the equator at 83°E long. over the Indian Ocean. Indonesia's 5,000 populated islands of a total of 13,000 stretch over 5,000 km.

New laser video pickup

A semiconductor laser pickup one twentieth of the volume of conventional optical videodisc pickups has been developed by Hitachi. The pickup uses a semiconductor laser source instead of the conventional helium neon source, which needs a bulky optical system. In addition, Hitachi say they have simplified the optical system by bringing the laser beams for the servo and video signals into one axis. Tests carried out with the pickup at 0.5 mW output power produced images with a 40dB signal to noise ratio, they say. The pickup is compatible with the conventional HeNe laser pickup.

Motoring news

A group has been set up to study the case for a public experiment of the BBC's proposal for broadcast traffic information, demonstrated to the press in mid-March. The group, which will also study "the role of area broadcasting in driver information systems," has been set up by representatives of the Association of Chief Police Officers, the BBC and the Transport and Road Research Laboratory, and follows a seminar held by the TRRL and the BBC at the end of July. The seminar was attended by about 40 delegates from the IBA, the Home Office, the Department of the Environment, police, motoring organisations and radio manufacturers.

The BBC, having departed from the EBU's view that such a service ought to be on v.h.f., are particularly anxious to win the police over to their system. The police, for their part, were concerned that the BBC system, described in May *Wireless World*, only gave information every eight minutes. They were assured that the interval could be shortened. The IBA are sceptical of the value of the scheme, which they do not regard as providing much more than is already available on local radio, with the additional disadvantage that it ties up a whole UK medium wave channel. The BBC's use of the word "area" instead of "local" may be a reflection of this criticism. On the other hand, unlike the EBU continental motoring network, the BBC motoring announcements can be heard on a cheaper radio, and unlike some TRRL proposals for using radiating loops on motorways, they can be heard by the motorist before he reaches the motorway or even leaves his garage.

Measuring pollution

The Water Pollution Research Laboratory has developed an instrument which records the dissolved organic content in water. The organic pollution monitor, as it is called, is designed for use in sewerage treatment plants as a continuous automatic monitoring instrument, but can test samples in the laboratory. Tinsley, who make it, say the device is based on the principle that the absorption of ultraviolet light at an appropriate wavelength can be correlated with the organic carbon content of both river water and effluents. There is a relationship between ultraviolet absorption and the chemical and biological oxygen demands of samples of sewage at various stages of treatment. "There seems no immediate prospect of an automatic equivalent of the biological oxygen demand test, and automatic measurement of the permanganate value or chemical oxygen demand involves elaborate wet chemical procedures entailing reagent supply and waste disposal problems." The monitor overcomes these difficulties by recording the dissolved organic content, which is related to both these quantities.

Marconi have developed a similar device for measuring fog thickness consisting of an optical transmitter receiver unit and a reflector unit mounted facing each other. The light source is an electronically modulated l.e.d. and the reflector returns radiation to the transmitting lens which focuses it on to a silicon photodiode. The receiver has a phase sensitive detector, say Marconi, to provide good analogue signal to noise ratio. Analogue signals are converted to digital form for visual readout. The instrument is self calibrated to take account of contamination and component drift. The Royal Aircraft establishment will use the instrument, say Marconi, to measure the vertical profile of visibility from a balloon raised and lowered from 1000 ft. The MET1 transmissometer was developed for use on airfields, motorways, ships and in ports, industrial areas, tunnels and underpasses or any area where there is smoke or dust.

A portable device now marketed by Carboeglen, the RDM-101, measures atmospheric dust particle levels by measuring the radiation from a 100 microcurie beta source which is absorbed by dust particles collected on an impactor. The device is battery operated and gives a digital readout of the dust concentrations in mg/m³. If the sampling interval, some minutes, is altered different sensitivity ranges from the factory preset range can be obtained.

Electronic organ pioneer

Leslie Bourn, joint patentor of the first electronic organ and builder of the first organ in the Royal Festival Hall, has died at the age of 77. He took an idea for an electronic organ to John Compton, and in 1927 joined the Compton Organ Company, filing joint patents for the first electronic organ in the 1930s. At the time of his death on June 1 he was building an organ for one of his grandsons. "His friends and colleagues," writes Laurie Fincham, "remember him as an inventive man with a fine grasp of the fundamentals of electricity, and he was both an amiable and stimulating colleague."

On the way to a smaller, more effective CEI

It is possible to say, with as much accuracy as such assertions usually command, that the two year dispute over the future and composition of the Council of Engineering Institutions has passed over the heads of many professional engineers. As the outgoing president of the Institution of Electrical Engineers, Mr R. J. Clayton, told *Wireless World* in a recent interview, "About a third of the engineers I know who join the Institution do so because they think it worth joining, and the rest join so that they can keep up with developments in their own field."

Depending on your point of view, the argument can be viewed as another excrescence of the Middle Class Revolt, or a sign of insecurity among an important and productive group that sees its standing in the community, not least as measured by the amount the community seems prepared to pay it, falling ever lower. A CEI survey published last year showed that the real income of Britain's 250,000 chartered engineers had fallen by more than 7% in two years. Some older engineers were worse off now than nine years ago. The survey also reflected growing concern shared by the Government, the CBI and the Science Research Council about the lack of new entrants into the profession. Low recruitment, it has been said, is another sign of the falling status that the professional engineer enjoys.

While many engineers don't think about status — Mr Clayton confessed that he wasn't altogether sure what it meant — the one-third of activists seem concerned enough about raising it to want their collective voice heard where they think it matters: in Whitehall and Westminster. Originally this was one of the tasks entrusted to the CEI when it was formed in 1965, replacing the Engineering Institutions' Joint Council set up by the Mechanical, Civil and Electrical Institutions, the Big Three, in 1962.

Linked with this, and ostensibly even more important, was the CEI's duty to establish a common, and high, standard of entry into the engineering profession. Thus the title "chartered engineer" was created in 1965, but it was not until January 1, 1974 that a degree or its equivalent became the required academic standard.

But in the minds of those worried about such things, the larger failure of the CEI has been that the official and public idea of engineers does not measure up to the engineers' idea of themselves. At an IEE meeting in January last year Mr A. G. Milne, past president, succinctly explained: "I do not wish to deny or denigrate the success of the CEI in establishing, albeit late in the day, a reasonable standard of academic qualification, but we must recognise that the founders of the organisation were looking for much more than that. One of the main functions hoped for was, to use a trite phrase, that it should become the 'voice of the profession.' It was hoped that it would become the body to which Government could turn for ready and reliable advice, and which could focus the attention of the public generally upon the existence and achievements of professional engineers, and so create a better understanding of the contributions which they make to civilised living. Regrettably, the CEI has failed to make any significant progress in this direction."

Another source of irritation was that the CEI was looked on as something of an exclusive club. Of the forty or more institutions and societies which represented engineers only 15 were in the CEI. Engineers who were quite well qualified for the title "chartered engineer" could not use it unless members of one of the 15, a kind of engineering closed shop.

Each of the 15 had three members on the CEI board of 48. None of them felt empowered to act without consulting the institution which had delegated him and his two colleagues, and this federal structure was blamed for much of the failure of the CEI. What was needed, argued the militants, was a body which could act for engineers without reference to the institutions. Thus the board should be elected directly by the engineers themselves, whose representatives could then act without fear of retribution by the institutions.

This seems, on the face of it, an attractive argument, yet if the Big Three had felt two years ago that they already had greater influence in the affairs of the CEI than the others there might have been no attempt to reform the council. The IEE vice-president Professor Rawcliffe was perhaps more explicit at the January 1975 IEE meeting than some of his colleagues might have wished: "65% of the corporate membership of the CEI is in three major institutions (Civil, Mechanical and Electrical) and everyone knows that these institutions are higher in average status and standard than most of the others. But action is inhibited by the structure and bureaucracy of the CEI. In my view the proper first remedy for our troubles is that the three major institutions should insist that there should be some form of proportional representation in the CEI, so that they are not frustrated by smaller institutions."

The smaller institutions protested that the effect of this would have been to increase representation of the Big Three on the CEI board at their expense. With pressure at Westminster and in Whitehall growing for a public inquiry into the engineering profession, a CEI meeting on July 24, 1975 agreed, with the Big Three institutions predictably dissenting, on a compromise proposal whereby one representative would be elected for three years by the chartered engineers of each member institution. Individual chartered engineers could become members of the CEI provided they were members of an institution affiliated to the CEI.

In a statement issued in September the then IEE president, James Merriman, said the election proposal "would not, in our view, dissociate the CEI from the overriding influence of the institutions . . . In these circumstances our council thought the only proper course was to give notice of resignation." The IEE said it would leave at the end of 1976. They were joined in November by the mechanical engineers, though the mechanicals did not go so far as to give notice. It is difficult to compute membership figures because of cross-membership among the institutions, but had these two carried out their threat the CEI might have lost roughly half its 170,000 chartered engineers.

By January, 1976 however, things looked hopeful enough for the electricals and mechanicals to submit a joint proposal to the CEI chairman, Tony Dummett. They suggested that the TUC and the CBI should be represented as lay members of a reformed CEI, and that membership should also be open to non-chartered institutions which met certain standards, provided their chartered engineer membership was large enough. The CEI differed from the I Mech E and the IEE on these matters at an informal meeting in May, but otherwise there was substantial agreement.

Mr Clayton said he was not adamant about who the lay members should be: "Nobody has said that I must have what I asked for." He merely feels that the CEI should include "a couple of men who are not engineers who can give the outside world's opinion of engineers."

After a more formal meeting of the board in July, 1976, it emerged that outsiders might be invited from the legal profession, from engineers in the services or from the United Kingdom Association of Professional Engineers. As to non-chartered membership, the CEI felt that the joint proposal would have made the new board as cumbersome as before, but agreement was reached that there should be one representative from each institution, plus a number of individual members, up to two per institution, elected nationally by the single transferable

Continued on page 72.

Digital filter design

Programming a microprocessor to act as a digital filter

by V. J. Rees, M.B.E., M.A., B.Sc., D.U.S., *Army School of Signals*

This article has three aims. The first is to answer in simple terms the question, "What is a digital filter and why use it in place of a classical filter?". The second is to show one way in which filters can be designed; the process is unfortunately rather mathematical, but even if you do not wish to follow the mathematics in detail you should grasp fairly quickly the philosophy behind it. The third aim is to show that digital filters actually do what is expected of them; a low pass filter is designed, a triangular wave of voltage applied, and the output is seen to be what one would expect from the equivalent classical filter.

Filters are a very necessary part of communications, and have been with us for a long time. They started out as LC circuits, heavy and bulky at low frequencies; some then graduated to active types, where the inductors were discarded and replaced by integrated circuits. But they still had their limitations in modern communications systems. For one thing they were not very flexible; a different set of hardware was required for each filter and if the characteristics required changing a lot of soldering had to be done. For another communications is going "all digital"; no longer is an attempt made to preserve the electrical analogue of a signal from microphone to speaker. A few samples per second of the microphone waveform are taken and we are content to send these samples, in binary form, off down the communications link.

The recipient is left with the job of reconstituting the original signal from the samples. Typical of such systems is pulse code modulation; its advantages are well known to communications engineers. In retrospect we are doing no more than the man who is asked to plot a graph. He will ask for a number of numerical samples from the information available so that he can plot these as points on a graph; provided he is given enough samples he can interpolate between the points and produce his own continuous function. Signals down a communications link will therefore be at only 2 levels, a 1 or a 0, representing binary numbers. This is the second reason why classical filters are not entirely happy, they are required to work in a strange world of 1s and 0s.

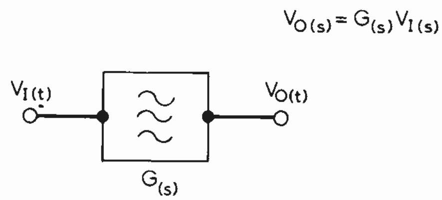


Fig. 1. Analogue filter.

Two reasons have been given for considering ordinary filters unsatisfactory: their inflexibility and their dislike of a digital signal processing environment. Something which is quite happy with digits and can respond rapidly to change is the digital computer. The question now arising is whether a computer could be placed in a communications link so that it accepted samples of a signal, processed them in real time by instructions from its software, and sent them on their way "filtered." If this can be done, and it can, the process being called digital filtering, the two objections to classical filtering are overcome. Changing the frequency response of the filter is merely a matter of changing the programme; no soldering required. And of course it is happy in a digital environment, always provided it can process the sample fast enough to work in real time; the sampling theorem says we must have at least two samples per cycle of the highest frequency we transmit, say 6k samples per second for speech.

To fix our ideas on digital filters consider Fig. 1 and Fig. 2. Fig. 1 shows the classical concept of a filter; a continuously varying input signal is processed so that the voltage/time waveform of the output is different. The relation between output and input is usually expressed as a transfer function $G_{(t)}$; in Fig. 1 the Laplace transform of this function is shown. Transforms will be needed later to explain how digital filters are designed. Fig. 2 shows how a digital filter could be used to replace the classical filter. Note the requirement of some form of sampler and analogue to digital converter to produce the digital samples for the computer to work on, and the need to convert these samples back to an analogue waveform. Remember we are now working on the "points in a graph" concept.

Digital filters would have their limitations if every receiver requiring a filter had connected to it a large and expensive computer, though in some static systems the time sharing capability of the computer might make it an economic proposition if it replaced several filters. However the arrival of the microprocessor has changed all that. This is, essentially, a cheap, single chip processor programmed by an

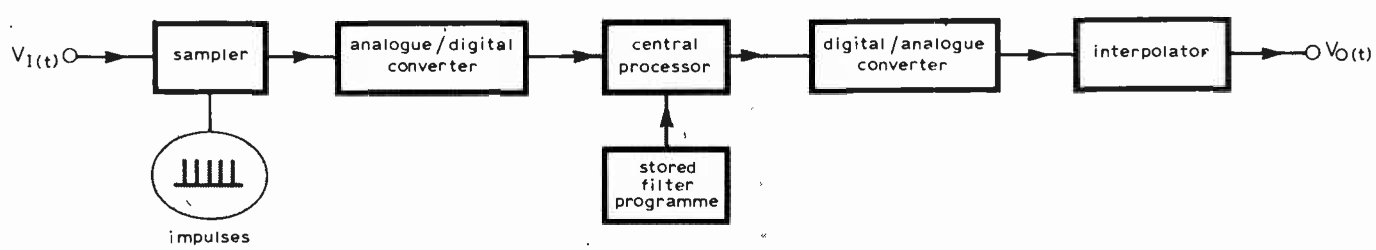


Fig. 2. Basic functions of a digital filter.

r.o.m.; it will be found within equipments fulfilling a number of functions, and used in this way the digital filter becomes an economic proposition, with of course the added advantage of changing filter characteristics simply by changing the r.o.m.

One can go a stage further, and visualise the filter becoming adaptive, that is to say looking continuously at the input signal and noise (or interference) and adjusting the filter characteristics (programme) so as to optimise the output signal to noise ratio. Perhaps the problems of electromagnetic compatibility and jamming will then assume another dimension. Certainly the future digital filter in micro-processor form looks exciting.

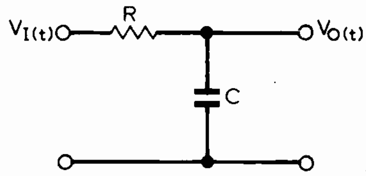


Fig. 3. Low pass filter.

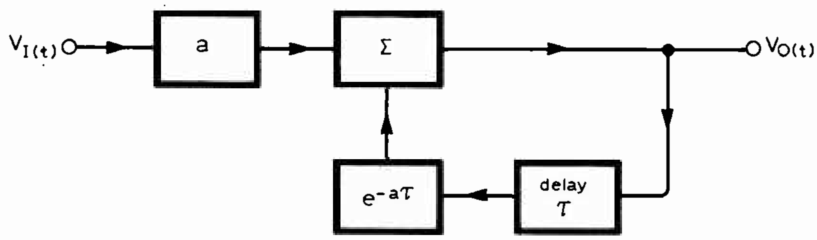


Fig. 4. Equivalent digital filter.

Digital filter design

Before proceeding to the detailed design of digital filters, a look at the problem in broader terms might help. If a computer programme is to act as a filter it must ask for a sample, process it, and send it on its way. Clearly filtering cannot be achieved without the process involving reference to previous samples; for example, a low pass filter must ensure that the rate at which sample amplitudes change is not too great to exceed the cut off frequency of the filter. Therefore the programme must hold previous samples for comparison with new samples, and we shall be looking for a programme which does this. Fig. 4 is just such a circuit and is capable of being written in computer programme form as is shown in Fig. 5. The circuit takes a sample and adds it to the sum of all the previous samples multiplied by a constant related to the filter characteristic (a) and the sampling rate ($1/\tau$); it is in fact a digital low pass filter. Fig. 4 is the heart of digital filtering. In the next section will be shown in detail how to obtain this algorithm relating input and output samples. If we accept that this can be done, filter contruction has been reduced to writing the correct algorithm to represent the filter characteristics, leaving the hardware design to the computer or better still the microprocessor designer. Of one thing you may be sure; you will be seeing a lot more of digital filters now microprocessors are with us.

And now to show that Fig. 4 is a digital filter. This is where problems arise. An elementary knowledge of Laplace transforms and impulse functions must be assumed; furthermore the modulation process involved in sampling a waveform should also be understood. You will be pleased to hear that the concept of Z transforms has been avoided.

Even if you do not follow through the mathematics, but are prepared to accept Fig. 4, the section starting "Verification of the programme" should be intelligible, and the detailed working of a low pass digital filter understood from the worked example.

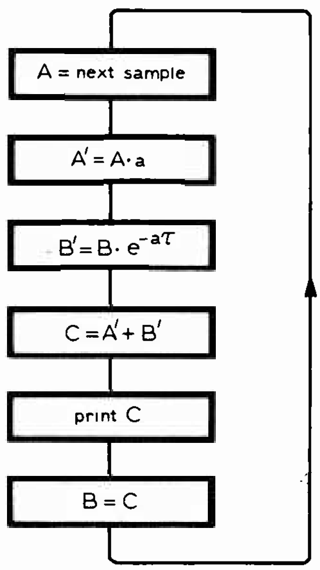


Fig. 5. Digital filter programme.

Obtaining an algorithm

Consider the transfer function of an analogue filter; in Laplace notation this is given by:

$$G_{(s)}=\frac{V_{O(s)}}{V_{I(s)}}$$

Now if $V_{I(t)}$ is an impulse function at time $t=0$, $V_{I(s)}=1$, and

$$G_{(s)}=V_{O(s)}$$

Thus the problem of determining $G_{(s)}$ can be reduced to obtaining the output of the filter when the input is an impulse. This is of course "old hat" for analogue filter designers. How does it help with the design of digital filters? The argument, which is fundamental to obtaining the algorithm, is as follows:

"In digital filtering the inputs to the filter are weighted impulse functions (actually coded in binary). Furthermore, output from the filter is only provided at the sampling times. Therefore we have constructed the digital equivalent of an analogue filter if they have identical outputs at the sampling times when an impluse function is used as an input."

An example being easier to understand than generalisations, consider the design of a digital filter to replace the simple analogue low pass filter of Fig. 3. $G_{(s)}$ can be written down by inspection, which is also $V_{O(s)}$ for an impulse input at time $t=0$; $V_{O(s)}$ can be converted to $V_{O(t)}$ by inspection. Since we are only interested in $V_{O(t)}$ at the sampling times, by obtaining this, the output of the equivalent digital filter will be obtained. Proceeding on these lines we obtain:

$$G_{(s)}=\frac{\dfrac{1}{sC}}{R+\dfrac{1}{sC}}=\frac{1}{1+sCR}=\frac{a}{a+s}$$

$$\text{where } a=\frac{1}{CR}$$

$$=2\pi\left(\begin{array}{c}\text{upper 3dB frequency}\\ \text{of filter}\end{array}\right)$$

Solving $G_{(s)}$, by inspection, for an impulse input, we have:

$$G_{(t)}=V_{O(t)}=ae^{-at}$$

Now we are only interested in $V_{O(t)}$ at the sampling intervals 0, τ, 2τ etc. Thus $V_{O(t)}$ will be:

a volts at $t=0$

$ae^{-a\tau}$ volts at $t=\tau$

$ae^{-2a\tau}$ volts at $t=2\tau$

etc

Turning these output samples $V_{O(t)}$ into $V_{O(s)}$ will give us $G_{(s)}$ of the identical digital filter. Using the transformation

$$\mathcal{L}\left\{\delta(t-\tau)\right\}=e^{-s\tau}$$

we have:

$$G_{(s)}=a+ae^{-a\tau}e^{-s\tau}+ae^{-2a\tau}e^{-2s\tau}+\text{etc.}$$

This is a geometric progression of ratio $e^{-a\tau}e^{-s\tau}$, and the sum is given by:

$$G_{(s)}=\frac{a\left\{1-(e^{-a\tau}e^{-s\tau})^n\right\}}{1-e^{-a\tau}e^{-s\tau}}=\frac{a}{1-e^{-a\tau}e^{-s\tau}}$$

Thus we have obtained an algorithm, in the s plane, for our digital low pass filter. The problem remaining is to write it in such a form that it is clearly amenable to programming.

The computer programme

We have:

$$G_{(s)}=\frac{V_{O(s)}}{V_{I(s)}}=\frac{a}{1-e^{-a\tau}e^{-s\tau}}$$

i.e. $V_{O(s)}(1-e^{-a\tau}e^{-s\tau})=aV_{I(s)}$

or $V_{O(s)} = aV_{I(s)} + e^{-a\tau}(V_{O(s)}e^{-s\tau})$

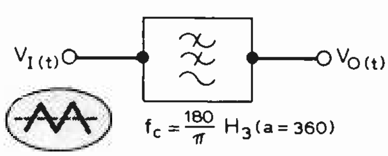
Remembering that V_I and V_0 are impulses and that

$\mathcal{L}\left\{V_{O(t)}\delta(t-\tau)\right\} = V_{O(s)}e^{-s\tau}$ it should be clear that Fig. 4 has the above relation between $V_{O(s)}$ and $V_{I(s)}$ and is therefore the required digital filter. There is no need to build this filter as the relation between $V_{O(t)}$ and $V_{I(t)}$ can be written as software for a computer. The simple programme for this filter is shown in Fig. 5. This would of course normally be run in real time, with the sampling rate determined by parameters outside the control of the filter. Intuitively it can be seen that filtering is achieved by comparing one sample with a modified version of the previous output, a process similar to delta modulation; it is ironing out the rapid changes which would be outside the filter bandwidth.

Verification of the programme

Confidence in the ability of digital filters to fulfil their purpose can best be obtained by specifying a function $V_{I(t)}$ and obtaining the corresponding $V_{O(t)}$. The programme is so simple that this can be carried out (not in real time!) by the following process:

Time (ms)	V_{in} (volts)	$a\tau V_{in}$ (volts)	$e^{-a\tau}a\tau V'_{out}$ (volts)	V_{out} (volts)
0	0	0	0	0
1	2	0.72	0	0.72
2	4	1.44	0.500	1.94
3	6	2.16	1.355	3.52
4	8	2.88	2.453	5.33
5	10	3.60	3.721	7.32
6	8	2.88	5.108	7.99
7	6	2.16	5.573	7.73
8	4	1.44	5.395	6.84
9	2	0.72	4.769	5.49
10	0	0	3.830	3.83
11	−2	−0.72	2.672	1.95
12	−4	−1.44	1.362	−0.08
13	−6	−2.16	−0.056	−2.22
14	−8	−2.88	−1.546	−4.43
15	−10	−3.6	−3.088	−6.69
16	−8	−2.88	−4.666	−7.55
17	−6	−2.16	−5.265	−7.42
18	−4	−1.44	−5.186	−6.62
19	−2	−0.72	−4.619	−5.34
20	0	0	−3.725	−3.73
21	2	0.72	−2.599	−1.88
22	4	1.44	−1.311	0.13
23	6	2.16	0.090	2.25
24	8	2.88	1.570	4.45
25	10	3.60	3.105	6.70
26	8	2.88	4.678	7.56
27	6	2.16	5.273	7.43



$V_{I(t)}$ symmetrical triangular voltage fundamental frequency 50Hz amplitude ±10V

τ 20 samples per cycle giving $\tau = 10^{-3}$ sec.

$a\tau = 0{\cdot}36$ $e^{-a\tau} = 0{\cdot}6977$

Fig. 6. Filter and input parameters.

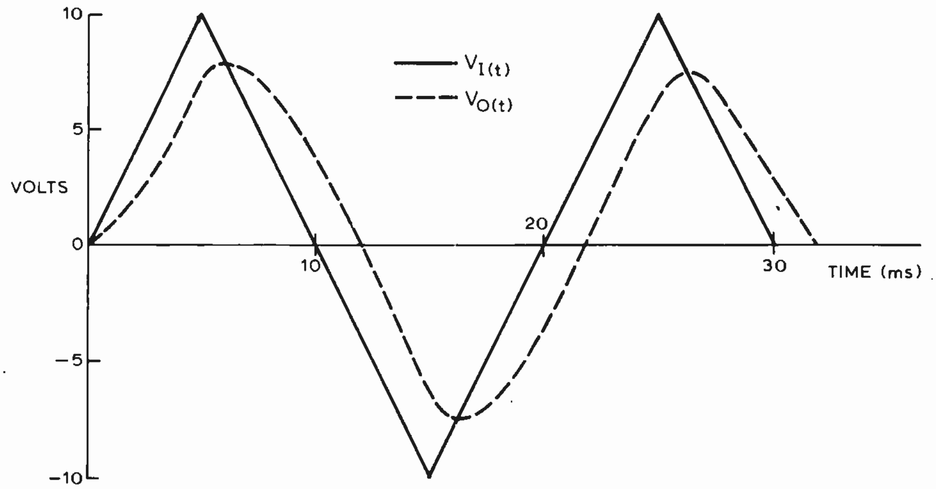


Fig. 7. Input/output signals for low-pass digital filter.

(a) Draw a graph of the analogue waveform $V_{I(t)}$ which you wish to filter

(b) Decide on a sampling rate, i.e. determine τ, and obtain from your graph $V_{I(t)}$ at the sampling times 0, τ, 2τ etc.

(c) Decide on the filter 3dB frequency; this determines the product CR and a. If you know nothing about the spectrum of a sampled waveform you will need to do some further reading to understand the limitations set on the relative values of filter bandwidth, sampling rate and input signal bandwidth.

(d) Put your weighted impulse functions (samples) through the programme manually to obtain $V_{O(t)}$ at the sampling times.

(e) Multiply the output samples by τ, plot them on the same axes as the input and interpolate between them by hand to obtain the analogue output signal. In practice, interpolation would probably be achieved with a sample and hold circuit. The requirement to multply by τ needs justifying. Without doing this the shape of the output version would be correct, but the amplitude too large. It is necessary to multiply by τ because in sampling the input signal, much of the sampled spectrum lies outside the filter bandwidth, and an adjustment must be made for this, which can be shown to amount to multiplying by τ. However, in practice absolute values of output are not important; gain can be built into the system.

(f) Ask yourself whether the output you have obtained is what you would expect from the filter. This check can be carried out either by considering the Fourier series for the input, or in the case of pulse inputs by considering the application of "step functions" to RC circuits.

The above process has been tried by the author for different forms of input signal. A worked example, the results of applying the triangular wave of Fig. 6 is shown in the table and Fig. 7. The 3dB frequency of the filter and the repetition frequency of the triangular wave have been chosen so that one would expect the output to be almost entirely the fundamental compoment of the Fourier series, and this is seen to be so. It is suggested that serious readers of this paper try a square wave input (check the output by "step function" approach), and also produce the algorithm and programme for a simple CR high pass filter.

Literature Received

Microprocessor Series 8000 users' manual is now available. The manual gives a general description of the 8000 family, details of the hardware available, and assistance with interfacing and programming. The users' manual costs £5 from General Instrument Microelectronics Ltd, 57-61 Mortimer St, London W1N 7TD.

Procedures under the Health & Safety at Work Act are outlined in a short leaflet, "Regulations, Approved Codes of Practice & Guidance Literature," available free from local offices of HM Factory Inspectorate, HM Inspectorate of Mines & Quarries and HM Alkali Inspectorate.

Wire-wrap boards, designed for microprocessor chip sets, are described in a brochure from Nimrod Electronics Ltd, 85 High Street, Billingshurst, West Sussex WW401

Harris operational amplifiers, a-to-d converters and associated devices, memories, and digital i.cs are briefly described in a short catalogue, distributed by Memec Ltd, The Firs, Whitchurch, Aylesbury, Bucks WW402

Intersil tell us that they have published a guide to their range of discrete semiconductors, which contains application guidance and a cross-indexed list of devices. Intersil Inc., 8 Tessa Road, Richfield Trading Estate, Reading, Berks.......... WW403

A book entitled "Thick-film Conductor Survey" is now obtainable from the Electrical Research Association. The book seeks to rationalize the huge amount of commercial data and presents information on formulation, characteristics, product lists, detailed data in various categories of characteristics, prices and souces. The material presented is international and is claimed to be independent. The 200-page book costs £45 (£41 to Association members) and is available from ERA at Cleeve Road, Leatherhead, Surrey KT22 7SA.

Electric power from the sun

One answer to the energy problem

by L. George Lawrence, Sc. D. *Ecola Institute, California*

Proposals to harness the power of the sun have enjoyed a long and continuous history. It is only in recent years, however, that advances in high-energy electronics and power engineering have brought tentative ideas into the hardware stage. In this article a profile is drawn on what has been and can be done in this critical field.

The sun

Solar radiation is so plentiful that energy arriving on only 0.5% of the land mass of the United States, for example, is more than the total energy requirement of that country projected to the year 2000. Today, as oil supplies approach depletion and arguments against the use of nuclear power and its massive waste problems increase, hopes are high – literally – for tapping the sun's abundance.

Technically, as summarized in Table 1, the sun presents itself as a thermonuclear proton-proton reactor capable of delivering 38×10^{22}kW at a continuous rate. Most of the star's high-quality energy is wasted in space. The total radiation continuously intercepted by our planet amounts to 173×10^{12}kW, or 232^{12}hp. The mean power or solar constant available for engineering use is 1.395kW/m^2. This is light energy; radio energy is not as intense or dominant. However, it was the latter type of energy that stimulated scientific hypotheses.

In 1893, shortly after Heinrich Hertz's discovery of radio waves, it was assumed that the sun's corona could emit this type of radiation and, pending development of suitable converters, the energy could be distributed via domestic power lines. It was foreseen that Edison batteries would be employed to store energy for night-time use.

Fundamentally, there is nothing wrong with the elegant simplicity of this scheme. Such techniques might be in fashion within the realm of postulated galactic super-civilisations (Von Däniken's "gods," et alia) who have to control and modify power outputs and spectra of selected stars. Unfortunately, our mundane situation offers little knowledge beyond the fact that wavelengths longer than 50cm are tremendously weakened by ionized gases of our local star's atmosphere. Only those from the sun's corona can escape into space, to be detected by terrestrial radiotelescopes. In addition, only those solar radio waves featuring wavelengths between 1 and 15cm are capable of penetrating the Earth's "admittance window" in the atmosphere. However, with solar dynamics being imperfectly understood, it is likely that major phenomena have been overlooked.

Thus, because of the enormous benefits that would result from direct high-power radio wave interceptions from the sun, electromagnetic and other properties are carefully re-examined.

The search for special energy-generating and deep-space power transfer mechanisms is reflected in the solar magnetogram, a magnetic map showing the location, field intensity, and polarities of magnetic fields for a given day.

Extended magnetic areas on the sun's sphere are typically bipolar and usually produce sunspots plus other solar activities. A powerful ultrasonic phenomenon was discovered recently, its waves ebbing back and forth at extremely high energy levels. Drs Schatzman, Ulmschneider and Kopp, among others, have considered acoustic waves to be of primary importance as heating agents for the solar corona. Better insight was provided by the NOAA Space Environment Laboratory (Boulder, Colorado), where Dr C. Sawyer employed time-lapse filter photography to measure the frequencies, or periods, of the "galloping" wave motions in the sun's chromosphere (atmosphere). Through joint research with Dr Sara Smith-Martin of Lockheed's solar observatory, it was determined that chromospheric wave crests advance at about 96 km/s and that a wave crest recurs in a given place about every 5 minutes.

However, contemporary solar models – and observations – cannot explain the sun's pulsation cycle of 2 hours 40 minutes. Where too are the "neutrinos" – the massless, chargeless particles which must exist to tally with accepted

TABLE 1: Characteristics of the sun

Type.	Dwarf star, spectral type G2
Absolute bolometric magnitude:	+4.7
Apparent visual magnitude:	−26.9
Energy mechanism:	Thermonuclear proton-proton reaction
Magnetic field strength.	1 to 2 gauss
Conversion rate:	4.2×10^6 tons of mass/second into energy
Density:	0.26 (Density of the Earth is 1)
Mass.	333,400 times mass of Earth of 1.99×10^{30}kg.
Distance from Earth.	149.6×10^6km.
Total radiation released constantly.	38×10^{22}kW
Radiation incident upon Earth's outer atmosphere:	137×10^{12}kW
Radiation incident upon Earth's surface.	85×10^{12}kW
Solar radiation constant.	1.395kW/m^2 on Earth's surface
Total radiation continuously intercepted by Earth:	173×10^{12}kW or 232×10^{12}hp.

theories on the sun's nuclear-fusion process? To that end Dr Raymond Davis, Jr. from Brookhaven National Laboratory and Dr John N. Bahcall from Princeton University mounted a three-year search for solar neutrinos using a detector buried deep in a goldmine in Lead, South Dakota. The team recently announced that fewer of the particles "than is consistent with standard ideas of stellar evolution" have been discovered.

Thus, a new question disturbs the scientific community: Is the sun controlled by – or acquiring the properties of – a "black hole"? The concept of the black hole, as the final stage of aging stars, was developed theoretically in the late 1960s by Dr John Wheller of Princeton, among others. According to the theory, the black hole is produced by the gravitational collapse of a dying star, and is so dense that a spoonful of material from its center would weigh over 1000 million tons. The hole's gravitational pull permits neither matter or radiation to escape, yet attracting matter as if it were a cosmic garbage disposal. In terms of solar-energy engineering, one fascinating question is, of course, whether black holes could be utilized as electromagnetic "energy sinks" for the purpose of planetary power generation, perhaps in a bipolar, electrostatic sense.

Today, unfortunately, the immensity of such dynamics and possibilities remains ill-defined. Magnetic mapping of the sun's features is but one diagnostic aid for solving the riddle of solar-power transmission over astronomical distances. Practical results can be expected from photovoltaic or optional-wave devices — solar cells currently in use.

Solar cells

Recent improvements in solar-cell fabrication have stimulated novel proposals for utilizing solar energy on a large scale. New and unfamiliar manufacturing techniques are not required, since photovoltaic cells were among the first semiconductor devices to be developed. Most noteworthy is the fact that efficiencies of up to 21 percent have been achieved, with higher power-output rates feasible in the near future.

Of particular interest are the AlGaAs type cells developed by Varian Associates in Palo Alto, California. According to the firm the starting material for their high-efficiency cells (21%) is a wafer of bulk n^+ type GaAs, on which a liquid epitaxial layer of n-type material is grown. The latter has a longer hole diffusion length than bulk material. The n^+n junction provides some carrier refinement, again increasing efficiency. An AlGaAs layer is grown on top of this layer and doped with a p-type source such as zinc, which diffuses a small distance into the n-type GaAs layer during the AlGaAs growth – thereby producing the p-n junction across which the photovoltage appears.

Fig. 1. Test rig for high-efficiency (21%) solar cells showing the optical light concentrator (mirror at centre-right) which concentrates sunlight 1000 times, GaAs cells, mount and cooling fins (above mirror) and the meter panel for power monitoring.

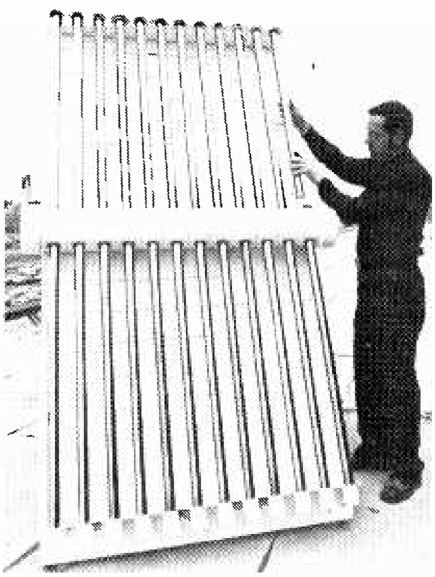


Fig. 2. Sunpak solar energy collector. Light entering the optical tube-like collectors heat a fluid which by heat transfer can provide electrical energy from thermo-electric cells, low-pressure steam turbine and generator plants, or other energy converters. High vacuum interfaces provide thermal insulation.

According to R. L. Moon, one of the project engineers, the p-GaAs, p-AlGaAs heterojunction "confines" the electrons generated in the p-GaAs layer. This restriction results in a low velocity surface recombination and greatly increases the efficiency over what is normally possible with a "straight" GaAs solar cell. The aforementioned layer is a window for photons that have energies below the AlGaAs band gap.

The development of the 21-percent solar cell, which brought Varian Associates into a leading position in the American stock market, breaks away from conventions in other ways too. Rather than using a customary flat-panel array for grouping cells together, the firm uses a sunlight concentrator or mirror to increase light on cells by as much as 1,000 times. Fig. 1 shows the test rig which has a mount with cooling fins and a package where the solar cell's power is metered. With this rig efficiencies as high as 23% can be achieved using simple concentrators. A 10MW power plant constructed of these cells would require only $80m^2$ of gallium arsenide. Using an equivalent system comprised of silicon cells with 12% efficiency would require an array covering 24.5 acres. It is prudent, however, to contrast cell efficiencies against costs and the availability of raw materials: gallium is nearly as abundant as lead, and silicon is nearly as abundant as sand. Both materials require complex refining processes and assembly operations, which determine costs per kWh to the end-user of solar power plants.

At present it is safe to assume that solar cells of the GaAs type will be used in initial power plants of the ground-mounted or terrestrial type. However, a given installation must have an additional means of storing energy for night-time operations. Electrochemical energy storage of the battery type is one possibility, but batteries of ample capacity and the ability to withstand heavy charging and discharging cycles have yet to be developed. Other more adventurous energy-storage schemes include huge flywheels coupled to motor-generator sets and hydrostorage involving lakes and turbines. Probably the most attractive proposal is that of converting surplus electrical energy into hydrogen, which could be reconverted to electricity in fuel cells. Unfortunately the problems of storing gaseous hydrogen and securing a source of inexpensive, long-lasting catalysts for fuel cells have not yet been solved.

Some of the above and other problems have directed attention to special heat exchangers combined with thermoelectric cells or energy-extraction devices. Thin, flat, glass-covered basins and glass tubes, filled with heat transfer fluids such as water or ethylene glycol, hold a special position in the solar energy sector — mainly due to their commercial attractiveness. Because heat stored in liquids can easily be circulated through conventional radiators installed in homes of factories, demands for electrical power are reduced to the small amount required for re-circulation pumps and blower motors. The same applies where the sun's energy is applied to coolants used for interior air conditioning.

Advanced solar energy collectors of the above type are exemplified by the Sunpak system, developed by Owens-Illinois. The unit, shown in Fig. 2, consists of a series of 24 glass tubes featuring special optical characteristics for maximum efficiency. Fig. 3 details the coaxially arranged interior parts.

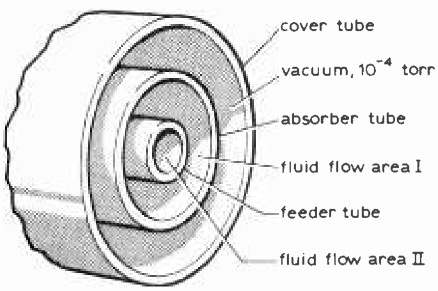


Fig 3. Construction of Sunpak solar glass absorber tube. Two inner tubes provide a heat-exchanger facility. Light from the sun heats the fluid; this heat is retained by the vacuum, acting as a thermal insulator, contained by the outer tube.

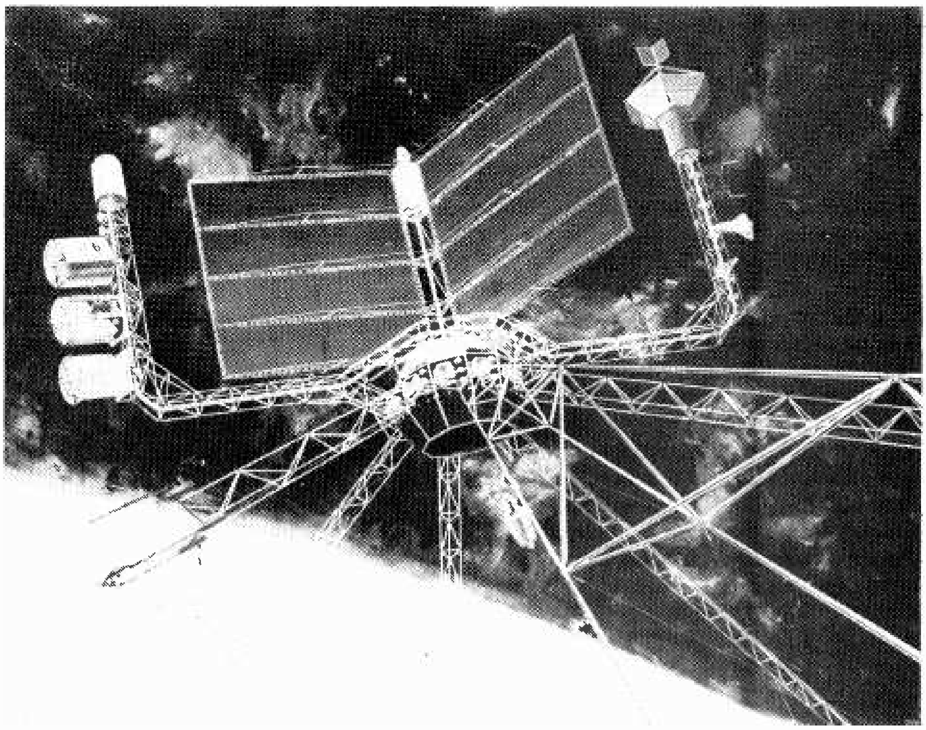


Fig. 4. Solar power satellite proposed by Boeing Aerospace Corporation is designed to transmit a collected solar power of 13.5GW via microwave beam to Earth.

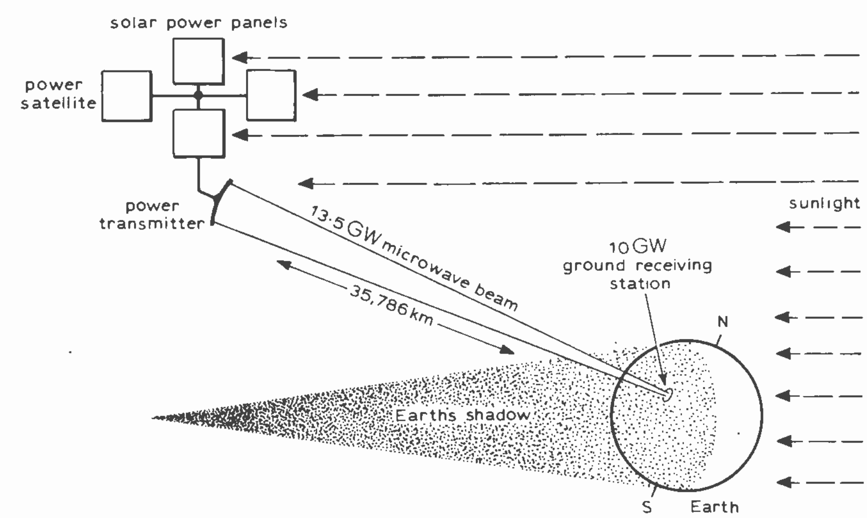


Fig. 5. Diagrammatic representation of the Powersat concept, capable of providing energy from the sun 24 hours per day.

Using a heat transfer fluid, the tubes maintain excellent thermal insulation due to a high-vacuum interface (10^{-4} torr). The tubes' round shape permits a better light-ray interception angle than can be obtained with basins, and is two to three times better than that of flat-plate solar energy collectors. A Sunpak can raise the temperature of the heat transfer fluid to 240°F, or 28°F above the boiling point of water. Here, as in related situations, the hot working fluid may be fed through heat exchangers, or low-pressure steam can be generated for operating piston – or turbine – type power plants. The required vacuum levels can be provided by conventional re-condensation schemes.

Gigawatt systems

By the year 1980 the world's annual consumption of electrical energy will have climbed to 6.5×12^{12}kWh. A consumption rate of 20 to 30×12^{12}kWh is projected for the year 2000. Clearly, unless living standards of the highly industrialized nations are dramatically reduced, the power needs cannot be met by generating systems of conventional design. The small supply of oil left must be set aside for the production of petro-chemicals, without which no synthetic materials and other basic chemicals can be produced.

Perhaps the most ambitious proposal for drawing electric power from the sun is that of the orbiting power satellite, "Powersat" for short. It is proposed that powersat be placed in a geostationary orbit 35,786km above the Earth where it is feasible to generate approximately 13,500MW of electricity from incident solar energy. This energy would then be transmitted to Earth by a phase-coherent microwave beam, where it would be received and re-converted into electricity by suitably equipped antennae farms. Fig. 4 depicts the powersat system evolved by the Boeing Aerospace Corporation. Here, an array of solar energy collectors covering 57.3km² would be kept in constant sunlight to generate constant power. The Earth's rotation and night (or shadow) state would not interfere. Fig. 5 shows the operational concept.

Allowing for system losses of 3.5GW, 10,000MW of power would be delivered to the terrestrial distribution network as useful power. The system is considered safe to biological organisms on Earth because of precautionary measures at the power receiving end. If, as per Fig. 6, a number of radiation spill detectors detect anomalous radiation outside of the assigned beam channel, control transmitters would beam a shut-off signal to the powersat. In addition, the powersat's synchronous position and/or angle of radiation incidence can be corrected by metering the microwave energy arriving at the rectifying diode panels. The possibility of the powersat cutting a "swath of death" across Earth is very remote because the ground receiving system has full control over the orbiting system.

Technically, two candidates for the powersat's electric generating system have emerged: (1) systems using photovoltaic devices, (2) systems using thermal concentrator/heat engines.

In space, a concentration ratio of 2 is about the maximum that can be used with AlGaAs solar cells without cooling them and therefore the size of cell arrays must be increased accordingly.

Heat engines for powersat use are far more complex than photovoltaic devices, but their high development make them suitable for in-space applications. The most attractive closed-cycle designs are the Rankine (liquid/vapour) and Brayton (gas) turbo-machines. The Brayton cycle offers some advantages in that it does not require two-phase devices such as boilers and condensers which must operate under zero-gravity conditions. The reliable simplicity of the Brayton cycle is shown in Fig. 7. Using standard formulae, we find that a heat engine producing 100MW of electricity, at 96% alternator efficiency, 40% thermal cycle efficiency and radiator temperature of 360°K (188°F), needs about 1km² of radiator. In this design it is assumed that the powersat's solar panels act as optical light-wave reflectors focused upon the engine's heater cavity.

However generated, the electricity will be beamed to Earth in the form of microwave energy using klystron (or similar) travelling-wave amplifiers. Designs close to 90% efficiency are close to realization. A leading worker in this field, Peter E. Glaser, envisages a wavelength of 10cm for energy transmissions to Earth. A dish antenna about 2km in diameter could handle 2.5×10^7kW and would irradiate a region about 3km diameter, the latter being the effective size of the antennae farm or receiving station on Earth, with a power density of less than 1 W/cm². Choice of the 10cm wavelength would minimize—if not eliminate — atmospheric absorption. Since passing microwaves through the planet's upper atmosphere produces a voltage gradient of less than 100V/cm, it is unlikely that the atmosphere would be ionized.

Taken together, the various engineering groups share the conviction that a powersat could be realized with present-day technologies. Impetus will be added once reusable space shuttles have been developed, plus special shuttles for transporting and/or providing living quarters for personnel.

Another breakthrough is expected from the semiconductor sector, pertaining to hyper-efficient microwave power receiving diodes, see Fig. 8. These development diodes are of the thermoelectric type: a part of the rectified microwave energy (d.c.) is fed back into a thermo-substrate cooling the diode's point-contact region and enhancing conductance. Ideally, if feedback could invoke low temperatures at cryogenic levels (0°K or −273.16°C), the device would provide zero electrical resistance during microwave half-cycles and maximum power transfer.

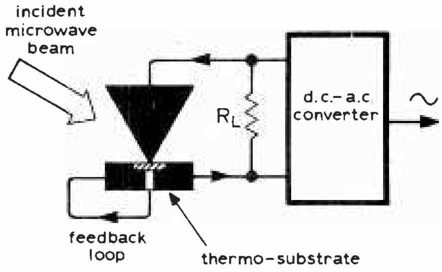


Fig. 8. Thermoelectric feedback diode for microwave rectification. Thermo-substrate is energized by feedback loop (R_L is the exciter load, see text).

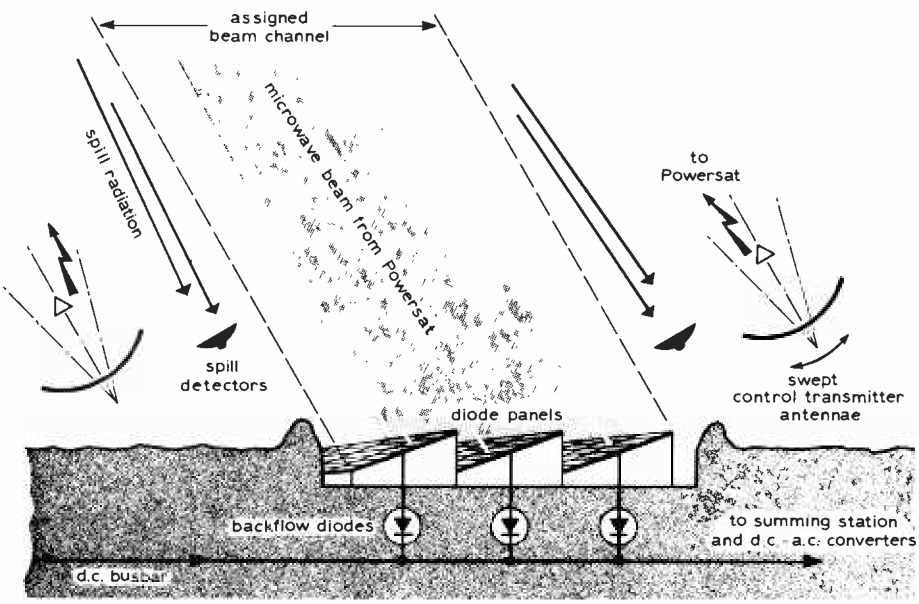


Fig. 6. Powersat ground receiving system or "antennae farm" designed to collect energy from a space-borne Powersat. Diode panels rectify the microwave energy and backflow diodes safeguard the current busbar. In the event of dangerous off-target radiation, spill detectors initiate Powersat's shut-off via control transmitters.

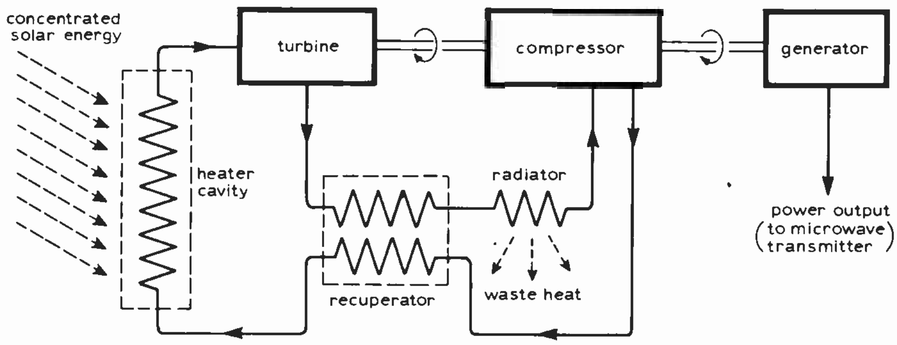


Fig. 7. Proposed Powersat generating system based on a closed Brayton cycle (see text).

The diode lattices, which are still in their patent pending stages, are expected to feature exceptionally wide bandwidths. Other improvements seal with mounting and admittance apertures.

Organic solar energy converters

The search for high-efficiency energy converters has directed attention towards organic semiconductors, including those innate to living biological systems. Nine primary processes are under investigation: electro-nuclear mechanics of photosynthesis, formation of free radicals, Hall-mode stream patterns, electron transfer, intramolecular rearrangement, photoionization, photoisomerization, carbon-carbon bonds supporting electron conduction, and photophysical processes involving electro-biological effects such as phosphorescence, fluorescence, and the like. Examples of hyper-efficient organic semiconductors are found in nerve complexes, brains, and other biological matter.

Much hope is based upon the "Hill reaction", named after the British biochemist Robin Hill who, in 1937, discovered that chloroplasts in green plant cells evolve oxygen from water when exposed to light rays in the presence of selected ferric compounds. When water is placed under ultra violet light, hydrogen and oxygen are separated, giving rise to the formation of free basic-element atoms and the transfer of electrons. Solar energy acts as a "pump", with certain end-effects resembling the quantum-mechanical processes found in c.w. laser systems.

Because of the promise of large-scale

electric power production from living systems, some special attention has been directed at the electrophysiological properties of large plants, including trees and other species.

Fig. 9, for example, depicts an experiment on a yucca, a hardy specimen that is common to the Mojave Desert in Southern California. The test set-up was designed to ascertain an electron-flow law under varying intensities of solar illumination (day-night cycles), magneto-biological effects, psychogalvanic sensitivities to environmental stress, and changes in electricity production following electron replenishment from artificial current sources (batteries). Other experimental series are augmented by weak radio-frequency fields applied to plant organs to investigate changes in current densities. Special catalysts may also be used.

The purpose of these and related experiments is to increase current flow to usable levels. At present, typical power outputs of plants are in the low milliwatt range – barely sufficient to operate a small transistor radio. However, the promise is there.

Fig. 9. Experiment for obtaining electrical energy from living plants. This test, on a yucca plant, was designed to study the electron flow within the plant under varying light intensities.

High-energy power transmission

Technically, the achievement of obtaining large amounts of electricity from the sun cannot stand alone. The availability of solar power would require low-loss terrestrial distribution systems in order to insure quality service and adequate returns on the massive financial investment required to achieve this aim.

Planners are considering using transmission cables insulated with compressed gas, cryoresistive transmission lines (cables cooled to the temperature of liquid nitrogen), and deep-cooled cables having super-conductive properties. Existing overhead lines may be augmented where international service grids are involved. The advantages of cables are that heat dissipation can either be reduced (as in the case of compressed gas cables), or effectively controlled (as in cases of cryoresistive and superconducting cables). Even with improved cooling, oil-filled cables will probably have only twice their present capacity. Unfortunately the immediate disadvantage of cooled long-distance cables are the high power requirements for refrigeration. Typically, a refrigeration station would use about 9.5 watts of power to pump 1 watt of heat away from a cable of conventional design.

However, progress in superconductivity has now taken a big leap forward with the development of a new superconducting cable by the US Naval Research Laboratory (NRL). The highest critical current density yet observed in superconducting material was demonstrated using vanadium-gallium (V_3Ga) composite wire. At 4.2°K, the V_3Ga-composition has shown a current density of $10^6 A/cm^2$ in a transverse magnetic field of 100kG. This density is about 40 per cent greater than any previously reported. The improvement resulted from raising the percentage of gallium in the alloys used to form the superconductor. Increasing this percentage increased the growth rate for the superconducing thin film, which forms between the two components of the wire, resulting in smaller grain size and higher critical current densities. NRL plans to develop 19-filament and 361-filament cables of the V_3Ga type, with ever better efficiences expected in the near future.

Tentatively, it is expected that no more than one refrigeration station will be needed for every 11km of high-efficiency superconducting cable. Of course the high cost of these very expensive service systems will be avoided if solar power plants, including suitable energy storage facilities, can be installed – at low cost – for individual communities.

Physical limits of sun power

For all terrestrial engineering purposes, the sun can be regarded as an infinite power source. Technically, the innate limits confronting our ability to draw maximum power from the star decrease in proportion to our developing knowledge in solar-energy engineering. For example: The solar radiation constant is $1.395kW/m^2$ on the Earth's surface. Assuming an overall solar-energy converter efficiency of 50%, approximately 700 watts of usable power per square metre of collector area could be generated by a ground-based system. Therefore multiples are algebraic ones: for example, $10{,}000m^2$ of effective collector area would render 7000 kW of electricity, and so on. Optical concentrators could multiply this further.

Clearly, future problems will be in obtaining better converter efficiencies and a sensible system of land management, i.e. the setting aside of "sunshine regions" – such as deserts with minor overcast profiles and low precipitation – for power generation and network distribution systems. Peripheral problems can be solved as well. Alkaline water, for example, which one frequently finds in deserts but is unsuitable for direct domestic consumption, can be electrically distilled. Good water of pH 7.0 can also be used for on-site agricultural purposes and later for growing structural timber. Further, the new abundance of electrical energy would permit mining of bauxite from low-yield regions and manufacture of aluminum cables and parts for power-grid systems.

In short, limits are set only by the creative imagination and the degree of farsightedness of executive planners.

Legal aspects of solar power

Who has the legal rights to energy from the sun? As history demonstrates, asserting property rights to the sky is nothing new. Even with solar energy in its development stages, battles will not be theoretical ones while tall office buildings rise to overshadow smaller neighbours, thereby keeping sunlight from rooftop solar energy collectors.

There is a "doctrine of ancient lights" (and rights!), but what has served in past centuries might be unworkable in the era of solar power.

Solar power is a young field, legally ill-defined. It would be prudent to suggest, perhaps, that impartial "solar energy masters" be appointed by courts. Thus, energy disputes can be handled in a manner similar to that of "water masters" in water rights cases.

Summary

Earth's ecological capabilities and supply of raw materials are adequate for supporting 600 million people comfortably, but not the current census of 3,800 million individuals. Whether or not our civilization will continue to develop depends upon our ability to secure alternate energy sources. Solar energy is one answer. Drawing power from the sun is less of a technological gamble than landing men on the moon or searching for life on Mars.

Further reading

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NTSC simulator

Simple design suitable for teaching

by Roy C. Whitehead, M.I.E.E.

This design can be used to demonstrate the basic character of the original N.T.S.C. colour TV system and its main limitation. The modulator circuit is shown in Fig. 1. Three generator symbols shown in Figs. 1 and 2 represent the three outputs from one generator (variable phase oscillator). The frequency used is 1590Hz, $\omega = 10000$, and all amplitudes are set to maximum. Two potentials in quadrature are produced across C_1 and R_1 to represent the *U* and *V* components of the N.T.S.C. subcarrier. Because the generator outputs are unbalanced it is necessary to introduce transformers T_1 and T_2 to produce balanced operation. The addition of the potentiometers results in the secondary circuits taking the form of bridges.

When the sliders of these potentiometers are at their midpoints the bridges are balanced, corresponding to a picture signal of zero saturation. The outputs of R_2 and R_3 represent the *U* and *V* signals respectively and are displayed by the double-beam oscilloscope which must have its timebase triggered directly from the generator. Ideally, the addition of these two signals should be displayed by the balanced-input oscilloscope, c.r.o.2, but in fact the instrument displays their difference. This oscilloscope also needs to have its timebase triggered directly from the generator.

A circuit for the two synchronous detectors is shown in Fig. 2. Input from the modulator is connected to the two detector circuits via transformers T_3 and T_4. The two reference inputs to the detectors are provided by the zero phase and +90° outputs of the generator, and the two signals are displayed finally by two 100–0–100 microammeters. Phase control of the generator can be set so that operation of R_2 causes corresponding deflections of M_1, and operation of R_3 causes deflections of M_2. This represents ideal N.T.S.C. performance.

Deliberate misadjustment of the phase control demonstrates cross-colour, i.e. mutual contaminations of *U* and *V* which occurs when the reference oscillator of a colour receiver is not correctly phased to the colour burst.

If an *X–Y* display unit is available, or an oscilliscope which is suitable for Lissajous displays, a modified detector circuit may be used. With the timebase of the oscilloscope switched off, and with both inputs set to zero, the spot is centred and the unit takes on the functions of a vectorscope.

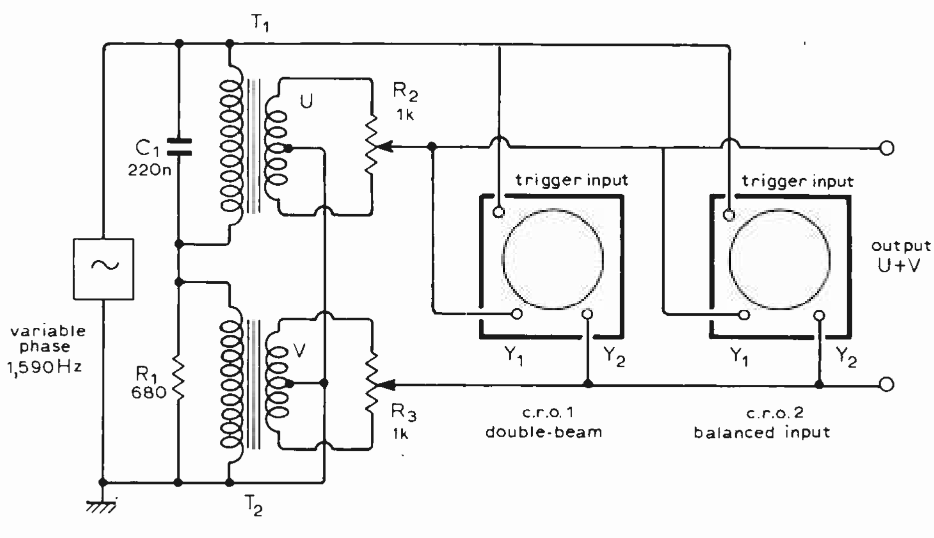

Fig. 1. Modulator unit. The transformers (RS Components TT/6) are used to provide a balanced output.

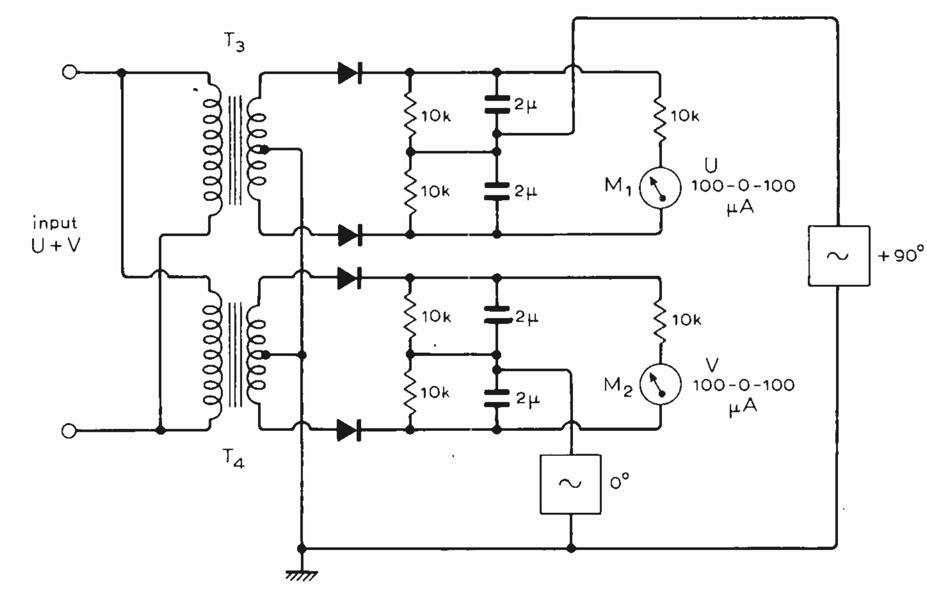

Fig. 2. Synchronous detectors.

Letters to the Editor

THE FUTURE OF TELEVISION

Britain was the first in the field with commercial television and after the war the original television market soon showed signs of saturating. The industry was re-vitalised by the introduction of the 625-line service and the opening up of the higher-frequency transmission bands. When the market was again saturating, the industry was re-invigorated by the introduction of colour. It will not be many years before the market for colour receivers is also saturated, especially through the mechanism of rental of receivers. We now have Teletext just coming on the market and various systems for recording/replaying on tape or disc for home use; but I do not think these are sufficient to keep the industry going at full strength for very long. Following the sequence basic television, higher definition, colour, the logical next step would be 3-D television.

Quite a number of methods are known for producing a 3-D picture, e.g. in the cinema; and most of these have been tried for television in the laboratory and discarded. There remains the use of the hologram. This is the most perfect method of recording a 3-D image, but television engineers have recoiled in horror on seeing the bandwidth requirement calculated as several gigahertz[1]. The subsequent suggestion[2] of a possible reduction by a factor of 4 did not significantly change the situation. The trouble with holography is that it is too sensitive. It will inherently record distance to an accuracy of better than a thousandth of a millimetre, whereas an accuracy of one millimetre in depth would be quite adequate for most TV scenes. I do not believe it is beyond the wit of man to find a means of discarding the unwanted excess of accuracy in such a way as to reduce the bandwidth required.

I remember reading in a popular book on radio which was published in the 1920s something like this: "The problems surrounding television are as thick as snowflakes round the North Pole, but they will be solved eventually." They were solved in less than 20 years. The report of the Television Committee 1943 (under the chairmanship of Lord Hankey) recomemmended that the restoration of the pre-war television service should be followed by an improved system "possibly incorporating colour and stereoscopic effects". We now have the colour, and it is only a matter of time before 3-D is introduced. But the question is where? Will it be, perhaps, in Japan[3] or will it be in Britain?

D. A. Bell,
Electronic Engineering Department,
University of Hull.

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3. Takanori Okoshi and Kazuo Hotate, *Electronics and Communications in Japan*, 57-C, 102-109, 1974.

COMMUNICATION THEORY

I would like to comment on the reference to Shannon's theory of information which Professor Bell makes in his article in *Wireless World*, April 1976. This, incidentally, is possibly the first occasion that any explanation of this famous theory[1] has been presented in the pages of *Wireless World*.

It is ironic that the fundamental basis of the communication process actually appears as a rather vague branch of mathematics having a very remote practical application. The conclusions arrived at by Shannon's theory are not to be challenged, but what I think should be open to question is the manner in a certain aspect of the theory is presented by many authors, including Professor Bell, and, originally, by Shannon himself.

I am concerned with the derivation of the expression

$$-\sum_{i=1}^{i=N} p_i \log p_i$$

This expression, states Professor Bell, can be shown mathematically to be the only satisfactory measure of the uncertainty relating to a finite group of probabilities. The idea behind such a demonstration is that information is some quantity which reduces uncertainty and that the above function can be shown to have certain mathematical properties which, it is asserted, one can intuitively expect. This approach was originated by Shannon and has been elaborately pursued by many writers since. It is, however, meaningless because it seeks to define a measure of information in complete isolation from any physical consideration and without any indication, initially, of the true purpose of such a measure. This, I feel, is one of the factors which contribute to the difficulty of the theory of information.

A simple example can be shown to reveal the purpose and philosophy of the theory of information. Consider the process of encoding the output of a discrete source of information into a discrete noiseless channel. The discrete source is specified by the group of source symbol probabilities, p_i. The discrete noiseless channel is capable of transmitting any one of a number, B, channel symbols per second. We now ask the question, what is the greatest rate at which the source symbols can be unambiguously encoded into the channel symbols and what is the relationship between this rate and the group of probabilities p_i? This is equivalent to asking what is the optimum of a process subjected to two sets of constraints, a probabilistic set and a deterministic set. Because of the probabilistic constraints an optimum condition can be realised only by an indefinitely large sample of the process. The answer to our question, therefore, is to be found by the application of an important statistical concept, namely, the law of large numbers. This law is, in fact, the central principle of Shannon's information theory and requires a knowledge of statistics very little beyond 'A' level in order to understand it. An application of the law in this case will give the answer to our question as C/H source symbols per second, where $C = \log B$ and

$$H = -\sum_{i=1}^{i=N} p_i \log p_i$$

H is a function of the source symbol probabilities only and measures an attribute of the source which can be called appropriately the "average information rate" and C can be called the "channel capacity." If the base of all the logarithms is chosen to be 2 then H is expressed in bits per source symbol and C in bits per second.

Deriving the above expression for H in this manner means that we can abandon the approach whereby the formula is quoted from the start, then shown to have certain mathematical properties and then given the name "entropy". The concept of entropy was first introduced in 1851 by Rankine (of ideal steam cycle fame) who called it the "thermodynamic function". The concept was extended by Clausius who coined the name entropy and a Professor Perry suggested that the unit should be called the "rank", in honour of Rankine[2]. As Professor Bell says, the exact relationship between different applications of entropy need not concern us here. I would agree with this and say also that entropy is of historical importance only in the present context and the use of the term should be avoided. There is, of course, a valid analogy between thermodynamic entropy and average information rate but this is of esoteric interest only.

Colin Hackney,
University of Salford.

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2. Wrangham D. A., "The Theory and Practice of Heat Engines," Cambridge University Press, 1942.

Professor Bell replies:

Since I was primarily concerned with *communication* I had (perhaps wrongly) refrained from discussing at great depth the measure of *information*, which is a more complicated subject than Dr Hackney suggests. The entropy formula for information enters into communication in two ways. Dr Hackney refers to one of them, the coding of the output of an information source to suit the characteristics of a discrete noiseless channel. Since channels are never noiseless in practice, one tends not to give too much importance to this application, though it is the theoretical background of schemes of "bandwidth compression" and these are finding some practical application in telemetry from space vehicles and in specialised forms of television such as Viewphone. But so long as the communication engineer is setting out to provide a channel to carry *any* signal within the bounds of a fixed information rate he cannot rely on source-to-channel coding. The other application is to the *noisy* channel, leading to Shannon's channel-capacity theorem.

The derivation of the entropy formula does not depend on any intuitive expectation as regards its mathematical form, and I have from time to time challenged critics to produce any other formula. One is tempted at first to think of "information" as an "instruction to act", since one does not know whether information has been received unless the recipient reacts in some way. But then he (she) may put the information into store so one then modifies this to "potential action." Next one has to consider what is called in common parlance the reliability of the information, or in technical terminology the signal-to noise ratio of the received signal. As the daily press would say, does it come from a reliable source? The information in a railway timetable is usually considered to be fairly reliable: one is surprised if an inter-city train does not appear at or about the advertised time. But consider the uncertainties of the financial prospect. After collecting all the available evidence – including beliefs about psychological factors – a financial expert will assign probabilities to the pound sterling being worth various values, say at 10 per cent steps between $1.50 and $2.00, in six months' time. But this is just formulating a set of probabilities which can be put in the formula $-\Sigma p_i \log p_i$. But of course the said financier may well have formulated at least qualitatively many other probabilities: whether a certain friend will arrive for a visit at the weekend, how good a crop his apple trees will have this year, whether his first-born will get a university place next October . . . The point of bringing in all these non-scientific examples is to suggest that a person's "world picture" consists very largely of a set of probabilities. It follows that information is that which changes a person's world picture. (Is this intuitive or axiomatic?) The second consequence is that one must always specify which probabilities are changed by a signal; and information (like entropy in thermodynamics) is always measured as a difference, not as an absolute value – one takes the difference between the information at the receiving end after a signal and that which was there before.

The exact mathematical form of the entropy measure, however, has nothing to do with the above. My authority for saying that it is the only possible form is A. Feinstein who gives the mathematical proof in his book "Foundations of Information Theory."[1] The assumptions are that information is *some* function of probabilities, that the measure is symmetrical in all the probabilities involved, and that it can take account of the result of sub-dividing a probability into component part probabilities. Given these basic assumptions, the entropy formula follows.

I am not sure where abstract scientific theory ends and the esoteric begins, but of course the relation between information and thermodynamic entropy can also be pursued through the "Maxwell demon" type of argument. But this is a large topic, and an outline of the arguments with references to the original papers can be found elsewhere[2].

There are cases in which Shannon's entropy measure is inappropriate, but I am not sure that what is being measured is information. The classic example is R. A. Fisher's use of the inverse of the variance of an experimental result which is inherently liable to statistical uncertainty, on the ground that this can be related to the financial value of the result. There is also the question of structure and complexity in a pattern, but in relation to artistic patterns my comments will appear in another journal.[3]
D. A. Bell

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1. A. Feinstein, Foundations of Information Theory, McGraw Hill, 1958.
2. D. A. Bell, Information Theory and its Engineering Applications, Pitman, 4th edn. 1972.
3. D. A. Bell, Information and Pattern, *Kybernetes* (publication pending).

PHASE IN THE EAR

I have followed the discussion regarding the importance of phase in sound reproduction with some feelings of regret that so much energy has been expended in the seeking of adequate explanations without a full knowledge of the facts. The main consideration has been the "interface" between the electrically driven transducer and the air. But there is another "interface" that is of equal importance and is indeed the final arbiter. This is the mechanism in the ear, a mechanism which converts sound waves to electrical nerve impulses. In the article "Acoustics" in Grove's Dictionary of Music (vol 1, page 33) it is stated that there are some 24,000 transverse fibres in the basilar membrane of the ear, and each one has its own natural frequency, and responding only to that frequency. If this be the case, the ear is an analyser of sound and no question of phase difference can arise. And incidentally harmonics are separated, the ones from the others, and distortion harmonics beyond audibility have no meaning except when intermodulation occurs.

And so everything seems satisfactorily explained until we find elsewhere in Grove's (vol. 6, page 349) that a 32ft organ tone can be obtained by sounding the second and third harmonics, 16ft and 10⅔ft pipes, the so-called Tartini effect. The development of beats in electrical engineering usually implies a multiplication or addition but it is rather hard to imagine either of these occurring in the ear. Incidentally, there is probably another "interface" in the connection between the ear nerves and the brain, functioning in much the same way as the reversal of direction that occurs between the eyeball and the sight area of the brain.

All this seems to point to the need for a closer understanding between engineers and physiologists.
Eric Neate,
Callington,
Cornwall.

THE INVENTORS

I have, with fits of exception, given up trying to get "error takeoff" into production. After all, what is perfection compared to the healthy grating sound of Class B!

But I do get a certain pleasure from the sheer delight of the system and recently made a step forward in my understanding which makes it much easier for me to design it. However, what I would like to hear from the National Research and Development Council (NRDC) who effectively rejected my idea is:

1. Do they recognise that we in Britain now have a chance to recapture the hi-fi amplifier market with amplifiers of perfect performance (not to mention other applications)?
2. Do they actually believe it works (my impression is of a lack of technical understanding, I may be wrong). I would be happy to demonstrate it to them.
3. Why, considering some of the things they have supported, will they not support a basic advance in understanding and application which "error takeoff" represents?

As for "industry," their attitude was "this is perpetual motion" in content although not in words or "yes, it works but we are happy with what we have got".

In my considered opinion the affairs of the "private inventor" should, in the long-term, be removed from the NRDC.
A. M. Sandman,
London NW3.

Editor's note: For an explanation of "error take-off", see Mr Sandman's article "Reducing amplifier distortion", *Wireless World*, October 1974 issue.

WIRELESS PIONEERS

The Society of Wireless Pioneers is interested in hearing from former or present wireless telegraph operators who have served or are serving ashore or afloat in the Merchant Service, the Post Office wireless telegraph service, or any branch of the military service. The Society of Wireless Pioneers is a non-profit organisation dedicated to wireless telegraph operators. Interested persons might write to: Mr John A. Edwards, G4BVA, SOWP Director, Great Britain, 81 Hunter Avenue, Brentwood, Essex, England.
H. J. Scott,
San Leandro,
Calif., USA

WAS BAIRD FOOLING THE PUBLIC?

In your April issue Mr F. H. Haynes stated: "It should be appreciated that Baird never successfully demonstrated television. Being without a method of synchronization over a distance, there could be no such event." Later in his letter he wrote (apropos Baird's endeavours to develop commercially his system of television), " . . . and to that end demonstrations had to be conjured and reports by staff contributors commissioned for publication."

These statements and others which Mr Haynes made, apparently in complete ignorance of the historical facts which are readily available to researchers, are so misleading and denigrating to the memory of Baird that it is most important that a factual rebuff be given to your correspondent's remarks.

Baird's numerous demonstrations of low definition television were given not only to newspaper correspondents and the general public but also to a number of notable scientists, Members of Parliament, engineers and administrators of the British Broadcasting Corporation and the General Post Office, *et al.*

Professor Sir Ambrose Fleming, Professor Taylor Jones, and Dr Alexander Russell all reported on Baird's experiments during the 1926-1928 period and their observations may be read in the appropriate volumes of *Nature* and the *Television* magazine. Additionally the opinions of Colonel A. S. Angwin, (former assistant engineer-in-chief, GPO) and Sir Noel Ashbridge, (former chief engineer, BBC), on the progress of Baird's work to 1936 are recorded in the archive collections of the BBC and GPO. Many other sources of information could, of course, be cited.

A few short extracts from these accounts will show that there was no need for Baird to "conjure" successful demonstrations of television.

In July 1926 Dr Alexander Russell[1] wrote that he was "agreeably surprised" to find that Baird had "made great progress in solving the (television) problem." Later in September 1926 *Radio News* (of the USA) sent a reporter to investigate Baird's claims: "Mr Baird has definitely and indisputably given a demonstration of real television.... It is the first time in history that this has been done in any part of the world." Professor E. Taylor Jones,[2] (of the University of Glasgow), in commenting on the London-Glasgow television transmission of May 1927 observed: "The image was perfectly steady in position, was remarkably free from distortion, and showed no sign of the 'streakiness' which was, I believe, in evidence in the earlier experiments." Approximately one year later (July 1928) Sir Ambrose Fleming[3] had the opportunity of "seeing in practical operation in Mr Baird's laboratory a very striking advance in the apparatus for television which (had) been recently made by Mr Baird."

Mr Haynes' ill-founded comments on synchronizing may be assessed by noting that *The Times*' correspondent found that: "By means of a Baird televisor and a little adjustment of the two knobs which respectively control the synchronization and the 'framing' of the picture the rapidly swirling pattern was resolved into a steady head and shoulders image of the speaker." This televisor was reviewed by *Wireless World* in its 12th March 1930 issue. The reviewer found that if the *single* LS5A valve, which gave an output of 1.5W (sic) was replaced by an LS6A valve, (rated output 5W), the process of synchronizing became easier. "For quite long intervals the picture remained steady. . . ." These statements may be compared with Mr Haynes' observation that: "With a monitored signal input (Big Ben clock face) and in an equipped laboratory where auxiliary gear, by way of a heavy duty synchronising and vision amplifier was to hand, the Baird televisor was shown to be a failure in fulfilling its intended purpose."

The first public low definition television service in the United Kingdom commenced broadcasting at 11.00 p.m. on 22nd August 1932. D. C. Birkinshaw,[4] (the BBC's television research engineer at that time), reported that "everything went off without a hitch of any sort, either technically or in the programme," on the opening night. Both he and Eustace Robb (the studio producer) made detailed improvements to the quality of the 30-line transmissions. The start of the service followed some "initiative" by W. Gladstone Murray (the BBC's assistant controller, information) and N. Ashbridge. After visiting the Baird laboratories on 12th October 1931 the BBC's chief engineer wrote a memorandum[5] in which he mentioned that the picture he had seen reproduced by means of a mirror drum/Kerr cell type of receiver "was easily the best television which I have seen so far . . ." "It was quite easy to recognise the persons even after seeing them once and there was no difficulty following facial expressions."

The 30-line service was operational until 10th August 1935. During its existence the Television Committee, (under the Chairmanship of Lord Selsdon), was established, (the first meeting was held on 29th May, 1934), and subsequently it considered, inter alia, the discontinuance of the low definition television broadcasts.

When the report[6] of the Committee was published it recommended, paragraph 34, that "the existing low definition broadcasts be maintained, if practicable, for the present." The Committee had been "rather impressed not by the number of protests but by the fact that they did appear to exist." These came not from Baird who felt the 30-line transmissions had "no commercial value" but from a number of different sources including Messrs Ferranti Ltd., *et al.* Mr V. Z. de Ferranti told Lord Selsdon: " . . . I was amazed that it was so good considering the limitations. . . ." "If you could let us (the people in the North) have it . . . I would like it very much."

Mr Haynes states in his letter – regarding the 30-line service: "No radio enthusiast was fooled. Radio Societies, then much attended, were amused." But an examination of the documentary evidence presented to Lord Selsdon's committee will show that it was the representations of many radio enthusiasts, the Television Society, certain industries, (large and small), which prevailed upon Lord Selsdon and his committee to extend the life of the 30-line service. A survey carried out by the Television Society in 1934 showed that 93% of the respondents wanted the 30-line transmission extended.

Additionally Mr Haynes commented: "*Wireless World*, always ready to pursue and report, remained silent": about what? – 30-line television? During the formative period of the low definition experimental television service, 1927-1930, *Wireless World* published 50 contributions on television, including 9 editorials, 38 letters from subscribers and 3 equipment reports!

Mr Haynes mentioned, (second paragraph): "This was the time of early talking films and picture telegraphy when the stable photocell and bright recording lamp were both readily available. Baird claimed to use visual purple as the light sensitive material." I have not come across this claim and would be pleased if Mr Haynes could quote his primary source. Baird had a notion (circa 1925) about using visual purple in an experimental cell but nothing came of this. He certainly utilised selenium cells in 1925 but by 1928 was employing gas-filled potassium photo-emissive cells.

Another statement which Mr Haynes made — "Proper electrical circuits for conveying the light values were not to be found in the various Baird set-ups" — is untrue. Indeed Mr Haynes' letter abounds with untruths designed to show Baird in a poor light. How any inventor could demonstrate, over a span of many years, the transmission and reception of images to leading scientists and engineers of the day and not use proper electrical circuits must surely be a mystery. Of course there is no mystery. A detailed description of the apparatus used by Baird in 1928 to demonstrate colour television was published in the *Journal of the Royal Society of Arts* and an account of the Baird 1930 television transmitter was given by T. H. Bridewater in *Wireless World* (3rd December 1930). Later, from 1932, responsibility for the 30-line transmission was accepted by the BBC (in co-operation with Baird's engineers).

It is unfortunate that Mr Haynes *prima facie* should have taken so little care with his letter. The writing of history is best left to those who are prepared to consult primary source documents – unpublished and published.

R. W. Burns,
Dept of Electrical and Electronic Engg.
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Trent Polytechnic,
Nottingham.

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3 Fleming, Sir A.: *Television Magazine*, July 1928.
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5 Ashbridge, N.: Report to Reith, Sir J., 10th October 1931, file T23, BBC, WAC.
6 Report of the Television Committee, Cmd. 4793, 1935, HMSO.
7 Wilson, J.C.: "Trichromatic reproduction in television" *Journal of the Royal Society of Arts*, Vol. 82, No. 4258, 29th June 1934, p.842.

CITIZENS' BAND

I am a holder of a Class B Amateur Radio licence and if no other place could be found for a Citizen's Band, I would not feel "cheated" if segments of the amateur bands were allocated for this use. I am sure this would bring screams of protest from other amateurs, but if this could help us save the life of a mountain climber, small boat owner, hiker or rustic, this would surely justify the action. I shall not presume to draft licence conditions and regulations but surely no-one could object to the introduction of a Citizen's Band strictly limited and controlled in the first instance to people engaged in dangerous activities such as the aforementioned.

This may even lead to amateurs taking a long hard look at themselves and operating methods. We may even notice that we are no more than sophisticated CB'ers ourselves (I apologise to the few exceptions).

I hope this letter does not offend too many amateurs.

Malcolm G. Black,
Handsworth Wood,
Birmingham.

EQUAL-TEMPERED PITCHES — *CORRECTION*

We apologize to readers that the end of a letter on generating equal tempered pitches was accidentally omitted from page 78 of the September issue. This reads as follows.

The biggest error is for F, but this is not sufficient to give the impression (with the other frequencies) of the scale gravitating towards a key — as would probably be the case with the smaller divisors in the first example given in the article.

Sven F. Weber,
Stronsay,
Orkney.
(Former Professor, Royal Academy of Music).

Electronic systems — 5

Reception and demodulation

by R. Ashmore *Assistant Editor, Wireless World*

Electronic systems 3 and 4 discussed the various techniques, advantages and disadvantages of both amplitude and frequency modulation of carrier signals. This section will describe some of the methods of receiving and demodulating amplitude-modulated carrier waves.

Station selection

To receive a particular broadcast from amongst the many different transmissions within the radio broadcast bands it is necessary to have a receiver tuned to the carrier frequency of the desired transmitter. In order to achieve optimum reception of this transmitted signal the bandwidth of the receiver must match that of the transmitter. If the bandwidth of the receiver is too wide the demodulated signal will contain undesirable interference from the adjacent channels. Reducing the receiver bandwidth will decrease the adjacent-channel interference but will restrict the reception of the high frequency components of the wanted station. The solution is that a compromise has to be made between the two above conditions, the term "selectivity" being introduced to describe the success of the receiver in rejecting the adjacent channels.

To demodulate a transmitted signal successfully the demodulator must be provided with an input signal of sufficient amplitude and therefore it is necessary to provide radio frequency amplification prior to demodulation in order to receive weak or distant transmissions.

The crystal set, which is the simplest form of a radio receiver, is constructed from a parallel tuned circuit and a crystal detector or demodulator. The crystal has semiconducting properties similar to the semiconductor diode which has since replaced it. This receiver does not need power from batteries or the mains supply because the power required to drive the earpiece is derived from the electrical signals induced in the aerial, consequently it is desirable to operate the set with a long aerial and a good earth connection. Voltages will be induced in the aerial due to the presence of signals from all transmitting stations, therefore a circuit is needed which will single out (tune to) the desired frequency — a circuit which will do this is called a tuned circuit.

This series of articles is based on a proposed Advanced Level course for schools and is prepared in consultation with Professor G. B. B. Chaplin, University of Essex. The next article will deal with more complex systems of reception and demodulation and will include the f.m. receiver.

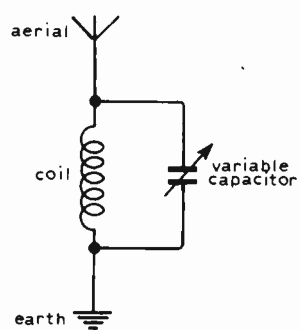


Fig. 1. Tuning circuit, shown connected between aerial and earth, consisting of an inductor in parallel with a variable capacitor.

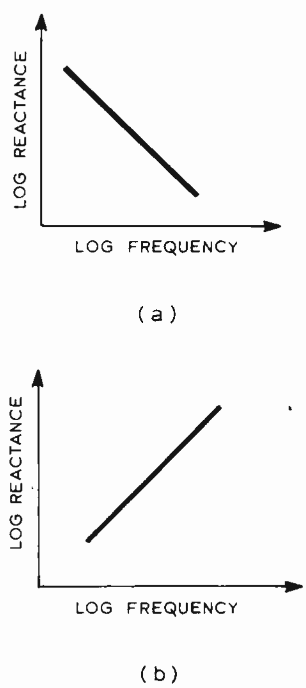


Fig. 2. Graphs of reactance against frequency for (a) capacitor and (b) inductor.

The tuned circuit used in a crystal set is an inductor connected in parallel with a variable capacitor, see Fig. 1. Let us now consider how this simple arrangement can single out a particular broadcast from a complex and full radio spectrum. Fig. 2 shows the plots of reactance against frequency for both the inductor and the capacitor. The equations for these impedances, for a capacitor C and an inductance L at a frequency f, are

$$\text{Capacitor: Impedance} = \frac{1}{2\pi fc}$$

$$\text{Inductor: Impedance} = 2\pi fL$$

For a given inductor/capacitor pair there will be a frequency at which the impedance of both components will be the same.

$$\text{i.e. when: } \frac{1}{2\pi fC} = 2\pi fL$$

$$\text{therefore: } f = \frac{1}{2\pi\sqrt{LC}}$$

At this frequency the parallel tuned circuit, made from the components L and C, are said to be in resonance and are tuned to the frequency f. The frequency response of the parallel tuned circuit described above is given in Fig. 3.

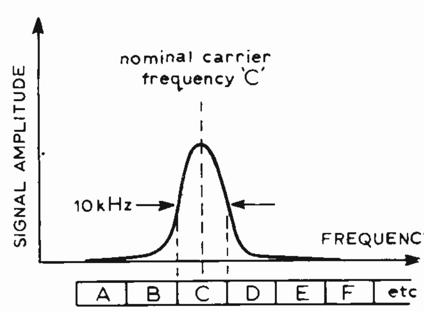


Fig. 3. Frequency response of the tuned circuit shown in Fig. 1, when tuned to station C. Ideally the response required would be a rectangular one with maximum amplitude within the bandwidth of C and zero amplitude at frequencies above and below C, so that all of the frequencies within channel C could be received with no interference from the adjacent stations.

The blocked frequency markings represent the channels allocated to a number of different transmitting stations. It can be seen that, for the conditions shown in Fig. 3, the tuned circuit would have very little response from stations A or E, some response from stations B and D, but the most response from station C. Although the circuit is capable of rejecting all stations whose carrier frequency is below that of B and above that of D, it has a poor selectivity, due to only partial rejection of the adjacent stations. The response from stations B and D is considered as adjacent-channel interference when attempting to receive station C only.

If the value of the capacitor is changed, the frequency at which the impedances of the inductor and the capacitor are equal will also change, hence the resonant frequency will be different. Reducing the value of the capacitor will increase the resonant frequency, conversely increasing the value of the capacitor will decrease the resonant frequency. The variable capacitor allows the resonant frequency of the tuned circuit to be altered so that it is coincident with any particular transmitted carrier frequency, thus allowing any chosen broadcast to be received.

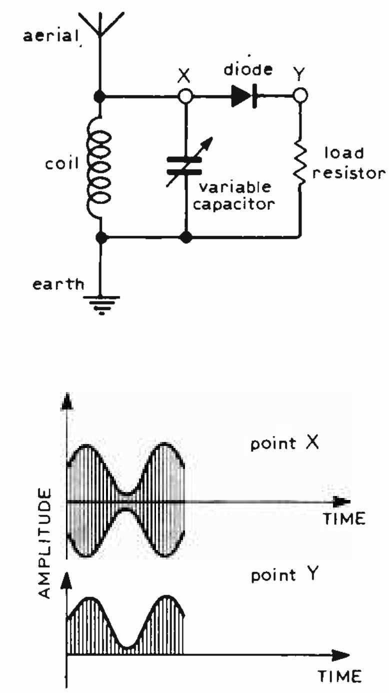


Fig. 4. Demodulating circuit. Signal at point X is of the same form as the output of the modulator in the transmitter – it is a modulated carrier signal. In order to recover the modulating signal it is necessary to rectify the carrier signal to remove all of the negative going, or positive going, voltages to obtain an average d.c. level. Resulting rectified signal is shown at point Y.

Demodulation

Demodulation is the process of recovering the information, impressed on the carrier wave, from the composite transmitted signal developed across the tuned circuit which, see diagram referring to point X in Fig. 4, is of the same form as the output of the modulator in the transmitter.

The average d.c. value of the waveform, over a complete cycle of the modulated carrier signal, is zero, and it is therefore necessary to remove all the negative going, or positive going, voltages in order to recover the modulating signal. This is achieved using a device such as a diode which will pass current in one direction only. Fig. 4 shows a circuit which achieves this result.

The signal at Y is a rectified version of the signal at X.

Since the signal at X has a mean d.c. level it is now only necessary to remove the remaining carrier components and the information which was transmitted will have been recovered. This is done by using a capacitor to filter out the high frequency components of the carrier signal. Because a capacitor has the property that its impedance decreases as frequency increases, selection of a suitable value of capacitance will ensure that it has a relatively low impedance to the high-frequency carrier signal and a relatively high impedance to the much lower frequency modulation signal. So that the broadcast stations can be heard, the load resistor is replaced by a pair of high impedance headphones which convert the tiny electrical currents into audible sound waves.

A suitable capacitor value may be chosen relative to the impedance of the headphones; it must have a lower impedance than the headphones at the carrier frequency and a high impedance at the frequency of the modulating signal. This is summarised in the equation given below.

The impedance of the capacitor C at a frequency f is:

$$\text{Impedance} = \frac{1}{2\pi fC}$$

Let the carrier frequency be f_c, the modulation frequency be f_m and the impedance of the headphones be R, then

$$\frac{1}{2\pi f_c C} << R << \frac{1}{2\pi f_m C}$$

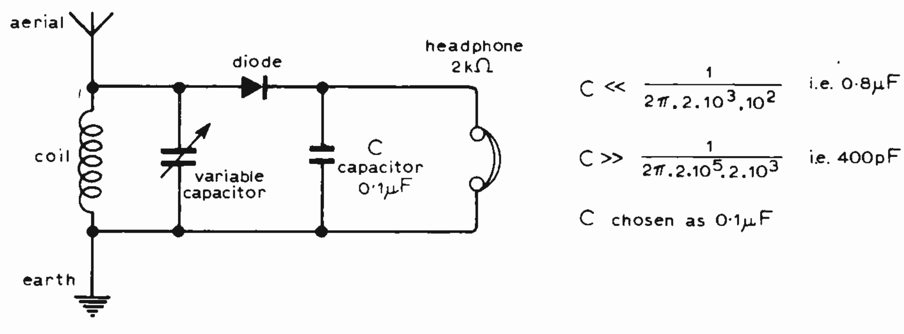
Fig. 5 shows the complete circuit of the crystal set with typical component values. In order to comply with the above conditions the value of capacitor C has been chosen as 0.1μF, see conditions formulated in Fig. 5.

A receiver of this kind will drive a pair of headphones, if the aerial and earth are sufficient, but it is unlikely that it will provide enough output to drive a loudspeaker; it is also lacking in sensitivity and selectivity. The next article will describe receivers which are designed to improve these characteristics.

Further reading

Obtainable from Mr R. A. Smith, Department of Electrical Engineering Science, University of Essex, Wivenhoe Park, Colchester CO4 3SQ, Essex, are the teaching texts for the electronic system pilot A-level course.

Fig. 5. Crystal set showing typical component values and the conditions for estimating a value for C. First condition says that the value of C should be such that its impedance is high, at the modulating frequency (in this case 100Hz), compared to the impedance of the headphones (in this case 2kΩ). Second condition says that the value of C should be such that its impedance at the carrier frequency (in this case 200kHz) should be low compared to the impedance of the headphones.



Correction

It has been pointed out to us that in Part 4 of "Electronic Systems" (July issue), Fig. 3 and the associated text give the impression that 9kHz channels are used all over the world in the l.f. and m.f. bands. In fact, 9kHz is used only in ITU Region 1 and the position in the Far East, Australia and Canada is that 10kHz channels are used. Fig. 3 also suggests, incorrectly, that adjacent channels are allotted on an inter-continental basis. Apologies to readers for these errors.

Thévenin, Norton and dependent sources

Single theorem, replacing Thévenin's and Norton's, is valid for dependent sources

by Harry E. Stockman

The importance of dependent function sources in network theory has increased with rapid development in semiconductor devices. This theorem holds for dependent sources because the ratio between open-port voltage and closed-port current is derived, by looking away from the network, rather than into it.

Wireless World was the first journal to publish a single formulation for Thévenin's and Norton's theorems; a formulation which was not much longer than that used for each individual theorem.[1] Either the Thévenin equivalent generator or the Norton equivalent generator can be drawn from one and the same theorem formulation. Like the original formulations, this one was valid only for independent sources.

During the past ten years, thanks to the rapid progress of semiconductor devices, the importance of dependent function sources in network theory has increased very much. While the Thévenin and Norton theorems by themselves are invalid for dependent sources, the combination of the two is valid for dependent sources. This is because of the different manner in which the generator immittance is obtained. In the combination theorem, to be discussed below, we do not look from the port into the network, to passivate it by removing the sources. On the contrary, we look the other way through the port, away from the network, securing the ratio between the open-port voltage and the closed-port current, or the inverse of this ratio, depending on whether we want an impedance or an admittance. The technique involved is simple and direct, and deserves a more widespread use than it has had so far.

The distinction is made clear by Fig. 1, where only Thévenin's theorem is discussed since the Norton theorem approach is similar. Fig. 1(a) shows the result of formally applying the classical Thévenin theorem to a linear network, in which no dependent sources are allowed. Fig. 1(b) shows how the generator impedance is determined when the combination theorem, formulated below, is used. In this case both independent and dependent sources are allowed in the original network. This means primary sources, or independent function sources, or dependent function sources. The author prefers the following specific formulation of this theorem, referring to it as the Thévenin-Norton function source theorem:

For any linear network with mixed independent and dependent sources and an accessible port, there exists an equivalent generator consisting of the impedance representing the ratio of the open-port voltage and the closed-port current, having either the open-port voltage in series or the closed-port current in parallel.

Being universal to its nature, this theorem may be used as an alternative to the classical Thévenin theorem and the classical Norton theorem.

The example given by Fig. 2 may clarify how the theorem is applied. While symbolic notation is used, Laplace transform notation applies equally well. For open-port AB with $(g+G)=1/k$, we find

$$E^* = gkV_1(1-b).$$

For closed port AB,

$$I^* = \frac{gkV_1(1-b)}{k(1+a)(1-b)+jX} = \frac{gkV_1\,(1-b)}{Z}$$

where $X=\omega L$. The Thévenin generator then consists of the voltage source **E** in series with the impedance $Z^* = E^*/I^* = Z$.

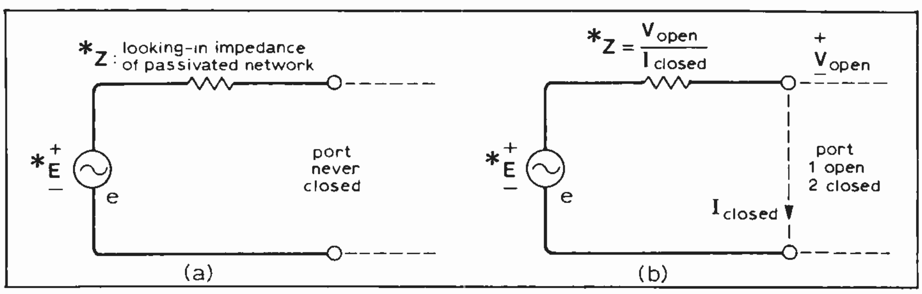
Two things are of particular interest here. One is that in more complicated problems we have to do a lot of

Thévenin and Norton theorems

Thévenin's theorem says the current in any impedance, Z_L, connected to two terminals of a linear network consisting of any number of impedances and generators (or voltage sources) is the same as though Z_L were connected to a simple generator, whose generated voltage is the open-circuited voltage at the terminals and whose impedance is the impedance of the network looking back from the terminals, with all generators replaced by impedances equal to the internal impedances of these generators.

Norton's theorem says the current in any impedance Z_R, connected to two terminals of a network, is the same as though Z_R were connected to a constant current generator whose generated current is equal to the current which flows through the two terminals when these terminals are short-circuited, the constant-current generator being in shunt with an impedance equal to the impedance of the network looking back from the terminals in question.

Fig 1(a). Thévenin generator for independent sources. (b) Thévenin generator for both independent and dependent sources.



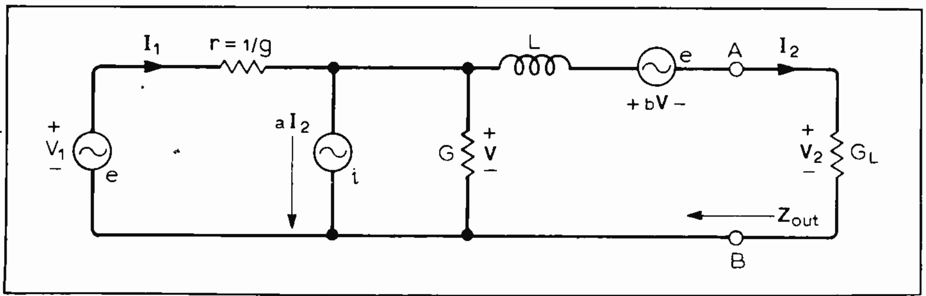


Fig. 2. Circuit used to illustrate application of theorems.

computation to derive the equivalent generator. The other one is that in many problems, particularly problems involving feedback, the early part of the solution produces the transfer function, such as $\mathbf{V}_2/V_1$ in this example. In fact some problems begin with a transfer function, and later in the problem solution we need to construct a Thévenin or Norton equivalent generator. In such a case there exists a theorem, the equivalent generator theorem, that will directly read out the Thévenin or Norton equivalent generator from the proper transfer function, eliminating need of computation. The simple application of this theorem is described in a recent publication,[2] but can be explained in a few words.

Using the example in Fig. 2, we have for $\mathbf{Z}=1/\mathbf{Y}$,

$$\frac{\mathbf{V}_2}{V_1}=\frac{gk(1-b)\,\mathbf{Y}}{\mathbf{Y}+G_L}$$

This transfer function directly gives $V_2=\mathbf{E}^*$ for $G_L=0$, and the equivalent generator admittance is the sum of all denominator terms, excepting the load admittance term G_L. For a current-driven system, the immittance read off in this matter pertains to an open input. This is the total theorem and it means that each time we have available the transfer function, we can directly read off from it either the Thévenin equivalent generator or the Norton equivalent generator. Particularly, we have at a glance the system output immittance, and there is no need to do what is conventionally done; either that we go back to the network and apply the component combination method, which will fail us, anyhow, if dependent sources are present, or apply a voltage to the output port and calculate the ensuing current. This theorem replaces such techniques; however, it does require that the proper transfer function is known.

The formulation of the equivalent generator theorem is as follows:

For any linear network with mixed independent and dependent sources and an accessible port, there exists an equivalent generator with an immittance equal to the sum of all the immittance terms except the load immittance term in the denominator of the proper transfer function, having either the open-port voltage in series or the closed-port current in parallel.

The output quantity can be current or voltage and the input quantity can be current or voltage; this choice deciding the immittance. Like the previous theorem, this one also holds for the Laplace transform, the concept of immittance restricting the use to the periodic steady state. Like the previous theorem, this one also provides an alternative to the classical Thévenin theorem and the classical Norton theorem, provided of course that the transfer function is known or is derived.

References

1. Stockman, H. E. Thévenin and Norton, *Wireless World* vol. 70, 1964, pp.295/6.

2. Stockman, H.E. Steinmetz' Symbolic Method, History, Worked Problems, 1974, SER Co., Box 78, Arlington, Mass. 02174, USA.

Announcements

Courses for radio amateurs

Enrolment for a course run by the Bury Radio Society took place at the Mosses Youth and Community Centre, Cecil Street, at 8pm on August 31 and September 7. The course begins on September 21.

Walsall College of Technology's course begins on September 20 at St Paul's Street.

North and West Farnborough Further Education Centre begin a course on September 30 at 7.30 p.m. at the Cove School, St John's Road. A morse proficiency course begins at Oak Farm School, Chaucer Road, on September 27.

Bridgenorth College of Further Education's course will be held on Monday evenings from September 20. Openshaw Technical College will begin their radio amateur's course at 6.45 pm on September 21.

The Society of Electronic and Radio Technicians are holding a residential symposium on microprocessors at Work at Sussex University from September 26 to 29.

The North East London Polytechnic is holding a 12 week **integrated circuit design workshop** from Wednesday November 17. Part one, comprising five weekly meetings beginning at 1.15 p.m., will include applications of transistor arrays, op. amps and parameter measurements, and part two will begin on January 12, including seven meetings on such subjects as comparators, timers, c.m.o.s., phase locked loops and multipliers. Both parts will be held at the Barking Precinct.

Cahse-Foster, Suffolk Circuits of Lady Lane Industrial Estate near Ipswich, has been appointed sole UK agent for microwave **printed-circuit laminates**. The laminates known as Di-Clad are available in two forms. The 522 laminate with a dissipation factor of 0.001 at 1 MHz and 0.0025 at the X-band with a dielectric constant of 2.5. Laminate 527 has the same dielectric constant but has a dissipation factor of 0.0019 at X-band.

Rank Audio Visual, who recently closed the Leak electronics factory at Bradford because of losses over the last four years, took 40 dealers to Hawaii for a week, starting on July 14, for the annual sales conference. The programme included a flight round the islands, a cruise in a catarmaran and shows at the Hilton, where they were staying.

EMI's medical electronics group is moving its headquarters to Windsor House, a £2 million, 9 storey, 40,000 sq ft office block at Slough. By the end of the year 200 staff will be installed, rising to 260 in 1977. Most of the leased block will be taken up by EMI Medical's sales and service division, which is moving from Hayes along with 100 staff. 150 clerical, engineering and sales jobs will be filled locally. Manufacturing for the medical electronics group will continue at Hayes, Radlett, Feltham, Fimley, Wells and Windsor.

IFPI celebration

Next year 560 record companies in 60 countries will take part in an international programme of events to celebrate the centenary of the invention and manufacture of the gramophone. The programme, organised by the International Federation of the Producers of Phonograms and Videograms (IFPI), will be co-ordinated by Mr Denis Comper.

A one term course on digital techniques in audio engineering will be held on Thursday evenings at 6.30 pm at the North London Polytechnic from October 28. Other courses run by the NLP's department of electronic and communications engineering include that on sound studios and recording, which begins on the same date and continues to June, 1977.

South London College is holding a series of nine lectures on teletext systems beginning on October 12. They will be presented by Wireless World deputy editor Philip Darrington and specialists from the BBC, ITCA, Decca and the Post Office. Another short course at SRC, Norwood, will be on integrated circuits, beginning October 14.

On October 4 and 5 the City University, London, will hold an introductory course on microprocessors. Reduced fees accepted if paid before September 24. Another series of short courses, on microelectronics, is being held by Middlesex Polytechnic, Enfield, on thick film hybrids, m.o.s. devices and circuits, microelectronics, basic thick film technology, and semiconductor devices and technology on various dates.

Contracts for phase one of the Post Office 120Mbit/s digital network have been awarded to GEC telecommunications. They will build equipment to multiplex signals from 56 30-channel p.c.m. equipments to a 120Mbit/s digital signal equivalent to 1,680 speech circuits. The contract comes after GEC did a feasibility study, in 1970, and a trial system was installed for the Post Office in late 1972 between Portsmouth and Southampton.

The Post Office are extending their fast machine sorting programme over the next 18 months and have awarded nine contracts together worth over £4 million for electronic coding and sorting machines. Sperry Gyroscope get two worth £1m. Frazer-Nash get three worth £1.4 million. GEC Mechanical Handling receive two contracts worth £1 million. Plessey get one worth £600,000 and ITT Components get a contract worth £100,000. Delivery should begin early in 1977, say the BPO.

Questionnaire winners

Some issues of August *Wireless World* contained a questionnaire in which prizes were offered for winning numbers. The numbers and their prizes are 33284 & 32314 Gould Advance digital voltmeter; 23013 Texas Scientific pocket calculator; 22618, 11702, 11893 & 17347 win Wahl rechargeable soldering irons. Winners will be notified in due course.

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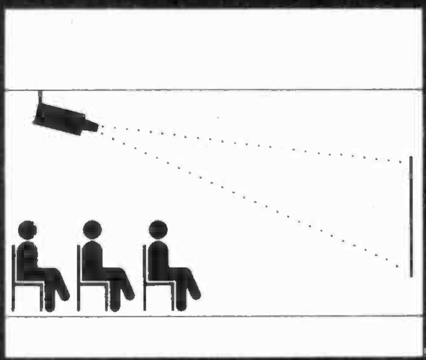

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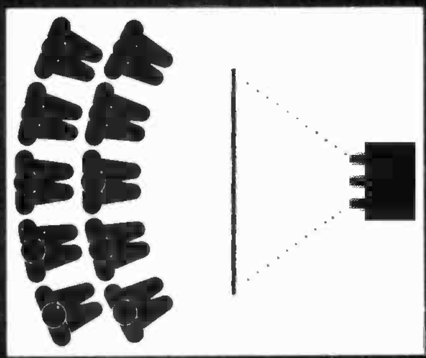

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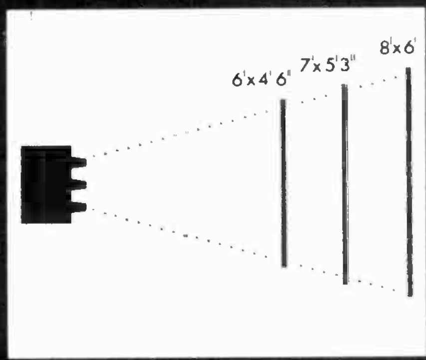

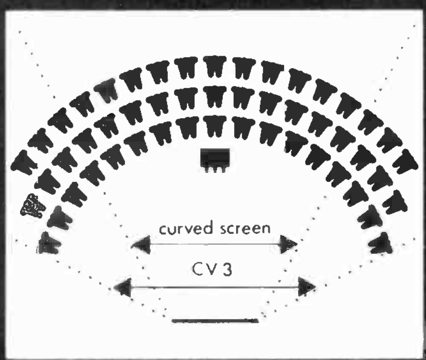

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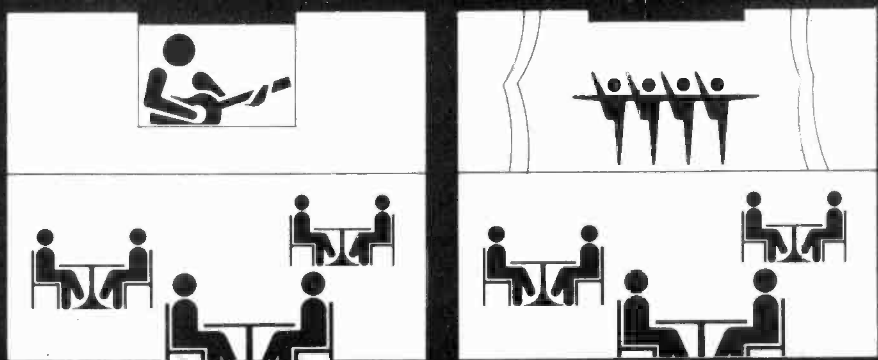

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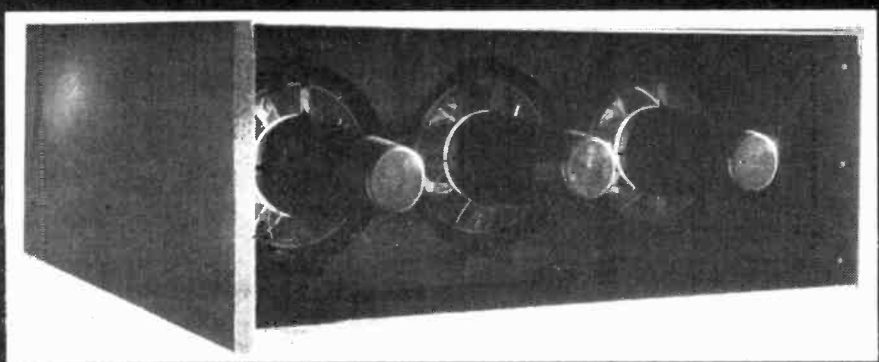

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Variable pre-emphasis in f.m. broadcasting

One scheme used in October IBA tests

by Len Lewis, *Audio & Design (Recording) Ltd*

Variable pre-emphasis is a technique whereby the pre-emphasis curve used in f.m. broadcasting is varied according to programme content. The aim is to prevent transmitter over-deviation by high level, high frequency signals while not unnecessarily attentuating low and mid-frequency components. No modification of receiving apparatus is required as the device is active on momentary peaks only and for less than 10% of the time. It can improve signal-to-noise ratio by at least 6dB to give increased transmitter range.

Since early f.m. broadcasting days much effort has been expended on attempts to improve the relatively poor signal-to-noise ratio inherent in transmitted signals. Early research soon established that the higher frequency elements of noise were subjectively most objectionable and thus worthy of greater investigation. Further, this hiss was unavoidably aggravated by the transmission process itself.

Fig. 1 demonstrates how energy distribution throughout the audio spectrum would have looked to those early researchers, for typical broadcast material of the time. Notice, particularly, how for both programme types there is a marked fall off in sound energy characteristic as frequency increases. Relating this to the known properties of hiss it was concluded that, by boosting or pre-emphasizing the higher frequencies where hiss occurs just prior to transmission and then de-emphasizing them on reception, a useful degree of noise attenuation would occur. Because higher frequency programme content was generally of a lower level such pre-emphasis was not likely to have any noticeable side effects. Consequently a standard pre-emphasis curve of 50µs time constant was arrived at collectively for Europe (against 75µs in America) by its broadcasting authorities and a complementary de-emphasis curve defined for incorporation, as standard, into receivers.

The curve, Fig. 2, has a 3dB boost at 3.18kHz rising to 10dB at 10kHz and Fig. 1 shows the effect on spectral distribution.

Unfortunately assumptions based on the falling h.f. characteristic of sound no longer hold true; with some types of modern sound balancing techniques, considerably higher levels can be presented for transmission. Instruments producing very high-pitched sounds are unnaturally emphasized, a condition commonly aggravated by the use of compressors, which tend to boost the average sound level anyway. This shift in emphasis, when modified by the 50µs pre-emphasis curve and presented for transmission, gives rise to an undesirable characteristic whereby, to prevent over-deviation of the transmitter by unnaturally emphasized h.f. signals, the whole signal is momentarily attenuated by the action of gain reduction at the transmitter limiter. In this way, low and mid-frequency programme components of subjectively major importance are attenuated to accommodate the higher frequencies. This significant change in spectral energy distribution now demonstrates that the 50µs pre-emphasis curve solution has clearly developed a serious, objectionable side-effect which warrants further investigation.

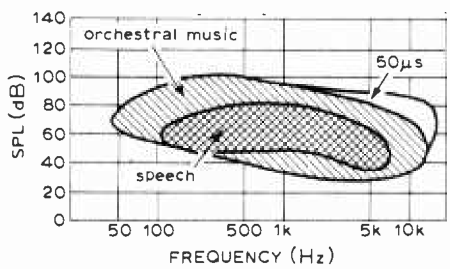


Fig. 1. Energy distribution in the audio spectrum, showing the effect of the 50µs pre-emphasis curve.

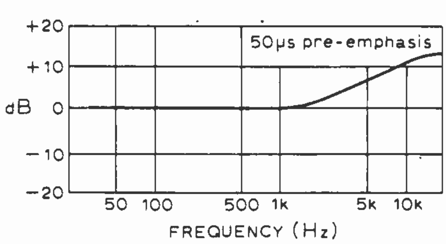


Fig. 2. The established 50µs pre-emphasis curve.

Obviously the simplest solution would be to reduce the overall level of programme presented to the transmitter to a point where limiting due to pre-emphasized h.f. content does not occur. This would, however, as with removing the 50µs curve at the transmitter altogether, give rise to an unacceptable deterioration in the overall signal-to-noise ratio. A far better solution would be to arrange pre-emphasis in such a way that dynamically, according to programme content, the 50µs curve only be reduced, as appropriate, avoiding over-deviation of the transmitter and unnecessary attentuation of important low and mid-frequency programme elements. Further benefits can be identified, notably that receiving equipment would require no modification to receive these signals and that higher levels could safely be presented for transmission, thus improving signal-to-noise ratio whilst retaining a high fidelity characteristic regarding the original sound source.

Through work carried out over the last three years into selective limiting, that is, limiting of one section of the audio band without affecting any other and experimentation in co-operation with IBA engineers, Audio & Design (Recording) Ltd has produced such a system. Termed variable pre-emphasis, its characteristic is to establish and then limit only (hence vary) a standard 50μs pre-emphasis curve.

Fig. 3 shows how R_1C_1, forming a 50μs time constant and R_2, acting as a "stopper" resistor, create the pre-emphasis curve. To obtain variable pre-emphasis it is necessary to split off the pre-emphasis from the main signal path and process it separately. The pre-emphasis signal is passed first through a limiter, Fig. 4, and then, optionally, through a diode clipper whose threshold is set approximately 1dB above the limit threshold to disallow over-shoot. As gain must be introduced for low distortion at this stage, a simultaneous input/output attenuator is employed, both to restore unity gain and to set the threshold of the system. The processed pre-emphasis signal is then added to the main signal, so producing a variable pre-emphasis signal.

Similar to the variable emphasis system of transmissions used by the BBC on their p.c.m. links, variable pre-emphasis offers many advantages to broadcasters. Being a single-ended processor, variable pre-emphasis requires no complex complementary decoding circuit or signal path modification to be made to receiving apparatus (the vast majority of f.m. receivers currently in use in the UK are incapable of modification anyway) to continue receiving high fidelity signals, the primary objective of f.m. stereo broadcasting. Tests have shown that at least 6dB increased modulation of the transmitter can be achieved, thus effecting a proportional improvement in signal-to-noise ratio and transmitter range yet requiring no increase in power consumption. In addition, the system is active for less than 10% of the time because limiting occurs at high level on high frequency content only, whereas in complementary encode/decode situations signal modification is typically operative 90% of the time.

This is important when considering any system's effect on transient performance, and of even greater significance to those listeners who possess receivers that could not be modified to decode. No part of the current transmission chain is made obsolete as a simple addition to the programme chain is all that is required to commence variable pre-emphasized transmissions. In addition to not substantially affecting the high fidelity content of broadcast programmes today, variable pre-emphasis gives broadcasters an open-ended system that could take advantage of future technical developments, without being made obsolete by them or tying broadcasters and listeners alike down to specifically encoded, thus unmodifiable, signals.

On-air tests being carried out by the IBA during October (see News, page 42) involve two techniques to improve signal-to-noise ratio and hence reduce background hiss for a given signal strength and receiver performance. The techniques, Dolby B encoding described on page 237 of the July 1974 issue, and the variable pre-emphasis, described briefly in these pages, have some effects on audio quality and the IBA hope to determine within statistical limits how noticeable they are. (In the tests, the variable pre-emphasis scheme will be used to provide only a 2dB signal-to-noise ratio improvement.) Test results will be carefully assessed before the IBA decides whether to seek Home Office approval for the use of either system. Observations on technical quality should be sent to Reception Tests, Engineering Information Service, IBA, Crawley Court, Winchester, Hampshire SO21 2QA.

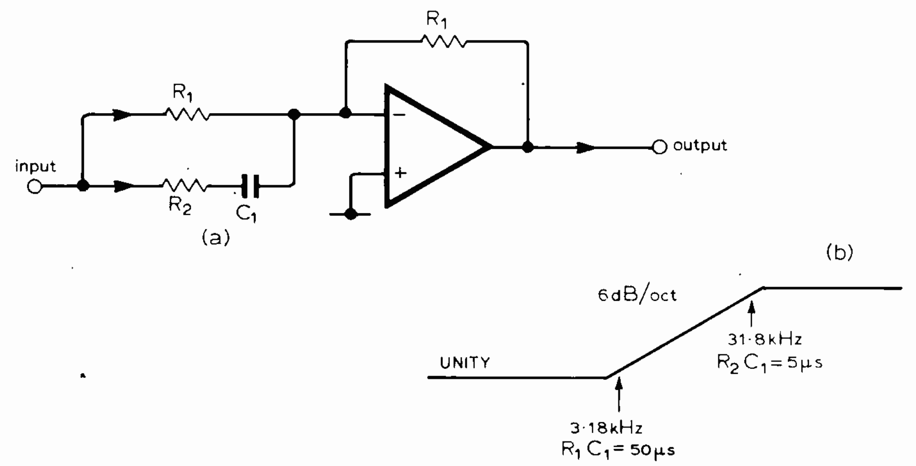


Fig. 3 (a) Method of obtaining the theoretical 50μs pre-emphasis of (b).

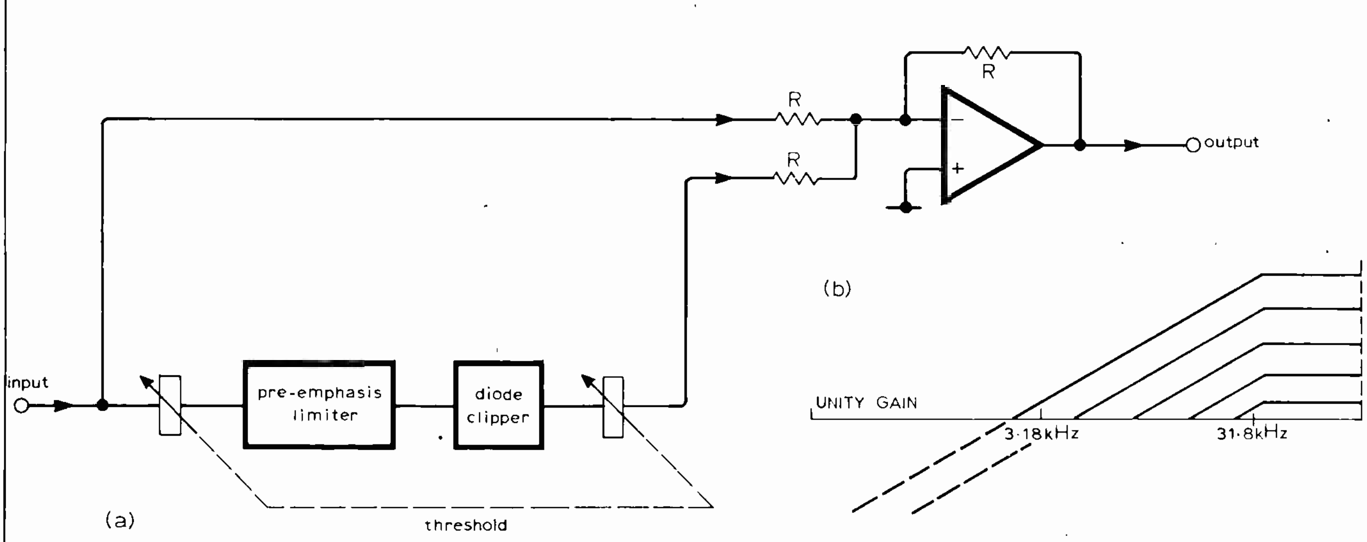


Fig. 4 (a). Variable pre-emphasis circuit and (b) the curves obtained.

Projection television—2

Refractive projectors

by Angus Robertson

The simplest form of television projection is to project the raster of an ordinary c.r.t. onto a screen using a lens. Light output depends upon the accelerating voltage and the efficiency and aperture of the projection lens; wide-aperture glass lenses are extremely expensive. There are two groups of refractive projectors, which are dealt with separately.

Trinitron projectors

Sony. The principle of the Sony VPP-2000, seen in Fig. 14, is shown diagrammatically in Fig. 15. A special 33cm Trinitron colour c.r.t. is used as the source, the light from which is directed, via a mirror, through the projection lens, with six elements, a focal length of 29cm, a diameter of 12.5cm and aperture f/2. A high-gain, solid screen, 1.02m by 0.76m, is used to obtain a quoted 34 nits (cd/m^2) luminance and, working backwards from this, the calculated light output is 10 lumens. Price is £1,500. Sony also produce a self-contained projection system, the KP-4000, whose principle is illustrated in Fig. 16. A Trinitron tube projects onto an internal 81cm by 61cm high-gain screen with a brightness of about 34 nits. Although not presently available in the UK, price in the States is similar to the VPP-2000. The VPK-1200E uses three 33m single colour tubes to project a 1.8m by 2.4m picture onto a high gain screen. Light output is about 200 lumens. Only two lenses are used; the outputs of the red and blue tubes are combined by a dichroic mirror. Lenses are f/2 with 30cm focal lengths. Price is expected to be around £16,000.

Muntz/Markoff Theatre Vision Inc. and **Tele-Theatre** (Fig. 17) both manufacture refractive projectors using a Trinitron colour tube and a separate 1.02m by 0.76m high gain screen. Tele-Theatre price is £1,000.

Shannon Communications Inc. has developed a 30cm diameter lens system moulded from acrylics. It fits in front of a Trinitron tube and unlike the previous systems is focusable. Unfortunately little experience exists in the moulding of lenses of this diameter and the British company who were originally going to

Fig. 14. Sony VPP-2000 uses a Trinitron source

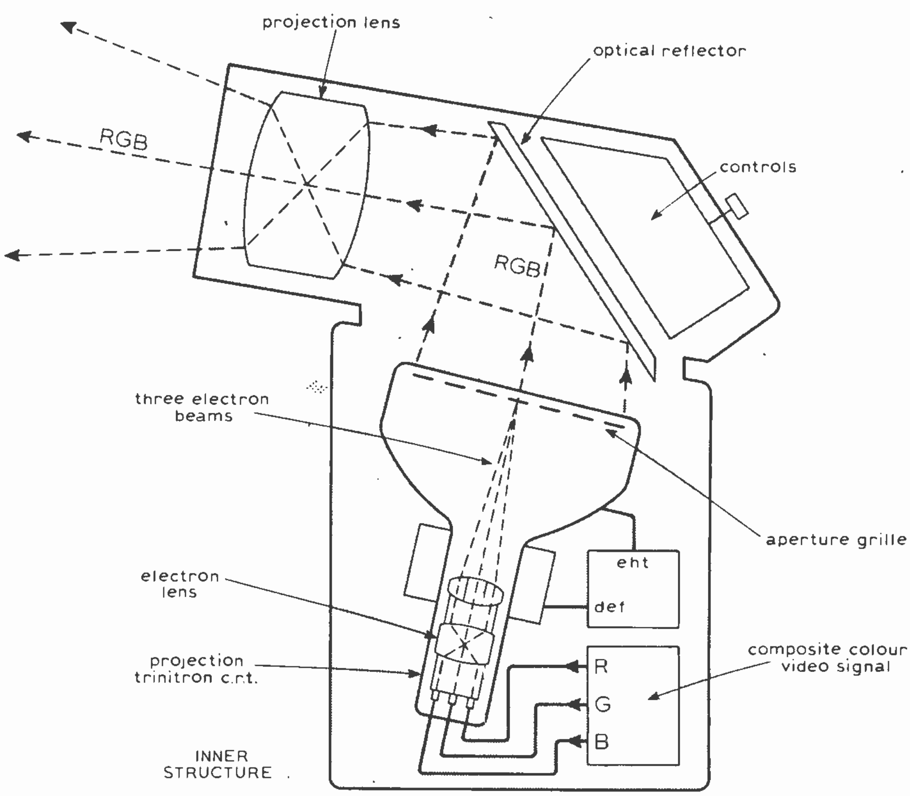


Fig. 15. Principle of the Sony VPP-2000

manufacture the acrylic lenses now feel unable to guarantee production. Whether the Shannon projector will be marketed in the near future now remains to be seen.

The problem with the manufacture of acrylic lenses is still to be solved. Lenses may be ground down from a solid blank which is an expensive process. Alternatively they may be hot moulded from acrylics. However when using this process to mould large diameter lenses (30cm), problems with expansion and cooling make accuracy extremely difficult. Until these snags are overcome, Mullard are going to try polishing lenses hot moulded to obtain greater accuracy.

The basic difficulty encountered with the previous refractive projectors is that the smallest colour tube available is the 33cm Trinitron. This uses an aperture grill and vertical stripes of coloured phosphor on the screen. About 400 groups of stripes are deposited across the screen and as mentioned earlier, this limits the resolution to 280 lines. It is not presently feasible to manufacture a colour tube of smaller dimensions because of the difficulties of maintaining sufficient resolution. Thus projector manufacturers are stuck with the problems of large diameter, wide-aparture lenses. There difficulties are not so prevalent when separate high-intensity, single-colour tubes are used. Shadow mask tubes may of course be used instead of the Trinitron tube.

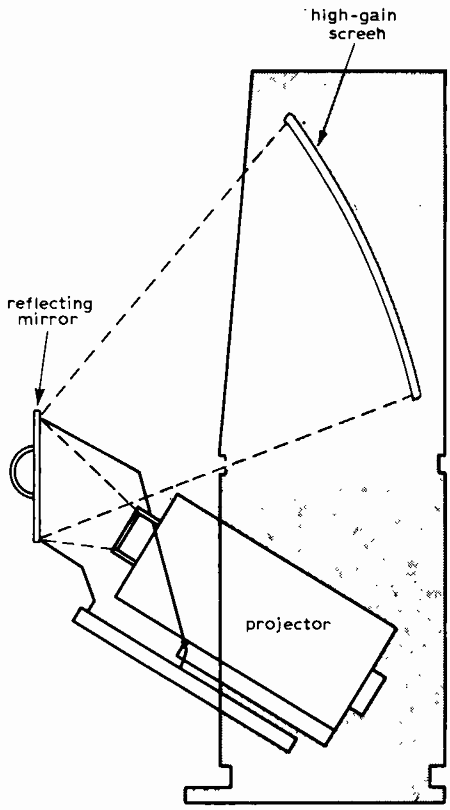


Fig. 16. Self-contained version of the Sony VPP-2000, the KP4000

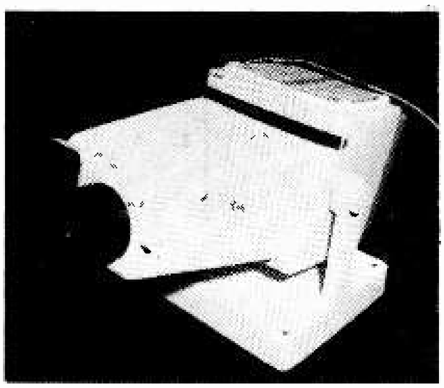


Fig. 17. Tele-Theatre refracting projector

Aeronutronic Ford

The refractive principle used by these projectors is perhaps the simplest to explain, but requires highly specialised techniques to obtain sufficiently high light outputs.

A 175mm c.r.t. is used as a basis for the projectors, shown in Fig. 18. The standard tube uses a glass faceplate with an active area of 10cm by 12.5cm; accelerating voltage used is 60kV with a very high beam current. To obtain a higher light output a sapphire faceplace may be used, which has a much higher thermal conductivity than glass, allowing power dissipation of up to 40W (six to seven times that of glass) from the faceplate. Such a large plate is bonded to the tube by an exclusive process that compensates for varying thermal stresses between the glass tube and sapphire faceplate.

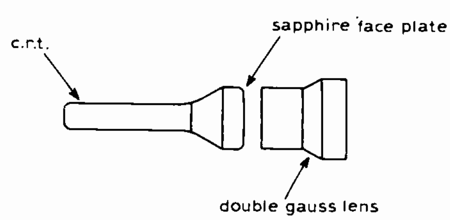


Fig. 18. Refractive projector from Aeronutronic Ford

The projectors are fully refractive using nine element lenses with a speed of f/0.87. Analogue circuits are used for coarse colour registration with a digital correction system using semiconductor storage to obtain an accuracy of half a picture element over the *entire* screen, not just the centre. To combine the outputs of the three colour tubes, two of which are not normal to the screen, the Scheimphlug condition is used where the plane of the screen, plane of the c.r.t. and plane perpendicular to the axis of the lens, intersect at a common line to preserve focus at expense of distortion (which can be corrected at the same time as the convergence errors).

Surprising compactness is obtained with these projectors; a single c.r.t. unit is 76cm high, 40cm wide and 106cm deep. Three units mounted vertically are used for colour and two colour units mounted side by side for high-power colour projection.

The ATP-1000 is a monochrome projector with a light output of 280 lumens using a glass-faceplate c.r.t. Resolution is 1,000 lines and contrast ratio 1:8. Price is $35,000 to $70,000. The ATP-3000 projects a 1,000 lumen colour picture, which is sufficient for a 2.7m by 3.6m picture. Price is $200,000 to $400,000. Finally the ATP-6000, shown in Fig. 19, is basically two ATP-3000 units providing 2,000 lumens with a 1,000 line horizontal resolution. Price is $400,000 to $500,000.

Advent has just introduced a refractive projector in the USA, fig 19a, which is effectively a baby version of the Aeronutronic Ford projectors. The Videobeam 750 uses three 12.5cm diameter c.r.t.s focused onto a 1.55m x 1.15m high gain screen using three 12.5cm refractive acrylic lenses. Price is presently $2,495 and introduction is expected in the UK during 1977.

Eidophor light valve

The Eidophor is a projector which, by means of a high-intensity light source and an oil layer influenced by the video signal, can project a black-and-white or coloured image by way of light valves.

The principle of the Eidophor is sketched in Fig. 20. The light source is a high-pressure xenon lamp which uniformly illuminates an aperture and is projected onto mirror bars with the aid of a condenser lens. The aperture image is reflected from the bars onto the concave mirror within the tube envelope. This arrangement of mirror bars is called a "dark field" projection system and ensures that no light can fall on the picture screen in spite of the concave mirror being intensely illuminated by the xenon lamp.

An oil layer 0.1mm thick is applied to the concave mirror and as long as its surface is completely smooth, the reflected light is not deflected and the picture screen remains dark.

However if this oil layer is deformed, part of the light is slightly deflected from its normal path and will pass between the mirror bars. This deflected light is focused by the projection lens onto the screen, the brightness increasing with increasing deformation of the oil layer.

The deformations are caused by an electron beam which exerts electrostatic forces on the oil and causes deformation. The electron spot size on the oil is chosen so that the resultant lines touch each other, distributing the charge evenly over the entire scanned area (72mm by 54mm): consequently the layer remains smooth. However, if the electron spot size is reduced, the lines no longer touch and the charge distribution assumes a line structure because the interline spacing carries no charge. This causes deformation of the surface and the smaller the spot, the larger the deformation. Thus, light reflected from the oil layer on the concave mirror is deflected past the

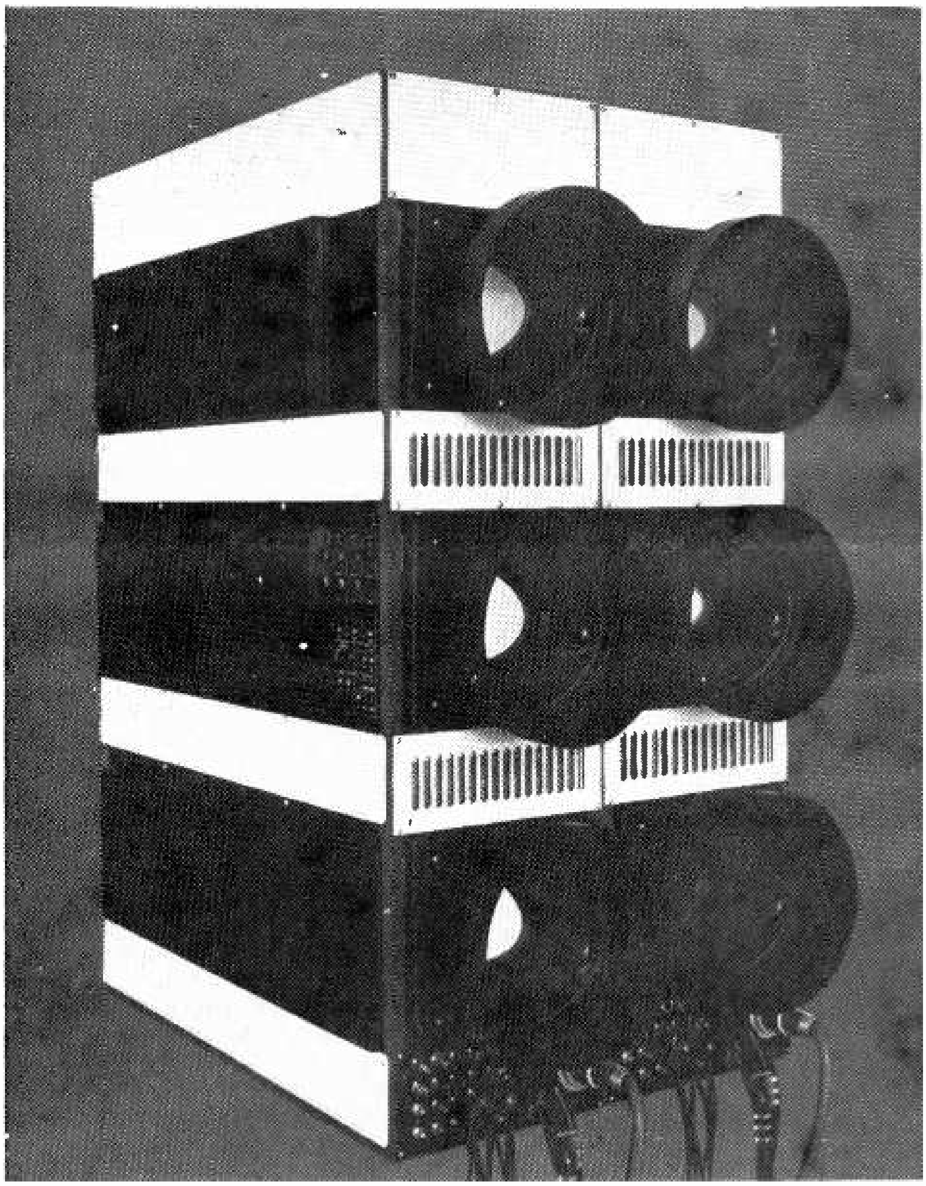


Fig. 19. Colour projector using the principle of Fig. 18

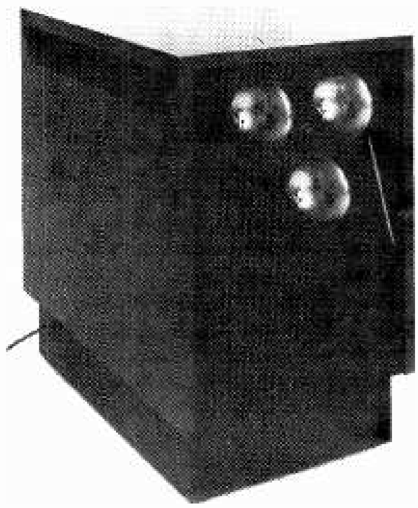


Fig. 19(a). Advent Videobeam colour projector – essentially a smaller version of half the Fig. 19 type

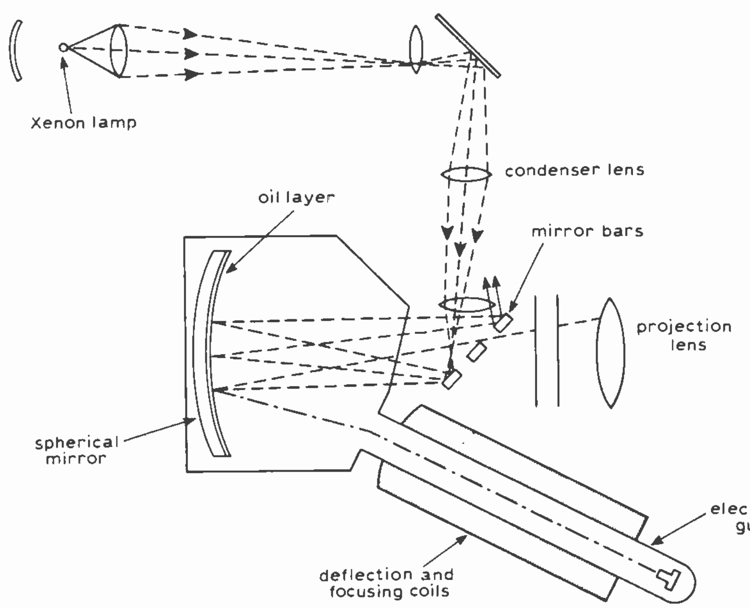


Fig. 20. Principle of the Eidophor. The lower ray is reflected between the mirror bars by the deformed oil layer

mirror bars and onto the screen. By continuously varying the spot size, a full brightness range may be obtained.

The nonconductive oil is made partially conductive and this, combined with the surface tension of the oil, provides for the oil to be smoothed after each field in readiness for new deformations. The great advantage of this technique is that the light source intensity is independent of the electrical power of the electron beam. Another feature inherent in the dark field technique is the contrast ratio of 1:100.

A colour Eidophor is arranged as shown in Fig. 21. The light from a single xenon source is split, using dichroic mirrors, into red, green and blue light, each beam being separately treated in a similar tube to the monochrome projector.

The EP8 monochrome Eidophor projector has an output of 4,000 lumens from a 2.5kW lamp. Maximum picture size is about 12m by 9m. A wide range of lenses are available for varying projection distances. Price is 250,000 Swiss Francs. A new range of monochrome projectors will soon be available. The 5170 in Fig. 22 is a colour projector with 3,000 lumen output. Resolution is 800 lines in the picture centre, registration accuracy being 0.1% in a circle 80% of picture height. Price is 600,000 Swiss Francs. Finally the 5171 is a high intensity colour Eidophor which has a 7,000 lumen output with a 4.8kW lamp. Maximum picture size is 18m by 13.5m. Seven different lenses are available. This unit, the highest-powered TV projector available, costs 690,000 Swiss Francs.

Westinghouse mirror matrix

This is a reflective light valve which uses a matrix of mirrors built into a vidicon camera tube.

The light-reflecting Schlieren system employed is shown in Fig. 23, where the light valve is seen to be the faceplate in

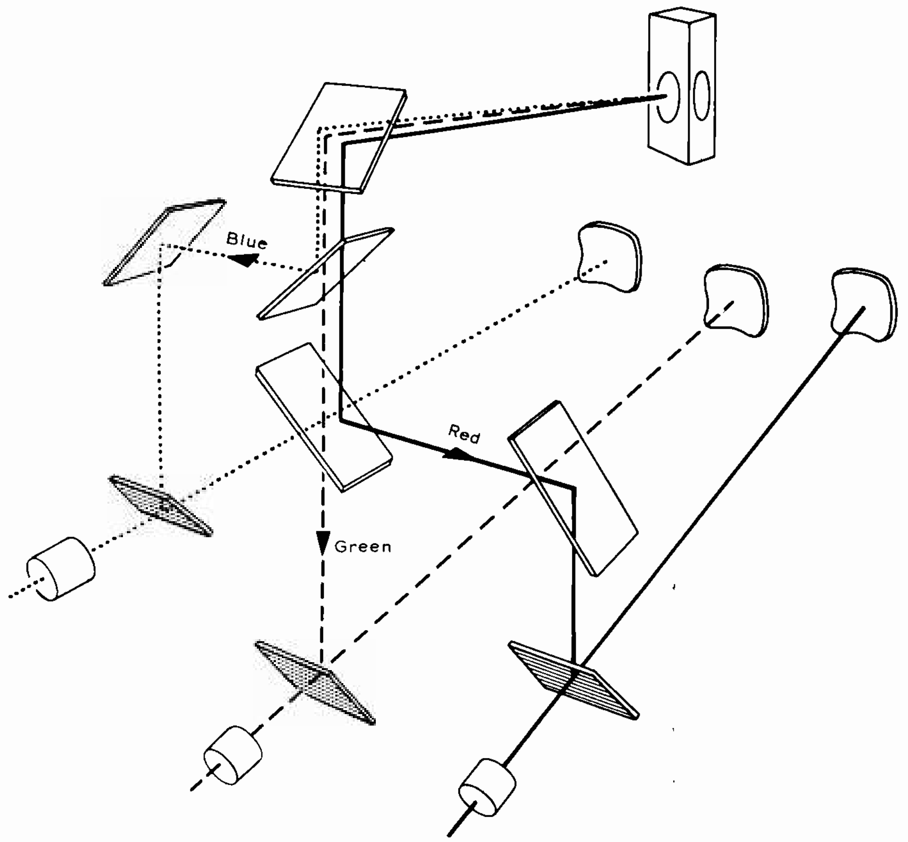


Fig. 21. Optical system of the colour Eidophor

an otherwise conventional sealed-off vidicon tube which uses standard focusing and deflection components. The target is fabricated from monocrystalline silicon-on-sapphire substrates, using high yield semiconductor techniques. It is composed of a dense matrix (25.5 elements/mm) of aluminised silicon dioxide membranes (about 3,000Å thickness) supported centrally on small silicon posts 4-5μm in height above the transport sapphire faceplate. These flat, stress-free oxide membranes can be deflected electrostatically by up to 4° when addressed with the electron beam. Thus, because light scattered by activated mirror elements is directed around the central stop in Fig. 23, an intensity-modulated display of the deposited charge pattern on the mirror matrix is produced on the screen.

Mechanical and optical considerations have led to a special four-leaf geometry of the mirror elements in Fig. 24, enabling operation at a voltage level of only 175V) and an optical gating efficiency of about 50% to be achieved. The latter stems from the fact that light from activated mirror elements is spatially separated from the fixed diffraction background produced by the segmented target structure. Since the modulated light is effectively directed away from the optical axis of the Schlieren projection system, high screen brightness and high contrast are provided simultaneously by use of a central, cross-shaped Schlieren stop.

The mirror matrix is fabricated using chemically-inert, low vapour-pressure materials, so its inclusion within the sealed-off vidicon envelope shows no detrimental effects on tube life. In addition, the electrical insulation properties of the mirror matrix structure give long storage times for the charge pattern and its low thermal impedance suggests its suitability for high light-level flux handling capabilities.

At present, the write and erase time of 1/30s is such that real-time video cannot be projected, but the storage time inherent in the tube (many hours) makes the projector very suitable for single frame display such as might be used for computer displays, Travel indicators and such applications. A 1.3m × 1m screen was used with the prototype projector, which exhibited a 400-line resolution and 15:1 contrast ratio, with full grey scale. Total gated light output was about 90 lumens using a 150W xenon lamp and f/3.5 lens. Substantially higher luminous flux outputs can be expected with a larger light source and improved optics. A limiting resolution of 600 lines has been

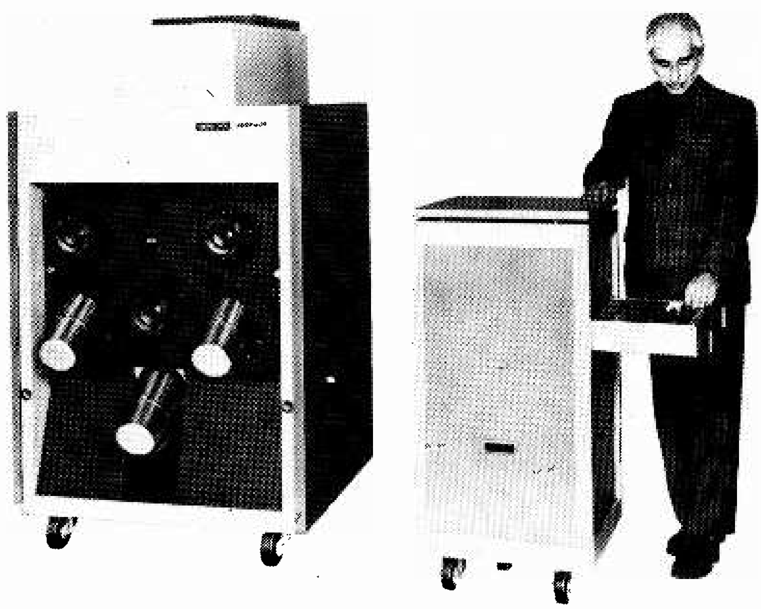


Fig. 22. Gretag 5170 colour Eidophor. Control circuitry is in separate console on right

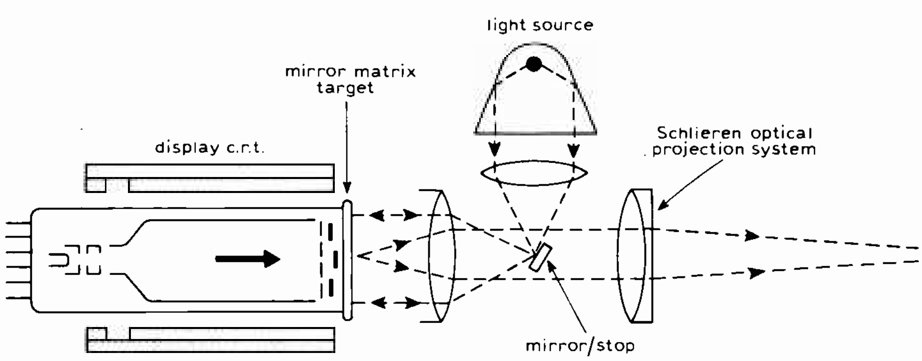


Fig. 23. Reflective type of light valve used in the Westinghouse mirror-matrix system

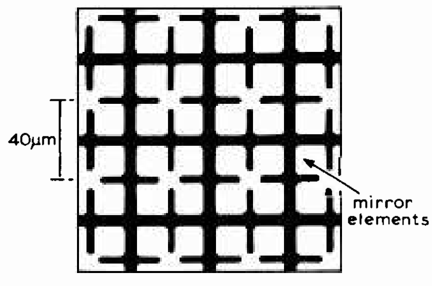
achieved using a 750,000 element array with fewer than 30 defective elements in a 50mm sealed tube. Price is expected to be between $2,500 and $3,500.

General Dynamics

A projection system similar to that of the Schmidt type is used by General Dynamics. The techniques uses a correction lens mounted between the c.r.t. and spherical mirror. Although providing better optical correction than the standard Schmidt, the large physical size and cost of the lens have prevented its wide use.

Lasers

Various attempts have been made to construct a projector using lasers as the light source. Although it is reasonably simple to modulate the laser light, scanning must be mechanical, using mirrors or prisms rotating at high speeds. However since the light path is very complex, efficiency is very low and this coupled with mechanical problems has frustrated development.



(a)

IBM deformographic

This uses a light valve containing a deformable target. Fig. 25 shows the principle of operation of the deformable storage display tube (d.s.d.t.) which uses a Schlieren optical system to convert the deformations of an optical surface into visual imaging points.

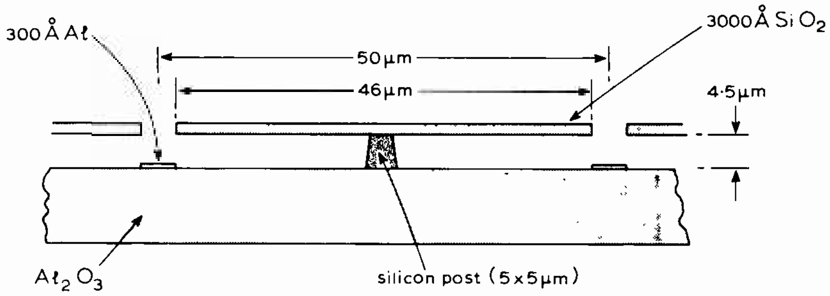
The heart of the d.s.d.t. is a dielectric membrane (target) which consists of an electronically-controllable storage substrate, a deformable material layer and a reflective layer. The target is mounted in the tube envelope so that the storage substrate faces the electron gun chamber of the tube. Deformations, created in the deformable material as a result of negative electrostatic charges deposited by the write gun of the d.s.d.t., are converted into a visual image by the off-axis Schlieren optical system. Since the substrate is a good insulator, it provides long-term image storage. Also, because of its secondary emission characteristic, the effective polarity of the deposited charge may be varied as a function of electron beam energy. Thus a deposited charge can be written and erased in a controlled manner by appropriately directed electron beams of selected energies.

Since the deformable material is isolated from the electron gun chamber, cathode poisoning is eliminated. By employing an elastomer as the deformable material, a simple mechanical restoring force provides the actual erase function once the deforming charge is removed. An additional advantage is the placing of the reflective layer on the deformable material, which allows an efficient reflective optical system to be employed instead of a complex transmissive system. Two electron guns are used mounted in the tube's rear. The write gun provides a magnetically deflected pencil beam while the erase gun is designed to cover the entire substrate with its electron beam cloud. Electronic control of these guns with time sequencing provides for such facilities as storage, variable persistance, selective erase, coloured images and optical processing.

Storage is achieved by sequentially writing and erasing. A single writing operation places information on the target where it is stored until neutralized by the erase gun up to several minutes later. Variable persistance is arranged by simultaneous operation of write and erase guns, the degree of persistence being controllable by varying the erase current. Selective erase may be arranged by altering the potential of the writing gun to produce a directional erase beam. Although theoretically possible, deflection problems with two different beam potentials could cause problems.

Coloured data may be displayed by exploiting the Schlieren plane effect. Fig. 26 shows two methods of producing coloured symbolic data. The top portion shows two E's generated from horizontal and vertical strokes. Because of the optical pattern created as a result of the stroke patterns, and crossed configuration separates the two characters into different colours at the image plane. The lower characters show colour generation by controlling depth of deformation. The lightly drawn character limits the reflective pattern to the inner annular filter ring while a heavily written character causes a large share of the reflected light to fall on the outer filter. The relative sizes of the characters shown in Fig. 26 are significant since the coloured characters made from directional strokes must be larger than black and white characters. Various other filter arrangements may be

Fig. 24. Mirror-matrix light valve. Cross-section of one element is shown at (b)



(b)

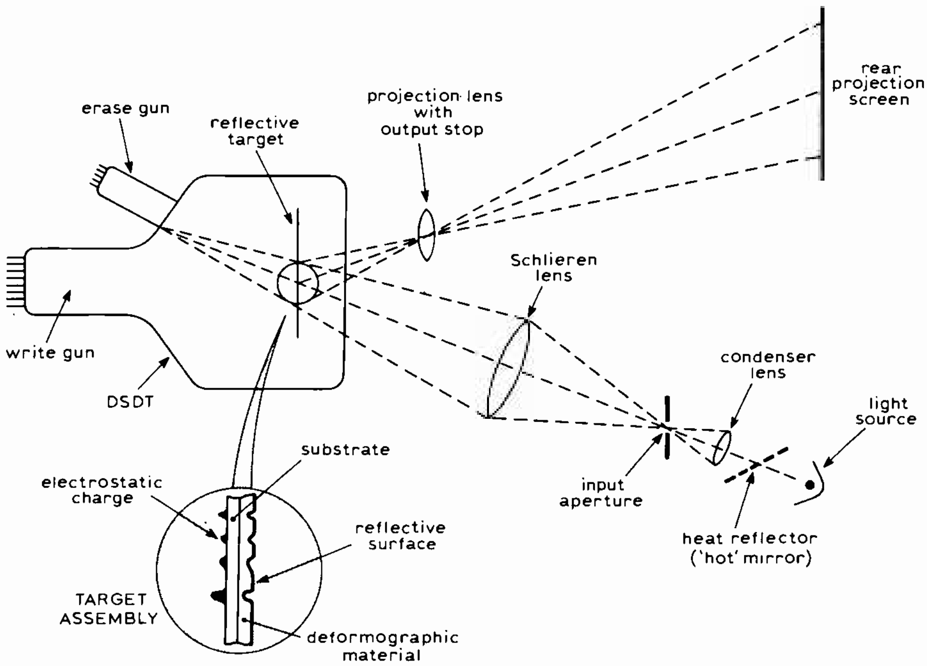


Fig. 25. System by IBM using a reflective, deforming surface – similar in some respects to that of Fig. 23

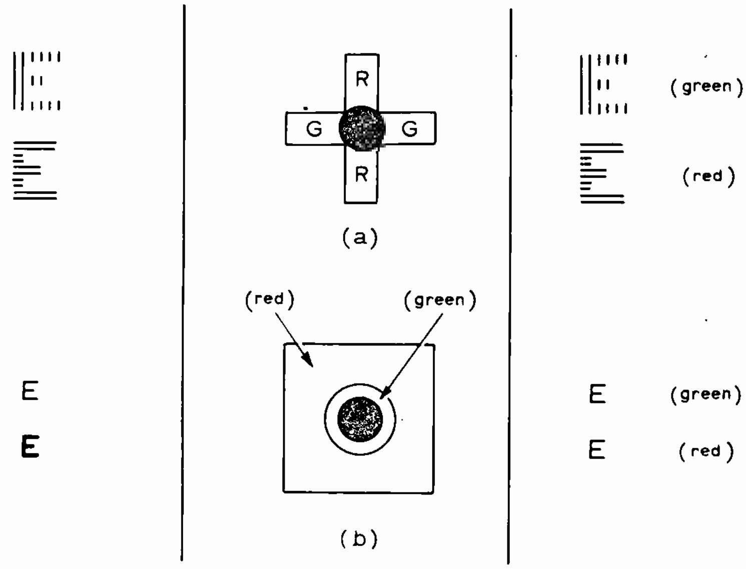


Fig. 26. Production of coloured symbols by crossed filters and symbols made up of vertical or horizontal lines is at (a), while (b) shows the method using differing degrees of deformation to include varying amounts of dissimilar filters

used in the Schlieren plant to enhance or interrogate the displayed tube.

Presently, a 150W xenon lamp is used as the light source and this provides a light output of between 300 and 500 lumens. Up to four different colours may be displayed, with a contrast ratio of 40:1. Rear-projected display systems suitable for computer generated alphanumerics and graphics projected on a 1.5m square screen are now available for purchase from IBM. Projectors are constructed individually by hand and cost around $200,000 but this will be reduced to about $28,000 when production starts.

Prices quoted in sterling indicate that the equipment is imported into the UK while those quoted in dollars would have to be purchased from the USA with all the additional costs that are incurred (freight, taxes etc).

I should like to thank the following people from both Europe and the USA who have provided the information necessary to write this article. Dr G. Baenziger, Gretag AG; Jacques Donjon, LEP; Vincent Donohoe, Speywood Communications Ltd; Patrick Gamuti, Projection Systems Inc; William Good, General Electric; Tom Holzel, Ideal Image Inc; John Huggett, Crown Cassette Communications Ltd; Alexander Jacobson, Hughes Research Laboratories; Harvey Nathanson, Westinghouse Research Laboratories; Michael Spooner, Redifon Flight Simulation; Jerrett Stafford, Aeronutronic Ford; Ronald Freeman, IBM.

Makers and importers

Advent: Crown Cassette Communications Ltd, 3 Soho Street, London, W1.
Aeronutronic Ford, 3939 Fabian Way, Palo Alto, California, USA.
Eidophor: Televictor Ltd, Channing House, Wargrave, Berks.
General Electric Co, Building 6, Electronics Park, Syracuse, New York.
IBM Corp, Department 102B, Building L91, Awego, State of New York 13827.
Ikegami: Dixon's Technical Ltd, 3 Soho Square, London, W1.
Image Magnification: REW Audio Visual Ltd, 10-12 High Street, Colliers Wood, London SW19.
Kalart Victor: British Films Ltd, 260 Balham High Street, London SW17.
Projection Systems: Speywood Communications Ltd, Northfield Industrial Estate, Beresford Avenue, Wembley, Middlesex.
Pye TVT Ltd, PO Box 41, Coldhams Lane, Cambridge.
Sony (UK) Ltd, 134 Regent Street, London W1.
Tele Theatre: Speywood Communications Ltd, Northfield Industrial Estate, Beresford Avenue, Wembley, Middlesex.
Westinghouse Electric Corp, R. and D. Centre, Beulah Road, Pittsburgh, Pennsylvania 15355.

News of the month

Continued from page 46

vote. Members of the executive and chairmen of standing committees would normally be appointed from among board members.

Mr Clayton said the July meeting had been "as satisfactory if not more so than we could have hoped for." They had reached sufficient agreement on the redrafting of the charter and bylaws to be able to recommend to a meeting of the IEE council in Sheffield on September 9 that the resignation be rescinded. This, he hoped, would happen by a special resolution at a CEI meeting on September 22. "We shall then have the things that we need: a clear definition of the role of the CEI, direct elections of members of the CEI by the membership, and the possibility that those who are not members of chartered institutions can be represented on the CEI." The only qualification for affiliation to the CEI on the part of unchartered institutions, he said, was that an institution had enough people in it who were likely to become members. This would not make the board membership of the CEI unwieldly again because he could only think of one or two institutions that would want to come in.

"The first role of the CEI is to endorse acadamic examinations which a man must take before he can call himself a chartered engineer. It is also up to the CEI to establish a code of professional conduct and enforce it." Speaking of the comparative jurisdiction of the CEI with the individual institutions he said: "It can speak for the engineering profession as a whole in matters that affect the engineering profession as a whole, but there aren't all that many such matters, and that doesn't prevent each institution speaking individually.

"The CEI represents chartered engineers, not institutions," he asserted, and while he agreed that the name no longer reflected what the CEI was about, he said he could think of many bodies known by their acronym whose full name no longer reflected their function. "The existence of the CEI shows that a lot of people who are working in the same field can on matters of common interest represent a viewpoint together. We can do something useful in the CEI but it's not going to be transformed overnight."

As his year of office, one of the stormiest in the IEE's 105 years, closed, Mr Clayton said he recalled two things more vividly than the CEI battle. One was the inter-relationship between engineering and physics, "and our relationship with the mechanical engineers. We are two very close institutions and our links are getting closer all the time." Was the rumoured merger between the two a possibility? "All things are possible."

Microprocessor predictions

AMI Microsystems predict that sales of m.o.s.i.cs which provide memories for microprocessors will increase by 113% over the next 2½ years. The growth will extend, they say, into an increasing range of data processing, industrial and consumer products. Microprocessor sales are expected to increase by nearly half during the period, but US manufacturers are expected to get more than 80% of worldwide sales, which will increase, according to AMI's director of research, from last year's $64 million to $300 million in 1979. Ancillary memory sales will rise from $11 million to $190 million.

Self-setting time code clock

3 — Alignment procedure

by N. C. Helsby, M.A., *University of Essex*

On completion, align the clock as follows.

Short the receiver input and adjust R_3 to give 4.3V at TP1. Remove the short and a signal should appear as soon as the a.g.c. has reduced the gain to the correct value. A voltmeter connected to the output of IC_3 will indicate signal strength by monitoring the a.g.c. amplifier output.

Adjust the aerial and T_1 tuning controls for maximum reading at this point, taking into account the slow response of the a.g.c. Note that the a.g.c. reference may be checked at the junction of $R_2 - R_3$ and should be about 2.9V. Similarly, the junction of $R_1 - R_2$ should be at about 3.6V. If the 5V supply is slightly high these values will be increased and the 4.3V should be raised accordingly.

Connect an audio amplifier to TP1, via a suitable capacitor, to check the overall noise level. Audible bleeps during the break in carrier may be heard using the tone generator.

In the decoder circuit, break the link on pin 4 of IC_{10} so that the timer runs continuously. If a timer/counter is available connect it to pin 3 of IC_{10}, and adjust R_{10} to give a period of 10ms. Alternatively, the output at pin 3 may be compared with 100Hz ripple on the power supply by adding the two signals and adjusting R_{10} for zero beats using an audio amplifier as shown in Fig. 16.

The code recognition circuitry may be set up using an audio oscillator and a pair of headphones. The oscillator is required to give a rectangular-wave output of about 4V pk to pk at 25Hz. The output should go from zero to +4V; if it does not it may be restored by means of a diode and capacitor. Disconnect the receiver from the decoder and connect the audio generator as shown in Fig. 17. Connect a link from the collector of Tr_3 to the base of Tr_5 so that the two collector resistors are shorted. Connect an audio amplifier or headphones to pin 8 of IC_{6b} via a 10kΩ resistor. Starting with R_8, adjust until the 25Hz output at pin 8 just ceases. Disconnect the link between Tr_3 and Tr_5, and with the same input signal, adjust R_7 so that the audio output just returns. This is the correct position for R_7 and, if an oscilloscope is available, the output at pin 8 should be high for 12ms under these conditions. If an oscilloscope is

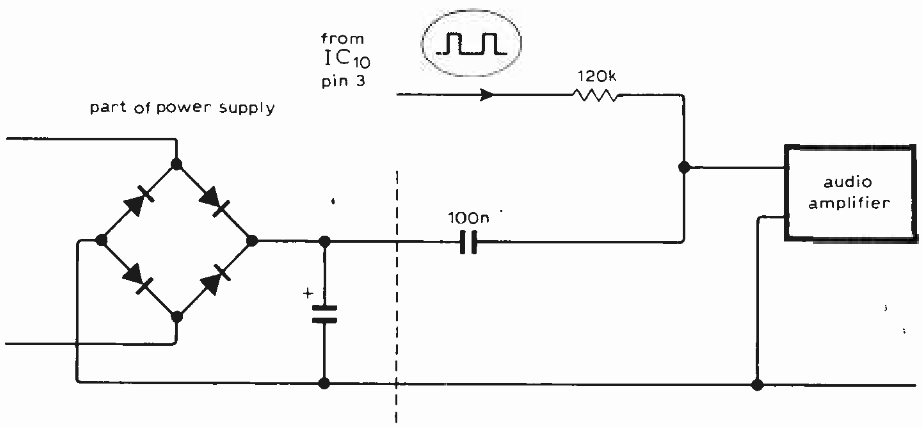


Fig. 16. Zero beat method of adjusting R_{10} avoids use of timer/counter.

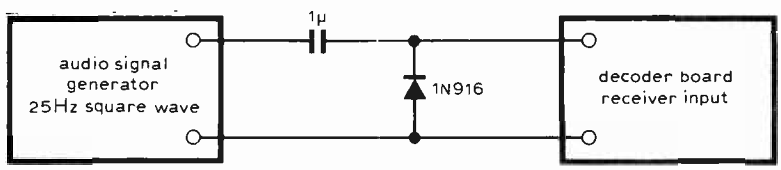


Fig. 17. D.C. restoration components ensure 0-4V input to code recognition circuitry.

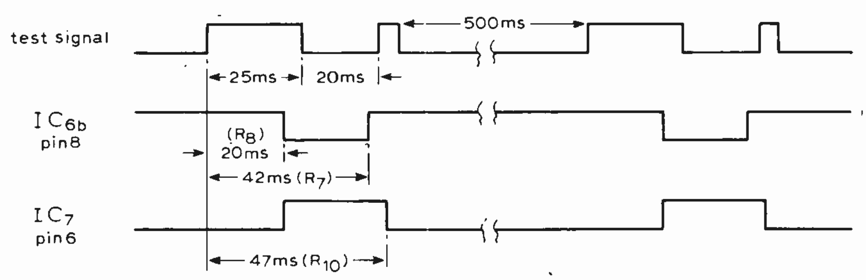


Fig. 18. Adjust R_7 and R_8 to give lower two waveforms, given test signal as shown.

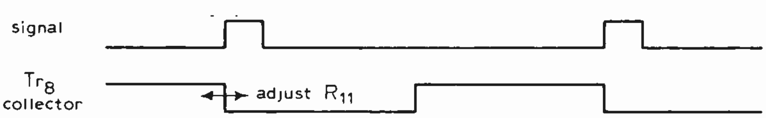
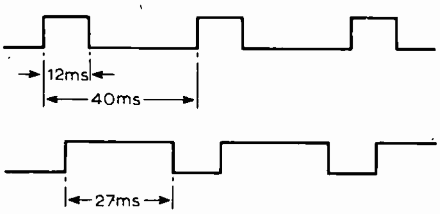


Fig. 19. Resistor R_{11} is adjusted for coincidence of positive and negative-going edges.



Waveforms on pin 8, IC_{6b} for correct setting of R_7 and on pin 6, IC_7 for a correctly-set R_{10}.

available continue to feed in the 25Hz test signal and set R_{10} to give a positive pulse length on pin 6 IC_7 of 27ms. If an oscilloscope is not available, adjust R_{10} to give the longest available pulse length. Disconnect the signal generator and connect the receiver output to the input of the decoder board. Decoding should proceed at each minute. To optimize the noise immunity, in the case where R_{10} was set, progressively advance it until decoding at the minute ceases, and then return it by a reasonable margin. The 25Hz oscillator continuously applied does not cause the decoder to trigger its clock, but it does so once each time it is switched to the input of the decoder.

As an alternative to the above procedure a test generator which gives the same waveform as the start of the time code may be constructed from monostables or standard test equipment. This waveform is applied at 500ms intervals and R_7, R_8 adjusted to give the waveform shown in Fig. 18 at pin 9 of IC_{6b}. The previous method using a 25Hz generator gives similar results. The timings shown allow for a margin of error in the transmitted code and the waveform shown will trigger the decoder clock every 500ms.

For the seconds counter and parity checker, remove the input seconds pulses by shorting the receiver aerial. Disconnect the link between R_{13} and pin 2 of IC_{16} and measure the voltage on pin 2 which should be around 3.5V. Apply the voltmeter between R_{13} and ground and adjust R_{12} to the same value as on pin 2. Reconnect the link and remove the short-circuit across the receiver aerial. Find the exremes of R_{18} at which the p.l.l. loses lock, as indicated by the out-of-lock l.e.d., and note the positions. Set R_{18}midway between these positions. (When lock is lost the indicator flashes on and off as the c.c.o. comes in and out of phase with the input signal). This adjustment must be made very slowly due to the long time constants involved. Adjust R_{11} so that the negative-going edge on the collector of Tr_8 is coincident with the positive-going edge of the received seconds pulses as shown in Fig. 19 (available on the edge of the seconds counting board). By mixing these signals through an audio amplifier, the exact coincidence point may be heard. This completes the alignment of the time code clock.

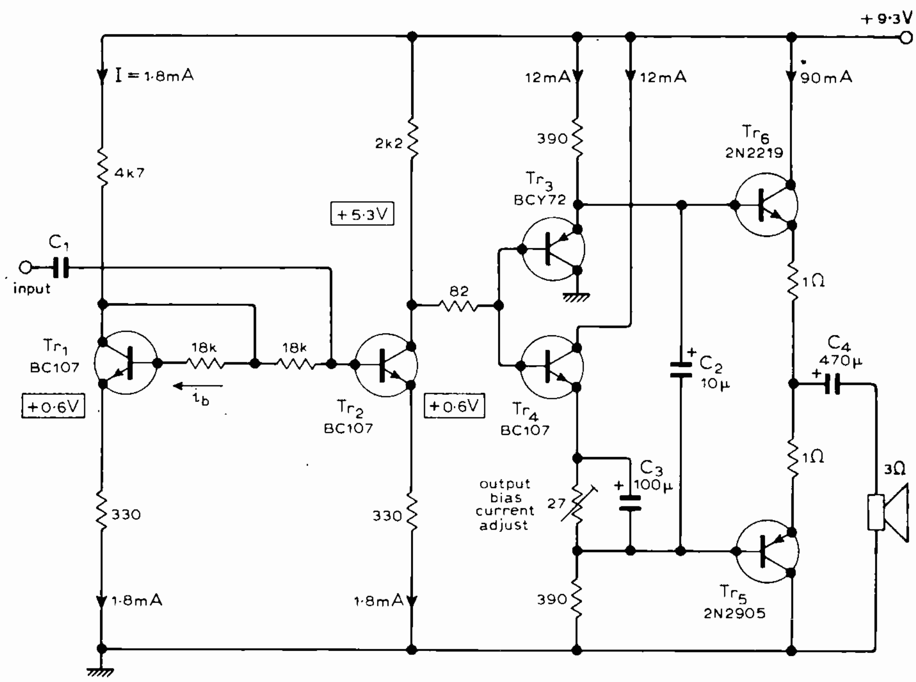
Printed circuit boards

Wireless World has arranged a supply of glass fibre boards for the time code clock. The p.c.bs are available as a set which comprises three double-sided and two single-sided boards for the receiver, GMT/BST converter, decoder, seconds counter, and display. The boards mount on top of each other (see photo) to form a compact module which can be housed in a case approximately 8 × 5 × 3in. The set of boards is priced at £13.50 inclusive or £11.00 undrilled.

A set of special components is also available which comprises an aerial assembly, receiver coil assembly (LA4145), N5596K multiplier, MPS H05 transistor, two 1.5kΩ metal-film resistors, and the NE567 tone decoder. This set is priced at £7.50 inclusive.

Available from M. R. Sagin at 11 Villiers Road, London NW2.

Circuit Ideas



Low voltage audio amplifier

This d.c. coupled amplifier does not include over all feed-back and is suitable for low supply voltage applications such as in-car entertainment. With a regulated 9V supply the circuit provides high quality sound at ample volume.

The double d.c. coupled push-pull emitter follower stages $Tr_{3, 4, 5, 6}$ provide base-emitter temperature corrected bias, as well as a low output impedance. Output bias current is adjusted with the 27Ω resistor. On positive transitions Tr_4 and Tr_6 are driven on, while Tr_3 and Tr_5 are cut off. Capacitor C_2 couples the emitter of Tr_4 to the base of Tr_6 via C_3, so Tr_6 is driven hard on from the low impedance source of Tr_4. On negative transitions Tr_3 and Tr_5 are on, while Tr_4 and Tr_6 are off. Again, C_2 couples Tr_3 emitter to Tr_5 base. Thus, a symmetrical low output impedance is achieved on positive and negative transitions of an audio waveform. Driver transistor Tr_2 is designed to provide a temperature compensated bias and a maximum symmetrical voltage swing to the output stages. Collector voltage of Tr_2 is set at approximately 5V d.c. so the emitter swing has to be contained within zero and one volt d.c. This means a low value for the emitter resistor and, therefore, a sensitivity to temperature variations. Temperature compensation is provided by a symmetrically biased transistor Tr_1, using collector to base negative feedback.

G. Kalanit,
New Malden,
Surrey.

Distortion levels in r.f. clipping

Theoretical intermodulation distortion levels from clipping a two-tone s.s.b. signal

by D. A. Tong, B.Sc. Ph.D.
Datong Electronics Ltd

Speech clipping at r.f. is now a well known and accepted method of increasing effective transmitter power. So far little experimental work has been done to determine the levels of intermodulation distortion generated by r.f. clipping. This study attempts to find the magnitude of distortion that can be expected when ideal clipping is applied. The analysis shows that quite high i.d. occurs with a two-equal-tone signal even for small amounts of clipping but, probably due to the waveform, this is not so objectionable when listening to speech.

In the use of a.m. and f.m. transmitters a.f. speech clipping has been widely used to raise the average-to-peak amplitude ratio of the speech waveform. Disadvantages of this technique are a high level of distortion, and the incompatibility with s.s.b. transmitters which are now the most common kind in use. If, however, the clipping is performed, at r.f. on a s.s.b. signal most of the distortion is eliminated and there is no incompatibility with s.s.b. transmitters. Radio frequency clipping by 15 to 20 dB can increase effective peak power by a factor of ten.

An add-on r.f. clipper can be placed in series with the transmitter microphone lead because the device generates its own s.s.b., clips it and demodulates it back to a.f. A single audio frequency sine wave, when processed in such a way, is reproduced as a sine wave with, assuming an ideal system, zero distortion, no matter what the degree of clipping. If the same signal is subjected to direct clipping it approaches a square wave and a set of odd harmonics is generated. If the wanted frequency is at the low end of the speech band, many of the harmonics are also in the speech bandwidth and cannot be filtered out. When several sine waves are simultaneously fed into a clipper the situation is more complex because a range of sum and difference products between various harmonics are generated.

The calculation which follows was undertaken in an attempt to find out how much distortion can be expected with ideal r.f. clipping applied to a typical two-tone s.s.b. test signal. Although a general calculation for the intermodulation produced by simultaneously clipping sine waves of varying amplitude would be complex, the special case of two equal-amplitude sine waves is more easily solved. The analysis shows that quite high intermodulation distortion occurs, even for small amounts of clipping. This is certainly not a condemnation of r.f. clipping for speech transmissions, but a point against in-band distortion, produced from a two-tone test signal, being used as an important parameter for characterizing a transmitter used for speech communications.

Calculation

A two-tone test signal can be regarded as a double sideband suppressed carrier signal produced by multiplying together two hypothetical signals. The test signal is defined as

$$f(t) = A_0\cos\omega_1 t + A_0\cos\omega_2 t, \qquad (1)$$

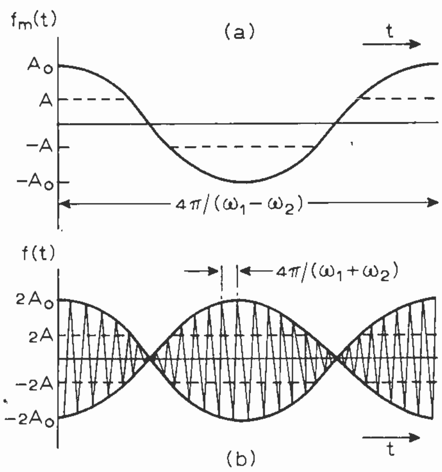


Fig. 1. (a) Modulating waveform, $f_m(t)$, which, when multiplied by cos $((\omega_1+\omega_2)/2)$ gives the two-tone test signal f(t). (b) Two-tone test signal f(t). Note its peak amplitude is twice that of the waveform in (a). The phase of the waveform with period $4\pi/(\omega_1+\omega_2)$ is ***shifted by π radians (180°) in each*** *successive section of the envelope. In both (a) and (b) the effect of amplitude limitation is shown by the dotted line.*

i.e. the sum of two signals. This can be written in the product form as

$$f(t) = 2A_0\cos(\omega_1+\omega_2/2)t \,.\, \cos(\Delta\omega/2)t \qquad (2)$$

where $\Delta\omega = \omega_1 - \omega_2$. This second equation shows why the peak amplitude of the two-tone signal is twice that of each separate tone. It also shows that the envelope of the r.f. component, at angular frequency $\omega+\omega_2/2$ is amplitude modulated by a low frequency waveform which is equal to half the difference of the two original tones. The waveforms $f(t)$ and $2A_0\cos(\Delta\omega/2)t$ are shown in Fig. 1.

Because the envelope shape of $f(t)$ is directly related to that of the modulating waveform $2A\cos\Delta\omega t/2$, any amplitude limiting of the composite signal $f(t)$ can be regarded as due to similar limiting of the modulating waveform. This is indicated by the dotted lines in Fig. 1.

To predict the effects of r.f. clipping on a two-tone signal, one can first calculate the Fourier components representing a clipped cosine-wave, and then consider the effect of modulating $\cos(\omega_1+\omega_2/2)t$ separately by each of these components. The results of each modulation process, i.e. each multiplication, can then be added together to give the final frequency spectrum.

Any complex modulating signal ($f_m(t)$) with a fundamental frequency of $\Delta\omega/2$ can be represented as the following general Fourier series 1,

$$f_m(t) = a_0 + a_1\sin\Delta\omega t/2 + a_2\sin 2.\Delta\omega.t/2 + \ldots \text{etc.}$$
$$+ b_1\cos\Delta\omega t/2 + b_2\sin 2.\Delta\omega.t/2 + \ldots \text{etc.}$$

This expansion simplifies if there is no d.c. component in the waveform, and the clipping is symmetrical. Under these conditions only the odd cosine terms are left

$$f_m(t) = b_1\cos\Delta\omega.t/2 + b_3\cos 3.\Delta\omega.t/2 + b_5\cos 5.\Delta\omega.t/ + \ldots \text{etc.} \qquad (3)$$

This is why every effort should be made, in any a.f. or r.f. process to achieve

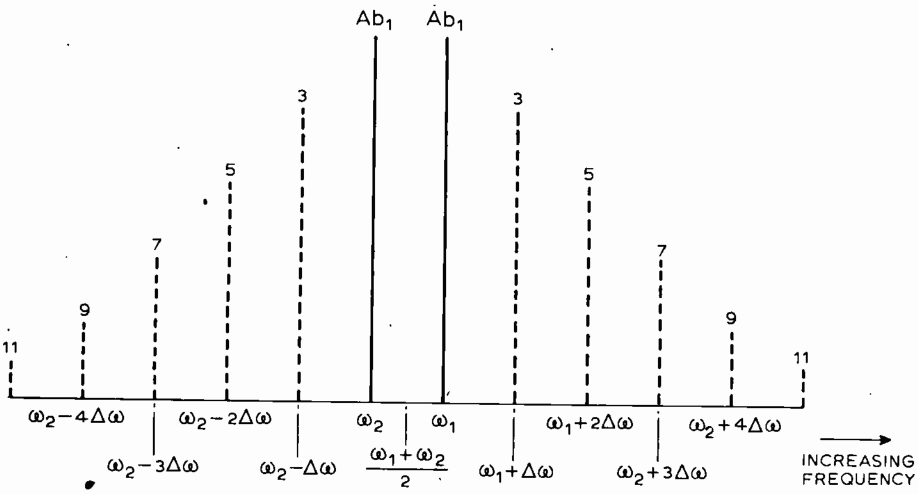
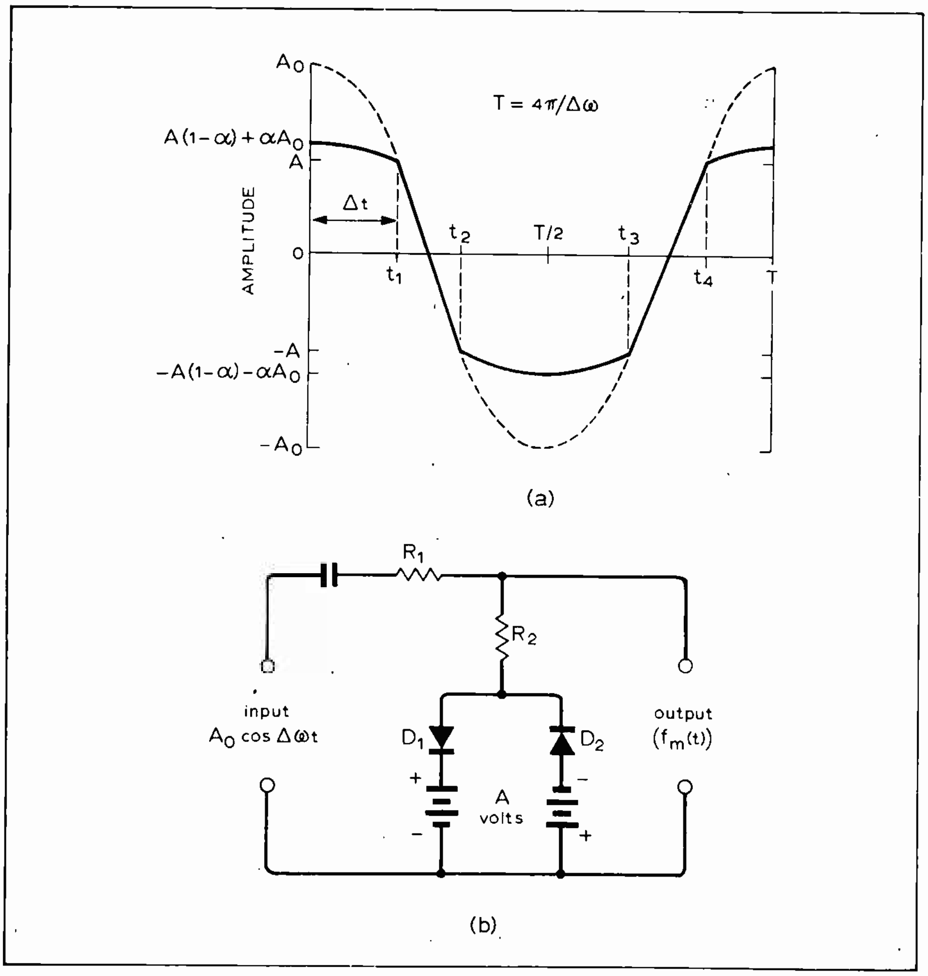


Fig. 2. Frequency components of the clipped waveform in Fig. 1(b). Note that there is no component with frequency $(\omega_1+\omega_2)/2$ despite the cyclic variation at this frequency in f(t).

Fig. 3(a). Function $f_m(t)$ used in the calculation of intermodulation levels (full line). Between t_1 and t_2, t_3 and t_4 it is an undistorted section of the waveform $A_0 \cos \Delta\omega t$. Elsewhere the latter has been attenuated to an extent dependent on the value of α. The full line is the waveform expected when feeding a cosine into the circuit of Fig. 3(b) which is an equivalent circuit of a practical diode clipper. Diodes D_1 and D_2 are assumed to have infinite reverse resistance, zero forward resistance, and zero offset voltage. The input signal comes from a source of zero internal resistance and the output is fed into an infinitely high load resistance. The parameter α is equal to $R_2/(R_1+R_2)$. The input $A_0 \cos \Delta\omega t$, is an imaginary signal. In a real situation the clipper would have the same circuit except that the battery voltages would be 2A.



symmetrical clipping. When each of these modulating components are used separately in equation (2), and the results are added to give the complete expansion for $f(t)$, the result is

$$f(t)=Ab_1\cos\omega_1 t+Ab_1\cos\omega_2 t+Ab_3\cos(\omega_1+\Delta\omega)t+Ab_3\cos(\omega_2-\Delta\omega)t+Ab_5\cos(\omega_1+2\Delta\omega)t+Ab_5\cos(\omega_2-2\Delta\omega)t+Ab_{1+2n}\cos(\omega_1+n\Delta\omega)t+Ab_{1+2n}\cos(\omega_2+n\Delta\omega)t.$$

The line spectrum corresponding to this expression is shown in Fig. 2. and the peak amplitude of each frequency component is shown above the corresponding spectral line.

Before discussing the actual magnitudes of b_1, b_3 etc., it is worth making a few points about Fig. 1 and 2. The higher the subscript, i.e. the higher the harmonic of $f_m(t)$ responsible for the particular component, the weaker the resulting component. Out of the unwanted intermodulation products, attention will be concentrated on the components at $\omega_1+\Delta\omega$ and $\omega_2-\Delta\omega$. These are the largest and also the closest in frequency to the desired signals and therefore the least likely to be filtered out. Fig. 1(b) is slightly misleading because the dotted lines, which represent the peak-to-peak amplitude after clipping, suggest that the waveform at frequency $(\omega_1+\omega_2)/2$ will be clipped. In fact, if this waveform is modulated by the clipped version of $f_m(t)$ shown in Fig. 1(a), i.e. a cosine wave of original amplitude A_0 clipped to a peak amplitude of A, the sine shape of the high frequency waveform will be retained. This treatment therefore applies only to the case where clipping is achieved by an ideal r.f. compressor with threshold at A and with a long time constant compared to $4\pi/(\omega_1+\omega_2)$ but negligible compared to $4\pi/(\omega_1-\omega_2)$. Nothing is said about the spectral components which will appear centred on harmonics of $(\omega_1+\omega_2)/2$, but, because these are always discarded by subsequent filtering, this is not important. One assumes that for components centred on $(\omega_1+\omega_2)/2$, there will be negligible difference between true clipping and the hypothetical r.f. compressor mentioned above. The same assumption is also implicit in Kahn's treatment of hard clippers [2].

The magnitudes of coefficients b_1 and b_3 can be derived using Fourier analysis for the waveform shown by the full line in Fig. 3(a). An ideal limiter or clipper (R_2 in Fig. 3(b) equal to zero) allows no increase in input waveform amplitude after it has reached a certain threshold as shown by A in Fig. 3(a). Practical clippers approach this condition and therefore, the calculation has been carried out for the general case. The two results are

$$b_1=A\left[\frac{2}{\pi}(1-\alpha)(1-x^2)^{1/2}+\right.$$

$$\left.\frac{1}{x}\left(1-(1-\alpha)\frac{2}{\pi}\cos^{-1}x\right)\right] \qquad (4)$$

$$b3=\frac{4A}{3\pi}(1-\alpha)\,(1-x^2)^{3/2} \qquad (5)$$

where $x=A/A_0$ and α is the gain of the clipper, see Fig. 3(a). It should be noted that in two-tone testing it is normal to measure the amplitude of the strongest intermodulation product relative to the product of the desired component. The intermodulation level in decibels will therefore be equal to

$$IP_{max}=20\log_{10}b_1/b_3 \qquad (6)$$

where b_1 and b_3 are given by equations (4) and (5). In the case of infinite clipping with an ideal clipper, α and A/A_0 are both zero. It can be shown that b_3 becomes $-4A/3\pi$ and b_1 becomes $4A/\pi$. For infinite clipping therefore, b_1/b_3 is 3. The minus sign is neglected because it merely implies a phase shift of π radians in the cos $3\Delta\omega t/2$ term relative to the cos $\Delta\omega t/2$ term. This result provides a check on the calculation because the waveform $f_m(t)$ is now a symmetrical square wave and the expansion for this is well known [1]. It also gives a useful result because the worst intermodulation product caused by infinite clipping of a two-tone signal will be at a level of −9.5dB relative to one of the wanted signals. In this special case it is easily shown that b_m is $4A/m\pi$, therefore the level of every intermodulation product can be derived, see Fig. 6.

A second check on the results can be obtained by making $A=A_0$ and $\Delta t=0$. It is found that $b_1=A_0$ and $b_3=0$ as expected because this is the case for no clipping. It was noted that with infinite clipping, b_1 is equal to $4A/\pi$. This amplitude is greater than the clipping threshold. If in addition α is non-zero, as in practical clippers, the wanted output will vary with the input amplitude even when the input is above the clipper threshold A. The degree of clipping in any situation is expressed as

$$B(\mathrm{dB})=20\log_{10}(A_0/b_1) \qquad (7)$$

and B represents the ratio of one wanted output to one of the inputs.

For a given degree of clipping it is useful to know how much the wanted output component has increased above the clipping level. This enables a.l.c. systems and other circuits following the clipper to be designed properly. The parameter is defined as

$$C(\mathrm{dB})=20\log_{10}b_1/A. \qquad (8)$$

In a practical system B and C are the important parameters from a performance point of view. From the design aspect A is important and it is worth noting that $B+C=-20\log_{10}x$ (9) where $x=A/A_0$ as before.

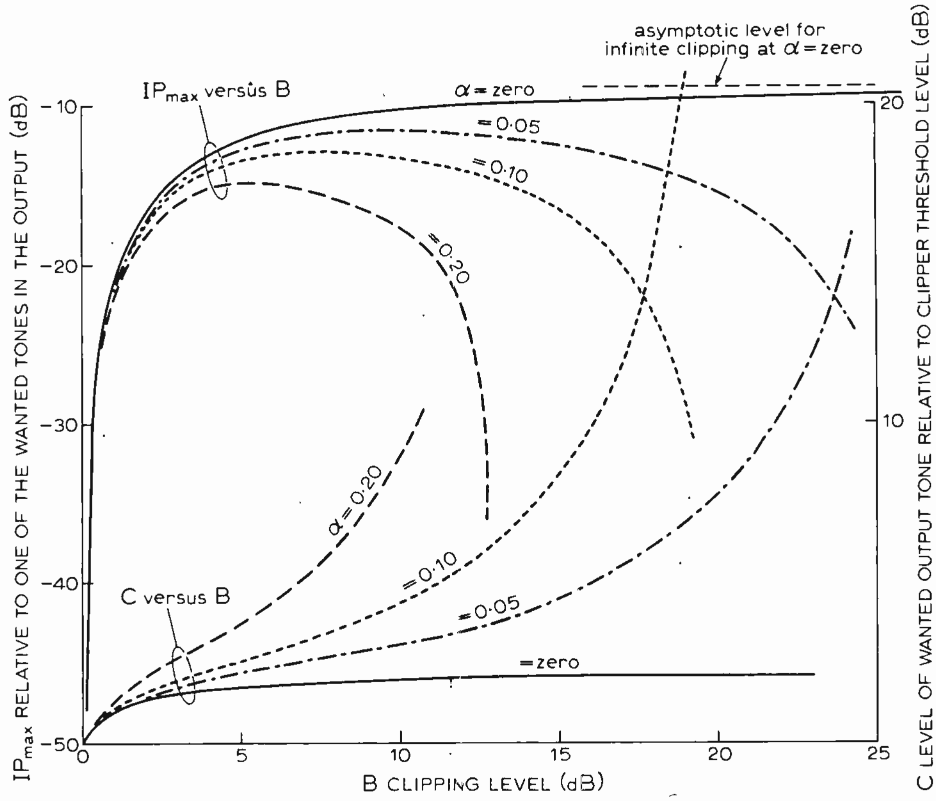


Fig. 4. The upper curves show the value of IP_{max} defined by equation (6), relative to one of the wanted tones in the clipper output as a function of clipping level. defined by equation (7). The lower curves show the corresponding variations in the level of the desired output signal. defined by equation (8).

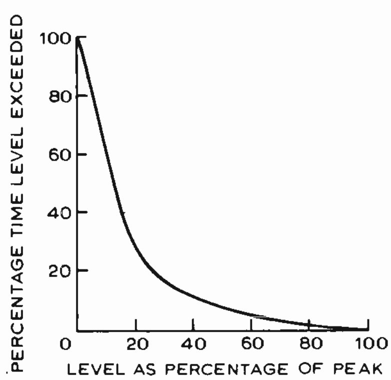


Fig. 5. Analysis of the instantaneous amplitude of phrases of speech spoken without pauses (taken from reference 5).

Numerical results

So that the expressions developed so far can be more easily used, the parameters IP_{max}, B and C as defined by equations (4) to (8) have been evaluated for a range of clipping levels and for various values of α using a calculator. The results are collected in Fig. 4 and 7. A most striking feature of these graphs is the high level of intermodulation distortion predicted for even small amounts of clipping. With an ideal clipper ($\alpha=0$) the amount of intermodulation produced, when one half of the r.f. signal is clipped, is obtained by putting $A/A_0=0.5$ in equation (9). This gives $B+C=+6$ dB. From the graph, B and C will then be 4.3 and 1.7 respectively and IP_{max} will be close to −13 dB. Note that the clipping level as defined in equation (7) will be 4.3 dB and not 6 dB. This situation is hardly improved by using a non-zero value of α. Although the IP_{max} curves for non-zero α bend over at high clipping levels to give an apparent improvement in i.p. levels, the curve for the level of wanted output rises steeply at the same time. This apparent improvement is therefore at the expense of large changes in output level. The explanation is, at high clipping levels with non-zero α, the distance between the levels A and $A(1-\alpha)+\alpha A_0$, in Fig. 3, has become so large relative to A, the latter has become negligible. The obvious steepness of the intermodulation curve at low clipping levels is a reflection of the flatness of the cosine function around the peaks. In this region a small increase in clipping level produces a large increase in the function affected by the clipper. For example, with only 1dB of clipping, Fig. 4 shows that $B=C=1$ and hence $A/A_0=0.794$. But cos $2\pi\Delta t/T=A/A_0$, and therefore $\Delta t/T=0.104$. This means that the flat sections of the clipped waveform in Fig. 3 account for as much as 41.6% of the total period T. The corresponding value for IP_{max} is −20.8 dB. As clipping increases, the discontinuities in the clipped waveform travel down ever steepening parts of the cosine function and the additional effect on i.p. level diminishes. At a clipping level of 10 dB, 84% of the waveform in Fig. 3 is flat and the intermodulation level is −10.4 dB, which is only 0.9 dB better than the ultimate value when the whole waveform is flat. Corresponding values for 3, 5 and 20 dB of clipping are 60% and −14.5 dB, 69% and −12.2 dB, 95% and −9.6 dB. It is striking that from only 3 dB of clipping to infinite clipping, the third order intermodulation products change by only 5 dB.

The percentage of a two-tone signal which has been flattened by clipping is easily measured using an oscilloscope. This parameter, called y, has been plotted against third order intermodulation level in Fig. 7 so that an upper limit for the intermodulation caused by flat-topping in a transmitter can be more easily estimated. Also shown is one quadrant of the cosine curve $x=\cos(\pi/2.y)$ which illustrates the comments made about the flatness around $y=0$. It also allows the ratio of clipper threshold to input amplitude, x, to be quickly related to y, and hence IP_{max}. It seems clear from these curves that a small amount of flat-topping in a transmitter will cause a lot of interference in adjacent channels if the transmitter is being driven by a two-equal-tone test signal. A similar point has also been made by L. A. Moxon (G6XN) in his recent review of r.f. speech clipping [8].

Unfortunately there seems to be a shortage of experimental data with which to compare the results of the calculation. Data points taken from the only sources located have been superimposed on the graph in Fig. 7. W. Sabin's (W0IYH) measurements agree well with the theoretical curve but are restricted to 10 and 20 dB of clipping. P. E. Chadwick (G3RZP) measured intermodulation products as a function of the parameter y [10] but he does not state whether his i.ps. are third order or the sum of all intermodulation products. The four values quoted seem fairly consistent but, compared with the theoretical curve they appear to underestimate the distortion as the clipping increases. The four points supplied by P. J. Horwood (G3FRB) do not agree with the theoretical curve or Sabin's data. It would have been useful if the two test-tone frequencies had been quoted, (those used by Sabin were 600Hz and 1kHz) because the low intermodulation level quoted for 10 dB of clipping raises the suspicion that the intermodulation products were being reduced by the post-clipper filter.

At 20 dB of clipping the present calculation and the data quoted indicate the i.p. level is substantial and would be objectionable if one were listening to a two-tone test signal. When listening to speech the i.p. is not so objectionable; this is probably due to the nature of the waveform. The graph in Fig. 5 shows

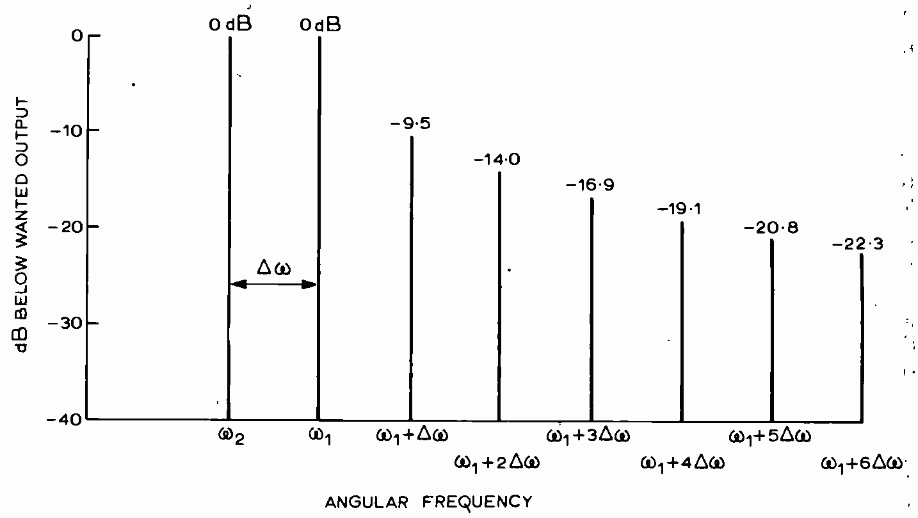
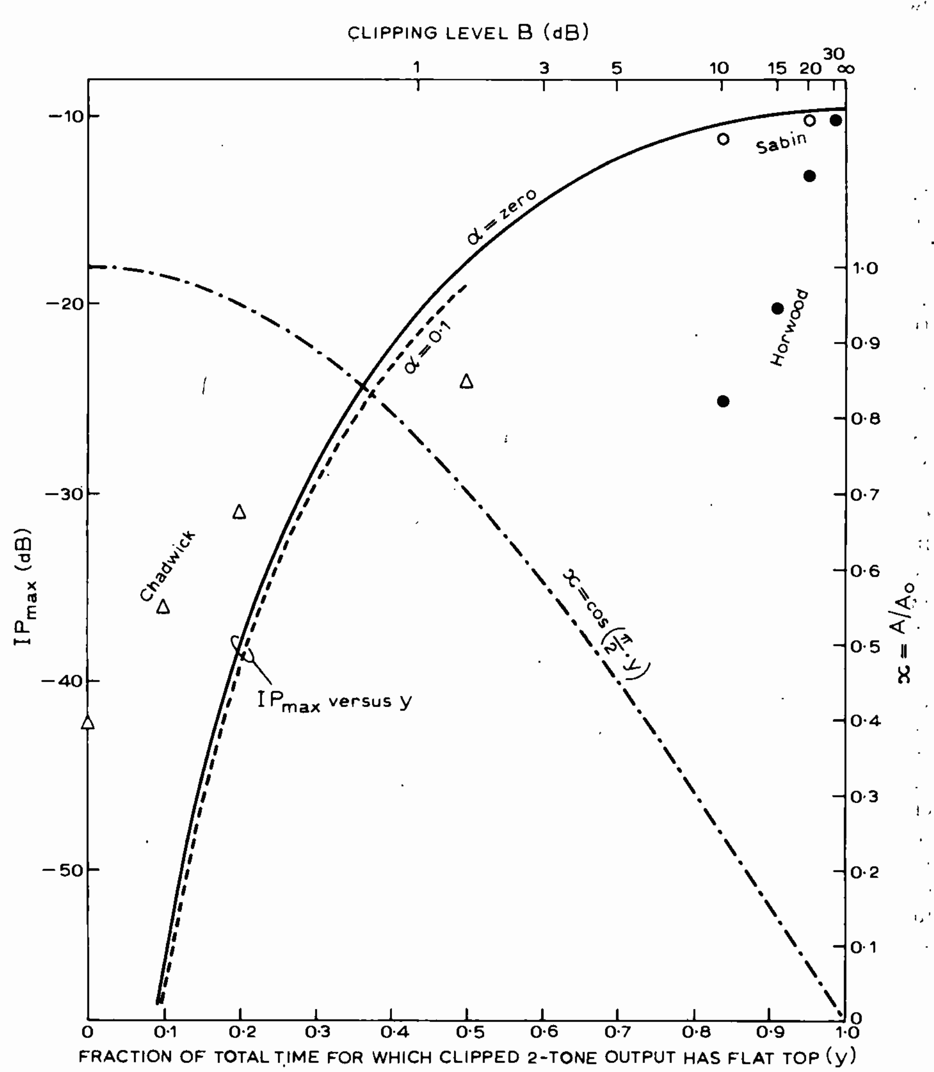


Fig. 6. Frequency spectrum of an infinitely clipped two-tone s.s.b. signal. The high levels of unwanted components (all except those with frequency ω_2 or ω_1) show the need for a narrow band filter after a r.f. clipper. The spectrum is symmetrical about $\omega_2+\omega_1/2$ but only frequencies greater than this are shown.

Fig. 7. Data in Fig. 4. is shown replotted to illustrate how the level of third order intermodulation products varies with y. The relationship between y and x is also plotted which is merely one quadrant of a cosine curve. Also plotted are some published experimental data for third order intermodulation levels.



the percentage of total observational time during which the instantaneous amplitude of speech waveforms exceeds a given percentage of the peak level (reference 4). The 33% level is exceeded for only 14% of the time. If, therefore, the speech clipping begins at the 33% level (i.e. $A/A_0 = 0.33$), up to about 8 dBs of clipping will occur, but only for a fraction of the total time. It seems quite reasonable therefore that neither r.f. nor a.f. clipping to this extent will cause much subjective deterioration of the speech, and this is what is observed in practice.

Because the remaining 86% of the speech has been raised in level by 9.5 dBs a large increase in talk power is achieved. Although this applies equally well to a.f. or r.f. clipping, the audible difference is less pronounced for the latter at high clipping levels because fewer distortion products are produced. For example, many pairs of frequencies in a speech waveform will have intermodulation products that fall outside the subsequent filter's pass-band. These two frequencies will appear undistorted whereas distortion products would still arise if a.f. clipping were used. Perhaps a more important point is that the level of intermodulation products produced when two tones are clipped at r.f. will reduce when their unclipped levels become unequal. In the limiting case of a single tone, no distortion is produced by an r.f. clipper. This is in direct contrast to audio clipping, where even a single tone would produce a series of odd harmonics which waste transmitter power.

Farkas and Gschwindt [5] have shown theoretically and empirically that for 20 dB of clipping, the output power from an audio clipper is 1.66 times that from a r.f. clipper. This extra 66% of power is wasted so far as wanted information is concerned. Furthermore, the extra power is being used to transmit interference within the information bandwidth and therefore, compared with r.f., a.f. clipping contains a built-in jammer which has 66% of the strength of a r.f. clipped signal.

Conclusion

In testing linear amplifiers for non-linearity at any frequency, a two-tone test input is widely used because of the relatively high levels of intermodulation products (compared to harmonics from a single tone of the same amplitude in the same situation) produced by a given degree of non-linearity [6]. Considering the extreme deviations from linear amplification produced by any form of clipper or amplitude limiter, the levels of intermodulation products calculated in Fig. 4 seem plausible. One feels, however, that maybe some other factor made the distortions figures, quoted in reference 3, so low.

For reasons noted already the two-equal-tone test signal is not suited for testing in-band distortion in a speech transmitter using a clipper. The result is too pessimistic when compared with the audible deterioration. On the other hand, when testing for out-of-band interference in a s.s.b. system using r.f. clipping, a two-tone signal is valuable because it represents a worst-case situation, which is what adjacent channel users are interested in. The present calculation could easily be carried further to evaluate the amplitudes of higher intermodulation products more likely to be outside the information bandwidths defined by the post-clipping filter. It is probably safer to assume the worst-case situation of infinite clipping where the amplitudes of intermodulation products produced by the two-equal-tone input are given by $b_m = |(4A/m\pi)|$. These components are plotted in terms of decibels below the wanted output in Fig. 6. A similar diagram appears in reference 7. The high level in adjacent channel regions shows why the filter following an r.f. clipper has to do more than remove harmonics at $2f$, $3f$, etc., where f is the carrier frequency, as has been implied in at least one publication. With a speech input Fig. 6 would appear more as a continuous spectrum. This figure emphasises the recommendation that the post-clipper filter should be of comparable specification to the original sideband selection filter. Such a filter also helps to reduce the carrier and unwanted sidebands to their original pre-clipping level.

Crossover distortion

The solid line in Fig. 3(a) can also be regarded as an exaggerated output from a class B audio amplifier suffering from cross-over distortion and where the input signal is a single sinusoid. The same calculation can therefore be used for determining the amplitudes of the harmonics produced by such an amplifier. Similarly the curves given in Fig. 4 for low values of α can be interpreted as giving the amplitude of the strongest inter-modulation product produced by a class B r.f. power amplifier with an arbitrary amount of cross-over distortion when fed with a two-equal-tone test signal. This treatment cannot be used to calculate the intermodulation products for a two-tone audio-frequency signal subjected to clipping or cross-over distortion for reasons given earlier. Qualitatively, however, the result of clipping such a signal will be a series of overlapping sets of products as in Fig. 2, with each set centred on a multiple of $(\omega_1 + \omega_2)/2$. Thus, the total number of unwanted products within the information bandwidth will be much larger than if the compression of dynamic range is carried out by heterodyning to r.f., clipping, filtering harmonics, and heterodyning the result back to a.f.

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Sixty Years Ago

Our occasional "Letter from America" was a feature of the journals as long ago as sixty years. The Letter in the October 1916 issue — incidentally written by David Sarnoff who later became chairman of RCA — includes among other things the small drama of a stolen crystal detector:

"The operator in charge of a wireless station installed on a vessel left his cabin for a few minutes, during which time an unscrupulous person entered the radio cabin and purloined the crystal detector from the tuner, as well as the spare crystal detectors which were lying in a box on the operating table. The ingenuity of this particular operator was not all that could be desired, and as a result the vessel was unable to receive wireless signals for a period of two and a half days."

The report then goes on to quote *The Electrical World:*

"A condition in which the operation of a wireless telegraph outfit must be entirely suspended on account of the lack of a spare bit of carborundum is not healthy. That it can exist reflects no credit upon either the operator himself, the company which trained and employed him, or the naval examiners who granted his licence certificate. This is quite over and above that part of the responsibility of the operator to construct a temporary detector of at least enough sensitiveness and reliability to keep the ship radio in operation.

" . . . Had the operator, who was forced to sit idly by his dead receiver because the crystal had been stolen, known a little of what expedients were made use of in the early years of wireless telegraphy there would have been no failure to protect his ship by radio service. Two needles and a pencil, a knife-blade and a broken incandescent lamp, a piece of dry-cell carbon and an iron wire — any of these could be used as a microphonic detector which would take the place of the crystal and receive signals from fifty to one hundred miles."

World of Amateur Radio

Suppressing d.s.b.?

The Radio Regulatory Division of the Home Office has gained a favourable reputation in its attitude towards amateur licence matters. It is therefore all the more inexplicable that it is withdrawing from British amateurs the right to use double-sideband suppressed-carrier (d.s.b.s.c.) modulation. In seeming direct contradiction to the international definition of the amateur service as a service of "self-training and technical investigations" the authorities are attempting to kill any further investigation into a modulation system for which it has itself provided funds for university research and which some engineers have endorsed as potentially more effective for amateur communication than s.s.b.

The reasons put forward by the Home Office for this strange banning of a system that has been permitted for many years are so extraordinary that they can be based only on a misunderstanding of d.s.b.s.c.

In the first place it claims that the mode is not specifically authorised by international radio regulations. But then this applies equally to other modes permitted to radio amateurs and certainly does not worry licensing authorities in other countries. If the Home Office is to ban systems on such grounds how can amateurs make technical investigations into experimental systems?

In what appears to be its key reason, the Home Office claims that d.s.b.s.c. is difficult to monitor without special equipment. This is simply not true: d.s.b.s.c. is fully compatible with s.s.b. and can be effectively received on any set that has sufficient selectivity and stability to receive s.s.b., the d.s.b.s.c. being converted to s.s.b. within the receiver. This misconception can be based on the fact that to take *full* advantage of the potential of d.s.b.s.c. the injection oscillator frequency should be locked in phase to the suppressed carrier to permit such techniques as binaural synchronous demodulation (which modern components are making far more possible than hitherto). With such demodulation, d.s.b.s.c. offers a theoretical advantage of 6dB over s.s.b.

As a third reason, the Home Office claims that no undue hardship would be placed on amateurs by the recall of this facility. This must mean that relatively few amateurs currently use d.s.b.s.c. (but then only a few transmit high-definition tv) and that since Japanese equipments do not feature d.s.b.s.c. very few amateurs can claim to have bought a manufactured d.s.b.s.c. transmitter recently. So much for encouraging home construction as a form of self-training!

As long ago as 1959, J. P. Costas delivered a mathematical broadside at the widely held belief that because d.s.b.s.c. needs more bandwidth than s.s.b. fewer d.s.b.s.c. stations could operate effectively in a restricted band. He showed clearly that this is true *only* where all frequencies are channelised, since d.s.b.s.c. signals are potentially much less vulnerable to interference than s.s.b. transmissions.

More recently, Home Office sponsored research under Professor Gosling at Swansea and Bath universities has underlined the value of d.s.b. with diminished carrier for mobile and hand-held v.h.f. equipments.

There is little doubt that d.s.b.s.c. is a fully compatible, effective, economical and (potentially) the most efficient of all amplitude modulation systems, at a stage where, with further development, fully synchronous demodulation may be easily implemented. We urge the Home Office to think again — and to rescind a decision that runs contrary to the best interests of amateur radio.

From all quarters

A band plan for 70MHz has been proposed by the RSGB v.h.f. committee as follows: 70.05 to 70.15 c.w. only; 70.02 s.s.b. calling frequency; 70.26 national mobile/net calling/working frequency; 70.475 f.m. channel; 70.5 f.m. calling; 70.525 f.m. channel; 70.56 r.t.t.y. calling frequency; 70.675 yo 70.7 MHz beacons.

Diana Hughes, G4EZI, is organising a regular net for British "yl" (young lady) operators on 3705kHz on Saturday mornings at 11 a.m. local time. Heard on 3.5MHz c.w. recently — Margaret Mills, G3ACC, who in the immediate post-war years was one of the best known "yl" operators in South London. After 13 years off the air she now operates from South Devon.

With several amateurs now having worked more than 100 different countries on 1.8MHz, Stewart Perry, W1BB, recommends the following hints to those hoping to work long-distance stations on the band during the coming season: (1) set clocks carefully and call CQ only during the first 2½ minutes of any 5 minute period; (2) do not keep working the same rare stations; (3) when closing a contact with a rare station give *his* frequency so that others can find him; (4) do not have long contacts on or near the "dx" frequencies; (5) keep dx contacts short; (6) keep CQ calls short.

The ARRL recently checked the intermodulation distortion two-tone dynamic range; blocking above noise floor; and noise floor of a number of current American and Japanese communications receivers. Receivers with the best dynamic range were the home-made sets. Compared with such figures as 95dB; 123dB and —141dBm. for good amateur designs, commercially manufactured sets for the amateur market were mostly in the ranges: 88 down to 59 dB; 116 down to about 97 dB; and —135 to —141 dBm. ARRL did not identify the factory-built designs.

An editorial in *QST* by Richard Baldwin, W1RU, general manager of ARRL, has urged American amateurs to make more use of the u.h.f. bands to take pressure off the 144, 220 and 420 MHz and to emphasise the need to retain bands of 1215MHz and above.

Recent successes on 10GHz have included a first England to Belgium two-way contact (G4ALN to ON6TS/P), and on 2.3GHz a contact between G3LQR and OZ9OR in Denmark appears to be a new world record.

Radcomex

Looking around the Radio Communications Exhibition at Alexandra Palace, a stranger might have supposed that British amateurs are firmly dedicated to building their own equipment. Indeed the trade provided a display that showed that it is still possible to find in the UK high-grade transmitting variable capacitors and inductors and surplus low-price quartz crystals in good quantities. That so many suppliers of packaged equipments preferred to stay away (even though many had booked stand space) says much for the power of their trade association, if little for any sense of service to their south-of-England customers. But such boycotting could misfire; amateurs might find they actually derive more interest from supporting component firms than the black-box suppliers.

In brief

Among a party of 30 miners from Donetsk, USSR, who visited the "twin city" of Sheffield recently was Leo Vailenko, UT5AA, president of the Donetsk Radio Society . . . A reminder that many courses for the Radio Amateurs Examination are just starting at evening class centres and by local radio societies. Classes include those at Aberdeen, Barry, Bath, Beckenham, Blackburn, Broadstairs, Bury, Canterbury, Chelmsford, Chesterfield, Eastbourne, Farnborough, London, Mansfield, Oldham, Portsmouth, Rolleston, Strood, Walsall, Weybridge (if in any doubt make local enquiries).

PAT HAWKER, G3VA

Characteristics and load lines

3 — Linear load lines

by S. W. Amos, B.Sc., M.I.E.E.

The fundamental law on which electronics is based is that of Georg Ohm which states that, subject to certain conditions, the current in a conductor is directly proportional to the voltage applied to it. Thus if the current in a conductor is plotted against the voltage applied to it, a graph such as that of Fig. 1 is obtained. The significant feature of the curve is that it is linear and passes through the origin. The slope of the straight line is a measure of the resistance of the conductor. If the line has a very small slope as for OA in Fig. 2 this indicates that high voltages give rise to small currents, a property of a high resistance. For curve OB, on the other hand, low voltages give rise to high currents and this is a property of a low resistance. As a generalisation, therefore, we can say that the more nearly horizontal the curve is, the higher is the value of resistance it represents and the more nearly vertical the curve is the lower is the value of resistance it represents. The voltage axis itself can be taken as the curve for an infinite resistance (an open circuit) and the current axis as the curve for zero resistance (a short circuit). Mathematically the slope of the curve is equal to 1/(resistance).

Consider a simple circuit consisting of two resistors connected in series across a battery as shown in Fig. 3. The lower end of R_1 is connected to a point of zero potential and the upper end A has a potential which increases in direct proportion to the current in R_1. By plotting the potential at A against the current we obtain a graph similar to that of Fig. 1. It is given in Fig. 4 and here the axes are calibrated so that the value of R_1 can be calculated. Fig. 4 shows that when the voltage across R_1 is 10, the current is 1mA so that R_1 must be 10 kilohms.

Now consider R_2. The upper end B of this resistor has a fixed potential of 24V and the lower end A has a potential which *decreases* as the current through R_2 increases, the extent of the decrease being directly proportional to the current. If the potential at A is plotted against the current through R_2 we obtain the curve shown in Fig. 5. It is again similar to Fig. 1 but is laterally reversed compared with it. From Fig. 5 we can see that when the voltage across R_2 is 10, the current in it is 0.5mA, which gives the value of R_2 as 20 kilohms.

By combining Figs. 4 and 5 we obtain Fig. 6, the interesting feature of which is that the two straight lines meet at the point P. This diagram is useful because

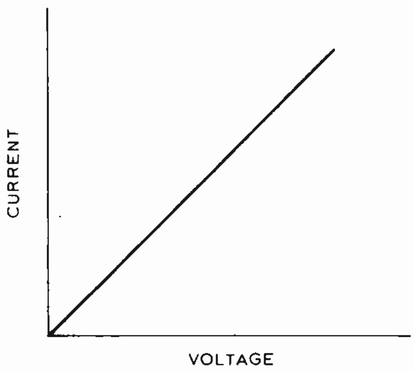


Fig. 1. Linear current-voltage relationship for a conductor.

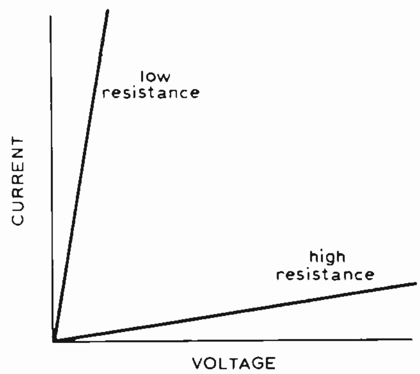


Fig. 2. Current-voltage relationships for low-resistance and high-resistance conductors.

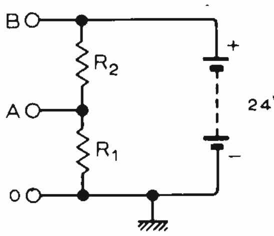


Fig. 3. A simple circuit of two resistors connected in series across a battery.

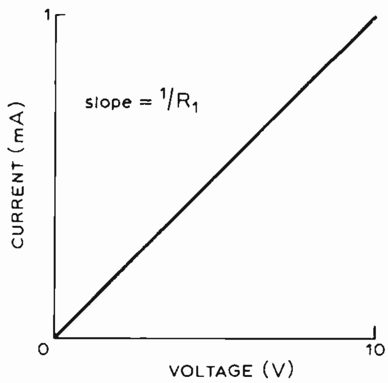


Fig. 4. Current-voltage relationship set for R_1 in Fig. 3.

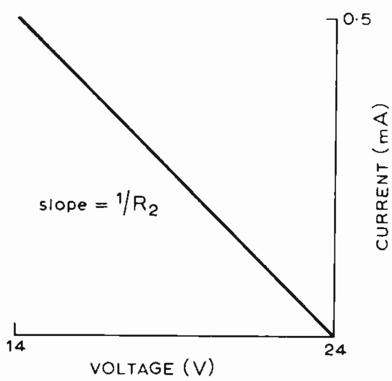


Fig. 5. Current-voltage relationship for R_2 in Fig. 3.

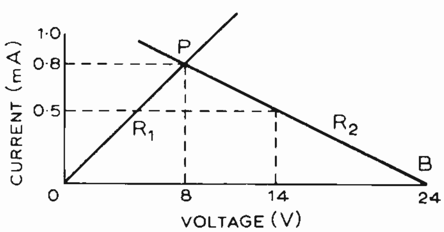


Fig. 6. Figs 4 and 5 combined.

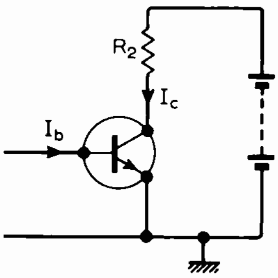


Fig. 7. The circuit of Fig. 3 in which R_1 has been replaced by a bipolar transistor.

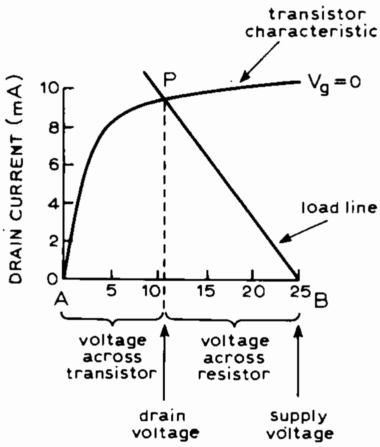


Fig. 8. A repeat of Fig. 6 in which AP is replaced by the I_d–V_d characteristic of a field-effect transistor.

it represents the voltages and currents in the circuit of Fig. 3. For example point P corresponds to a voltage of 8 and this is the potential at point A in the circuit if, as assumed, R_1 is 10 kilohms and R_2 20 kilohms. Simple theory easily confirms that this is correct: treating R_1 and R_2 as potential divider we have that the voltage at A is given by $24\,R_1/(R_1 + R_2) = 24 \times ⅓ = 8$. Fig. 6 also shows that point P corresponds to a current of 0.8mA and this is the current in the two resistors. Again simple theory confirms this: the current is given by $24/(R_1 + R_2) = 24/(30 \times 10^3) = 0.8$mA.

Fig. 6 is useful in predicting the changes which occur in the circuit if a resistance value is changed. For example if R_1 is increased in value, the slope of line OP decreases and P moves to the right and downward, indicating an increase in the potential at A and a decrease in current through the resistors. On the other hand if R_2 is increased, the slope of PB decreases, causing P to move downwards and to the left, corresponding to a decrease in the voltage at A and a decrease in current. Similar arguments can be used to show the effects in the circuit of decreasing R_1 and R_2.

RC-coupled loads

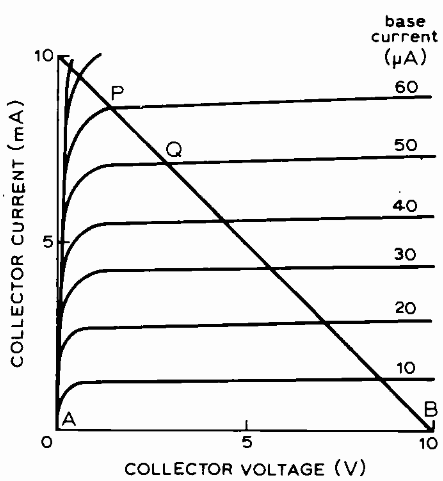
It is unlikely, of course, that anyone would use a graphical construction such as that of Fig. 6 to determine the voltages and current in a circuit as simple as that of Fig. 3: calculation using Ohm's law is simpler and quicker. But the principle of Fig. 6 is useful for solving problems where R_1 is not a linear resistor but a non-linear active device (e.g. a transistor) and R_2 is its load resistor as shown in Fig. 7. To illustrate this let us replace the straight line OP by the output characteristic of a field-effect transistor. This gives Fig. 8.

AP is the drain current – drain voltage characteristic for the transistor (for zero gate voltage) and BP is the load line with a slope corresponding to a resistance of 1.5 kilohms. The two curves intersect at P, showing that the drain voltage is just over 10V and that the current in transistor and resistor is 9.5mA. Because of the non-linearity of the transistor characteristic it would be difficult to calculate these values and this illustrates the usefulness of the graphical method.

It is important to realise that the load line BP defines the relationship between the current in the resistor and the voltage across it. This is a property of R_2 and is unaffected by conditions within the transistor. Similarly AP defines the current-voltage relationship for the transistor and this is independent of the load resistor. By plotting both curves on the same graph their points of intersection can give useful information about circuits in which the two devices are connected in series.

Fig. 8 applies when the gate of the transistor is held constant at zero volts. By using other values of input bias it is, of course, possible to obtain other output characteristics although their general shape remains the same. Fig. 9 illustrates a family of output characteristics (this time for a bipolar transistor) and superimposed on them is a load line for a resistance of 1 kilohm. If $I_b = 60\mu$A the intersection of the load line with the characteristic is at P where $V_c = 1.3$V and $I_c = 8.6$mA. By changing the bias current to 50μA the intersection moves to Q where $V_c = 3$V and $I_c = 7$mA. By suitable choice of I_b, in fact, the intersection can be moved to any desired point on the load line. If I_b is controlled by a signal then the point of intersection (usually called the operating point) moves up and down the load lines in sympathy with the signal.

If the input bias exceeds about 60μA the operating point is confined to the area above P in which there is very little voltage drop across the transistor and the collector current is around 8mA. Under such conditions the transistor is said to be saturated, bottomed or simply "on". On the other hand if the base current is less than 10μA (or is reversed in direction) the operating point is confined to the area around B where



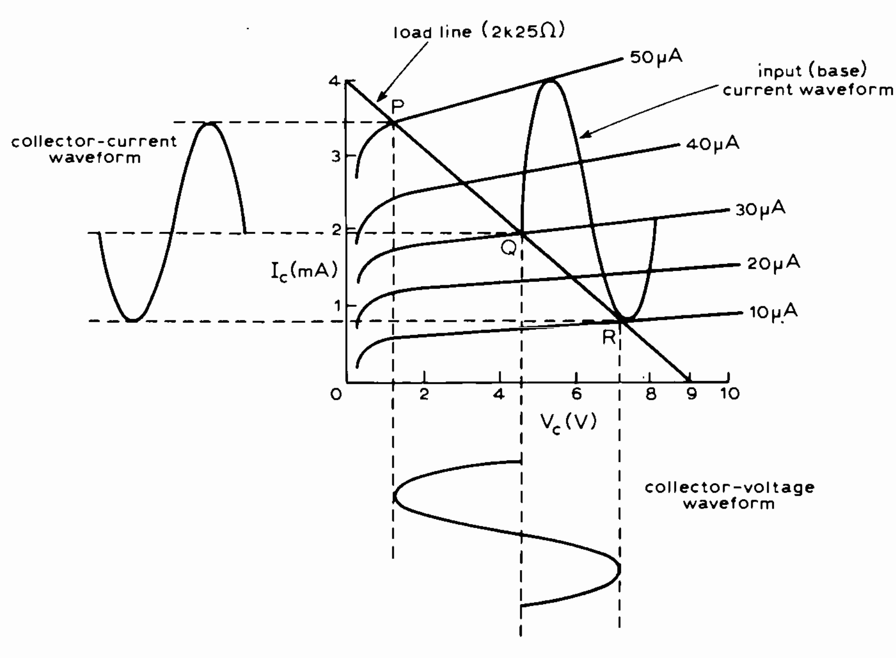


Fig. 9. A load line for a directly-coupled resistor superimposed on a set of I_c–V_c characteristics.

Fig. 10. A load line superimposed on a set of I_c–V_c characteristics illustrating analogue amplification.

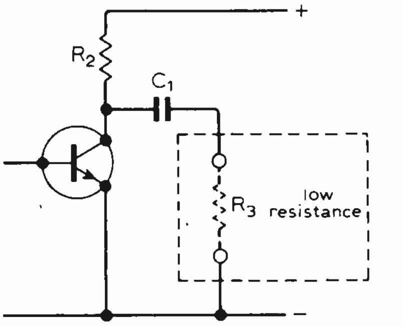


Fig. 11. Essential features of a current amplifier.

there is very little collector current and very little voltage drop across the load resistor. In this state the transistor is said to be cut off or simply "off". In digital equipment the transistors are always in the "on" or "off" state: in fact they are used as switches and the transition from one state to the other is as rapid as possible, causing the operating point to traverse the load line at very high speed.

The region between P and B which is of little concern to the designer of digital equipment is of great interest to the designer of analogue equipment. This is the region used in linear amplification and the way in which it occurs is illustrated in Fig. 10. This shows a sinusoidal input signal which swings the base current between the limits of 10μA and 50μA (a peak value of 20μA). Under the stimulus of this input signal the operating point moves up and down the load line between the limits of P and R. This causes the collector current to swing between the limits of 3.4mA and 0.8mA. This corresponds to a peak value of 1.3mA and shows that the transistor is giving a current gain of 65. The collector voltage also swings and its limits are 1.2V and 7.2V (a peak output of 3.0V).

The input signal is in fact a peak signal of 20μA superimposed on a steady bias of 30μA. Thus in the absence of an input signal the bias is present alone and the operating point is at Q, known as the quiescent point.

Linearity of the input-output characteristic depends on the uniformity of the intercepts made on the load line by the transistor characteristics and an account of this was given by Part 1 of this series.

Current amplifier

Bipolar transistors are commonly used as current amplifiers and if a basic circuit such as that of Fig. 7 is used for this purpose it normally feeds into a very low resistance R_3 as suggested in Fig. 11: the terminating resistance could well be the input resistance of another bipolar transistor. The low-value resistor is isolated from the first transistor by a series capacitor C_1. Thus d.c. conditions in the circuit are unchanged and the load line for R_2 is still as indicated in Fig. 10, with the operating point at Q. As soon as an alternating signal is applied to the base of the transistor, however, conditions change because the effective load resistance is now that of R_2 and R_3 in parallel. It is assumed that the reactance of C_1 is negligible compared with R_3 at the frequency of the applied signal. The effective load resistance is now $R_2R_3/(R_2+R_3)$ which is smaller than R_2 and thus the load line which applies to a.c. (signal) conditions has a greater slope than the d.c. load line. If R_2 has a slope corresponding to 2.25 kilohms (as for Fig. 10) and if R_3 is assumed to be a linear resistance of 1 kilohm, then the effective load resistance is composed of 2.25 kilohms and 1 kilohm in parallel, i.e. approximately 700 ohms. The a.c. load line EF in Fig. 12 is drawn with a slope corresponding to 700 ohms. The input signal shown is of 20μA peak value as in Fig. 10 but because EF is more nearly vertical than PR the output current in Fig. 12 is greater than in Fig. 10: it swings in fact between 3.7mA and 0.7mA, a peak value of 1.5mA corresponding to a current gain of 75. The output voltage is however smaller, swinging between 3.5V and 5.5V, a peak value of 1V. By making EF vertical the output current could be increased further still, bringing it to a maximum, the current gain then being equal to h_{fe} for the transistor. To make EF vertical the external load resistance R_3 must be zero, i.e. a short circuit. If EF is vertical the output voltage is of course zero.

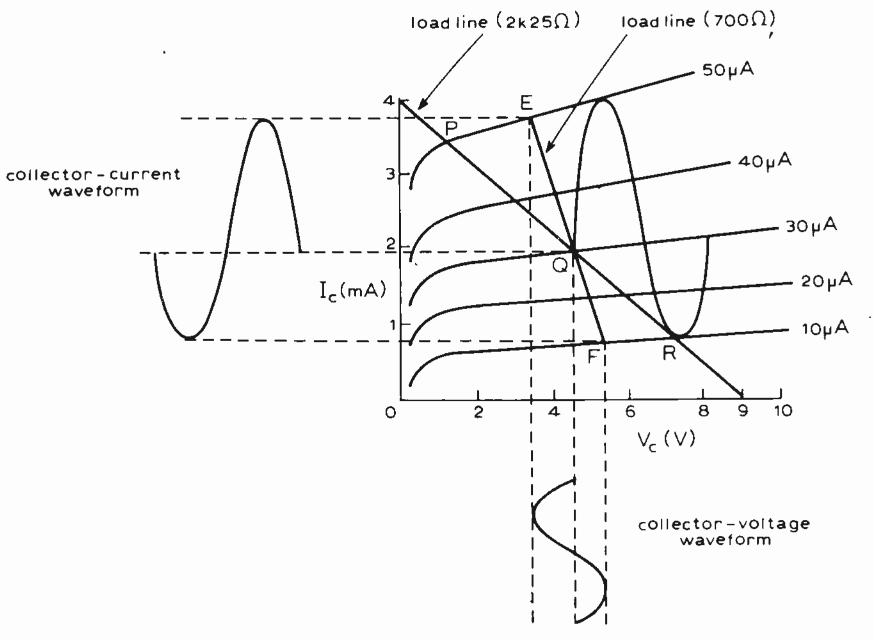


Fig. 12. EF is the effective (a.c.) load line for the current amplifier of Fig. 11.

Voltage amplifier

Fig. 12 shows how the shunting effect of R_3 curtails the voltage output from the transistor and it is clear that if the greatest output voltage swing is required R_2 must not be appreciably shunted by R_3. Thus R_3 must be large compared with R_2 so that the parallel resistance of R_2 and R_3 is not significantly less than R_2. In these circumstances the a.c. load line is almost coincident with the d.c. load line and Fig. 10 can be taken as the diagram for a practical amplifier.

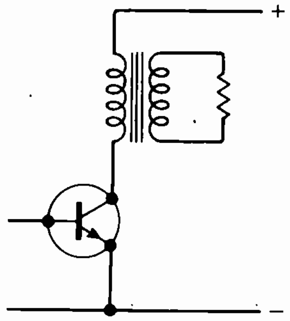
The knee of the I_c-V_c characteristics occurs at a very small collector voltage and it is thus possible by suitable choice of load resistance and base bias to obtain an output-voltage swing nearly equal to half the supply voltage V_{cc}. The quiescent point should be at the centre of the load line and thus the quiescent (no-signal) collector current corresponds to a quiescent collector voltage of $V_{cc}/2$. Thus we have the simple relationship

$$\text{quiescent } I_c = \frac{V_{cc}}{2R_2}$$

Thus if we have a supply voltage of 9 and we require a mean value of I_c of 1mA the R_2 should be 4.5 kilohms. The required value of I_c is achieved by adjustment of base bias current and in a practical circuit some means of ensuring that the mean current remains at 1mA in spite of spreads of transistor parameters and variations in temperature is desirable.

Transformer-coupled loads

A.C. and d.c. load lines. A transistor with a direct-coupled load as represented in Fig. 10 is capable of a good voltage output and a good current output simultaneously: in other words it can supply appreciable power. Nevertheless the power output is limited by the fact that the collector voltage swing cannot exceed half the supply voltage. This limitation disappears if the load resistance is connected to the collector circuit via a transformer as indicated in



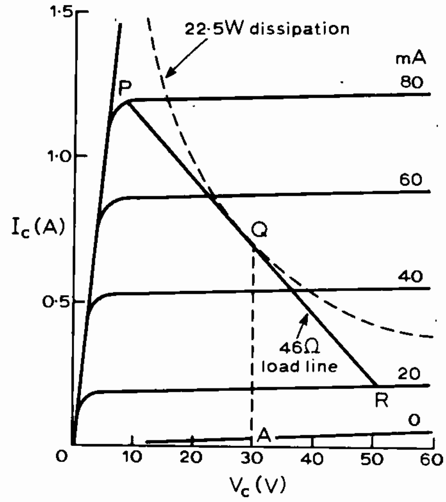


Fig. 13. A transistor amplifier with a transformer-coupled load.

Fig. 14. I_c–V_c characteristics for a power transistor and a suitable load line.

Fig. 13 because in such a circuit the collector voltage can swing above and below the supply voltage.

The operating conditions for a transformer-coupled load can be represented by d.c. and a.c. load lines. First consider the d.c. conditions. The resistance of the primary winding of the transformer is the only effective load for the transistor for d.c. and this is usually very small. Thus if we construct a load line for the primary resistance it will be almost a vertical line connecting the supply voltage A to the quiescent point Q as shown in Fig. 14. In power amplifiers it is normal, however, to assume the d.c. load line AQ to be vertical and to omit it, Q being located vertically above A.

When an alternating signal is applied to the base of the transistor the collector current varies in sympathy and generates a corresponding voltage across the transformer primary winding. By plotting this voltage against the collector current we can obtain the a.c. load line for the amplifier. Its slope depends on the effective resistance at the terminals of the transformer primary winding and this is given by n^2R where n:1 is the turns ratio of the transformer and R is the load resistance connected to the secondary winding. By choice of n and R the effective primary resistance can be made almost any desired value, but it is usually much greater than the d.c. load resistance. This contrasts with the capacitance-coupled circuit (Fig. 11) where the a.c. load resistance is inevitably less than the d.c. load resistance.

Output power. For an output stage the position of the quiescent point and the slope of the a.c. load line are chosen to give the maximum output power consistent with an acceptable degree of distortion. There are, however, practical limitations to be observed: for example there is a maximum value of I_c which must not be exceeded. There is also a maximum value of V_c which must not be exceeded and a maximum value of collector dissipation.

As an example Fig. 14 gives the I_c-V_c characteristics for a silicon power transistor. For the particular type of heat sink used the maximum safe collector dissipation is 22.5W and the curve (a hyperbola) for this value of dissipation is shown as a dotted line. The load line must not cross this curve but it may touch it, and a suitable load line is given by *PR*: it corresponds to a load resistance of approximately 46 ohms. A transformer-coupled load is assumed and 46 ohms is the effective resistance at the transformer primary winding. The base bias is 50mA and the input signal swings the base current between 20mA and 80mA, giving the following maximum and minimum values of I_c and V_c:

$$I_{max}=1.22\text{A} \qquad V_{max}=54\text{V}$$
$$I_{min}=0.24\text{A} \qquad V_{min}=8\text{V}$$

The peak output voltage swing is thus (54–8)/2, i.e. 23V and the peak output current swing is (1.22–0.24)/2 i.e. 0.49A. The power output is thus

$$\tfrac{1}{2}\times23\times0.49=5.6\text{W}$$

(To be continued)

Books Received

Liquid Crystals for Electronic Devices by Edward L. Williams. According to the forward, this publication serves two purposes — it supplies detailed technical information, and can be used as a guide to the U.S. patent literature in this field. Chapters cover cholestric compounds and applications, nematic compounds, nematic and smectic liquid crystal display systems and devices. The chemistry of liquid crystal compounds is discussed in some detail and the chemical structures of compounds are illustrated throughout the text. Price $36. Pp. 263. Noyes Data Corporation, Publicity Department, Mill Road at Grand Avenue, Park Ridge, N.J.07656, U.S.A.

Modern Communication Systems by R. F. W. Coates is intended to cover a two-year course on communication system engineering at B.Sc level. The first chapter concentrates on the use of Fourier methods in the analysis and processing of waveforms. Following chapters are concerned with methods of modulating a sinusoidal carrier. Final sections cover digital techniques such as pulse code modulation and coding for error protection. Although the text omits descriptions of differential pulse code modulation and delta modulation the general digital methods are covered in detail. Price £9.95 and £5.95 (paperback). Pp.292. Macmillan, 4 Little Essex Street, London WC2R 3LF.

Delta Modulation Systems by R. Steele. Delta modulation has "been around" since 1946, and the original systems had an ability to encode continuous signals, such as speech and television, into binary signals and to subsequently decode them, but these early systems had some serious disadvantages. Although the present generation of systems have greatly improved performance, this improvement has arrived too late for some speech networks where, due to investment, p.c.m. will be used. The author believes that delta modulation systems, however, have a role to play in local subscriber networks.

Chaper one describes the characteristics and parameters of linear delta modulation with a minimum of mathematical analysis. Chapter two considers an improvement to the system which requires the presence of a predicator, and continues with a description of exponential delta modulation. Following sections discuss slope overload noise in linear d.m. systems, transmission errors in linear systems, asynchronous systems, and syllabically companded delta modulation. The book concludes with sections on delta and pulse code modulation, encoders with multi-level quantizers, d.m. digital filters and instrumentation using d.m. Price £10. Pp.379. Pentech Press, 4 Graham Lodge, Graham Road, London N.W.4.

The UK Post Office and National Computing Centre Ltd have jointly produced the **Handbook of data communications.** Based on the P.O. data communications courses, the publication is intended for students although it should be of value to systems engineers, programmers and analysts. Initial chapters describe the origins and nature of data communication, telephone and telex systems, transmission and modulating systems, data terminals, line control and interfaces. Subsequent chapters cover data errors, concentrators, multiplexers, and final chapters describe data transmission services in the UK and internal communications. The book is well illustrated with diagrams, graphs, tabular information and photographs of equipment. A glossary is also provided which gives understandable definitions of technical terms. Price £8.50, pp. 395. NCC Publications, Oxford Road, Manchester M1 7ED.

Correction

In the September article by Jack Dinsdale on the Indian Satellite, the area of the Indian sub-continent was a little exaggerated. It should be 1.269 million square miles, whereas we (not Mr Dinsdale) added to India's problems by saying that the area is 1,269M square miles.

New Products

Low-cost indicator meters

Low-cost miniature indicator meters, available with full scales of 0-500μA or 0-180μA, have been introduced by Perdix Components Limited. Styles of mounting allow flat or edgewise presentation and the units, which may be illuminated from the rear, are moulded in transparent plastic, their robust construction allowing use in portable equipments without extra protection. The meter movement has a sinusoidally-distributed air gap giving a scale suppression at the end to guard against overload conditions. Prices range from 80p to £1.00 depending upon the quantity and specification required. Perdix Components Ltd, 98 Crofton Park Road, London S.E.4.

WW 301 for further details

Fast-recharge soldering iron

The Quick-charge cordless soldering iron incorporates nickel cadmium batteries to provide very fast recharging: it is claimed that completely dead battery cells can be brought to the full charge state in about 4 hours. In use this iron can be continually charged through its stand and, after pressing the on/off operating button, solder heat can be reached in 5 seconds. Up to 125 joints can be made from fully charged batteries. To eliminate electrical leakage the soldering tips, which are available in five sizes, are isolated. The iron gives a performance equivalent to up 50W with a 700°F tip temperature. Optional extras include a built-in light case and automobile charger/plug assembly. Greenwood Electronics, Portman Road, Reading, Berks RG3 1NE.

WW 302 for further details

Synthesized signal generator

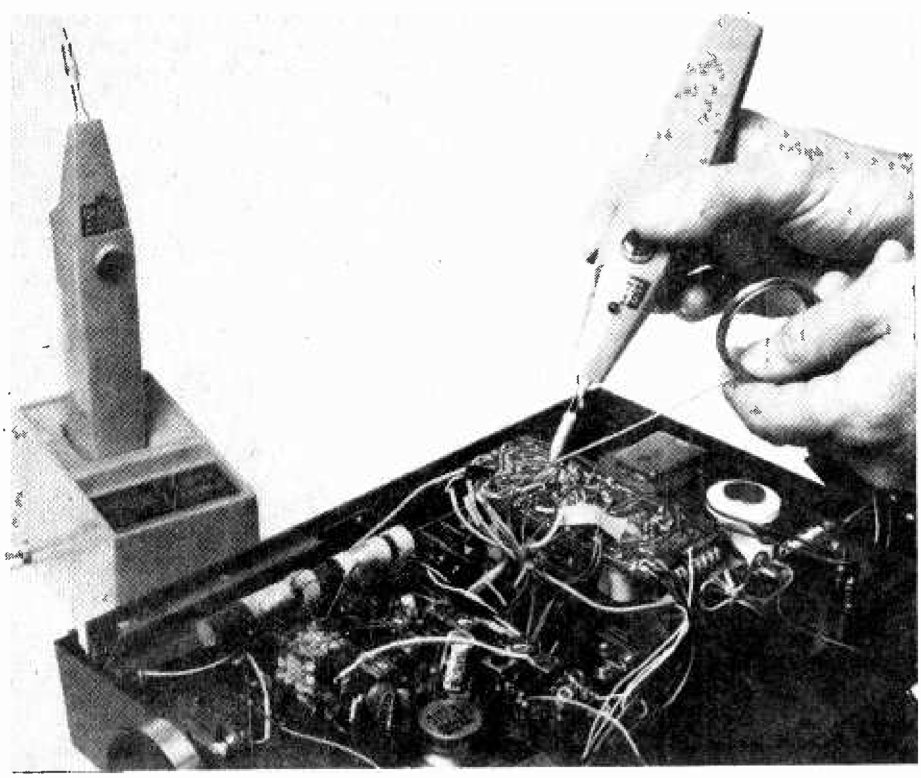
A digital signal generator, from Marconi Instruments Ltd, provides c.w., a.m. and f.m. outputs over the frequency range 50kHz to 520MHz. All of the operating functions, including carrier frequency, output level and modulation, may be controlled manually or remotely by applying programmed parallel binary-coded-decimal commands. Features of the generator are its high output level (2 volts into 50Ω for c.w. and f.m. signals), accurate output level setting switchable for up to 145.9dB attenuation in 0.1dB steps (accurate to ±1dB overall), and good noise performance – for example, at least 130dB/Hz below carrier level at 20kHz offset for s.s.b. Other features include a choice of a.m. depths from 0 to 99% in 1% steps and f.m. deviation from 0 to 299kHz in 3 ranges. An oscillator provides switch-selectable modulation frequencies ranging from 20Hz to 99kHz. Marconi Instruments Ltd, St. Albans, Herts, AL4 0JN.

WW 303 for further details

Low cost printer

The Olivetti NIP-18 is a non-impact printer which, it is claimed, is suitable for alphanumeric print-out applications where previously cost, size, weight and noise ruled out equipment of this type. This printer, which is small, silent and capable of printing a full 64 character sub-set, is available in two versions; the first, costing less than £60, is a print head type complete with motor; the second is an o.e.m. version complete with b.c.d. character generator, computer interface and paper holder etc., costing less than £200. Dot-matrix serial printing on electrosensitive paper is by a 7-electrode mobile head which prints numerals, letters of the alphabet and symbols to a maximum of 25 3mm-high characters per line at a speed of 2 lines per second. The NIP-18 measures 175 × 45 × 80mm. Radiatron Instruments Ltd, Crown Road, Twickenham, Middlesex TW1 3ET.

WW 304 for further details



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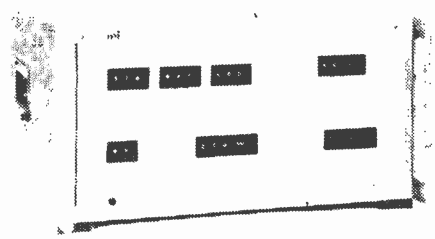
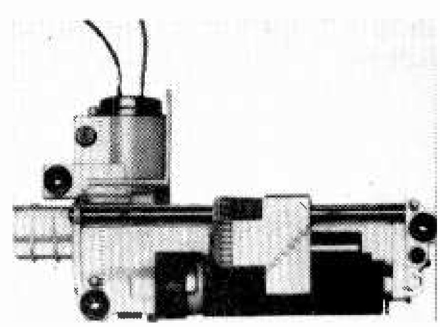


WW 303



WW 304

Squelch filter

The FB-239 is a low-power sub-audio active filter suitable for use as a squelch filter and tone encoder in portable and mobile communications equipment. This filter can be externally programmed with 2 resistors to cover all sub-audible frequencies and required Q-values, has a current drain of less than 300μA, and is available in a metal hermetic 14-pin d.i.l. package or a 9-pin edge-mounted plastic package. Suvicon Ltd, Westminster House, 188-190 Stratford Road, Shirley, Solihull B90 3AQ.

WW 305 for further details

Electro-optic transmission system

A compact electro-optic transmission system consisting of transmitter and receiver modules, optical couplers and electrical connectors, has been produced by Belling-Lee. The Fibretran system, as it is called, is capable of handling digital, analogue and television signals in a frequency range from 20Hz to 10MHz and will operate with light-guide cables up to 100m long. The receiver provides a composite output with a signal-to-noise ratio better than 40dB. Systems are available for mains or low voltage operation and are suitable for hazard areas and areas where security of transmission, isolation and freedom from interference are required. Belling and Lee Limited, Great Cambridge Road, Enfield, Middlesex EN1 3RY.

WW 306 for further details

Wow and flutter meter

The Leader LFM39 meter is designed for accurate, simple and rapid determination of wow and flutter and drift characteristics of tape recorders, gramophones and other playback/recording apparatus. These measurements can be made simultaneously. Weighted characteristics, in accordance with DIN, CCIR and JIS specifications, and wow and flutter are indicated on the meter in terms of effective percentage values to JIS specifications. In addition to the weighted measurements the centre frequency of 3.15kHz may also be measured in accordance with DIN specifications. Five full-scale ranges, 0.03, 0.1, 0.3, 1, and 3% are available. C. E. Hammond & Co. Ltd, Aveley/Cybervox, Chertsey Road, Byfleet, Surrey KT14 7LA.

WW 307 for further details

Miniature filament lamps

A range of miniature filament lamps, from IMO Electronics Ltd, includes radial and axial lead, bi-pin, grooved, screw and flanged base types. Supply voltages and currents range from 1.15 to 28V d.c. and from 15 to 320mA ±10% respectively. These lamps are selected and aged to provide long life and consistency of brightness. IMO Electronics Ltd, 349 Edgware Road, London W2 1BS.

WW 308 for further details

Dual-trace 50MHz oscilloscope

A portable 50MHz dual-trace oscilloscope, designated OS3300B, is intended for general purpose applications. The instrument, from Gould Advance, has a sensitivity of 1mV/cm (max) from 0 to 10MHz, a 10ns/cm (max) timebase and an e.h.t. of 13kV, making it suitable for displaying fast transients. In addition, triggering facilities are incorporated to ensure a stable trace on both channels, irrespective of frequency or waveform, and delayed-sweep and mixed-sweep timebase facilities allow detailed examination of complex waveforms and pulse trains. The oscilloscope has an 8 × 10cm rectangular-faced tube, measures 18 × 29 × 45cm and weighs 12.7kg. Gould Advance Ltd, Roebuck Road, Hainault, Essex.

WW 309 for further details

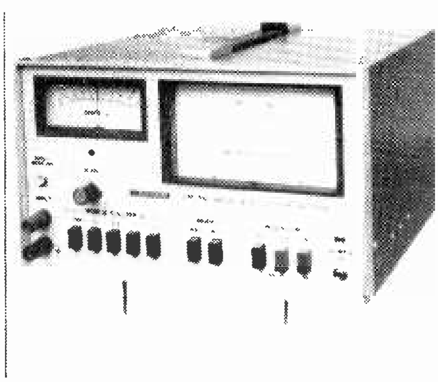
Teletext adaptor

The Labgear teletext adaptor, unlike receivers with built-in Ceefax and Oracle decoders, is an external "add-on" unit which may be fitted between the aerial and a standard 625-line colour (PAL) or black-and-white television receiver. Normal picture facilities are retained with the adaptor in circuit. This unit, type CM7026, can provide colour displays for all normal teletext facilities and may be used in specialised applications where pages of interest are required "piped" simultaneously to a number of receivers located throughout a building from a single adaptor, for example as in stock exchanges, bookmakers or education establishments. Labgear Ltd, Abbey Walk, Cambridge CB1 1RQ.

WW 310 for further details

Tape-tension gauge

Low-cost tape-tension gauges, in the Tentelometer range, are designed for use on most makes of video and audio magnetic-tape transports and are suitable for tape widths from ⅛ to 1 inch as standard, and 2 inches as special, or for applications requiring a damped response or small physical dimensions. These gauges, which use high-quality meter movements and three offset prongs through which the tape travels,



WW 307

WW 310

are claimed to be as accurate as more expensive electronic gauges. Static or dynamic responses may be measured with these gauges to diagnose faults leading to horizontal instability on video systems or wow-and-flutter on audio systems. Individual models cover tension ranges of 0 to 5oz (140gm), 0 to 12oz (340gm) and 0 to 20oz (600gm). Crow of Reading, P.O. Box 36, Reading RE1 2NB.
WW 311 for further details

Accumulators

Two 2-volt cells, one of 5Ah capacity and the other of 10Ah capacity, have been produced by Varley Dry Accumulators. The cells, which are made by building up the plates and separators under compression to form a porous block, are claimed to be spillproof, highly resistant to shock and vibration and capable of supplying discharge currents of up to approximately 30A (10Ah cell). Push-on contacts are provided with these cells. Varley Dry Accumulators Ltd, Alfreds Way, Barking, Essex IG11 0TB.
WW 312 for further details.

Strip-line attenuators

Strip-line pill-shape and chip attenuators, made by Pyrofilm of New Jersey, are now available in the UK. Ground plane spacing for the attenuators is only ⅛in and they can be used over the frequency band zero to 12GHz with a maximum v.s.w.r. of 1.25 up to 4GHz. Values available are 3, 6, 10 and 20dB at an accuracy of ±0.5dB at 1GHz, or 5%. Aspen Electronics Ltd, 2 Kildare Close, Eastcote, Middlesex HA4 9UW.
WW 313 for further details

R and C decade units

Pocket-sized resistance and capacitance substitution units are now available from Electronic Services and Products Ltd, who have been appointed the sole UK agents. The Mini-Ω-decade unit, 10×25×3cm, provides ½W 1% accuracy resistors ranging from 1Ω to 10MΩ and the Mini-C-decade unit, measuring 10 ×15 ×4cm, has a capacitance range from 100pF to 11μF with a 5% accuracy. Both units are housed in aluminium cases. Electronic Services and Products Ltd, Cross Lane, Braunston, Daventry, Northants NN11 7HH.
WW 314 for further details

Frequency counter

Telford Communications frequency meter, model TC12, has a frequency stability of 0.005% between 0 and 60°C, and not 0.05% as mentioned in our September issue, page 92. This unit is priced at £140.40 inclusive of v.a.t. (crystal oven and l.e.d. displays to order). Readers may have noticed the error in the advertisement in that issue, for which we apologise.
WW 315 for further details

Solid State Devices

Microwave coax detectors

Two miniature microwave-detectors, from Hewlett Packard, are coaxial diode modules designed for measurement applications. The detectors are packaged for rugged environments and can be replaced in the field. One detector, the 33330B, covers the range 0.01 to 18GHz, has a flat response of ±0.3dB to 12.4GHz and ±0.6dB to 18GHz and a s.w.r. of less than 1.5. The 33330C has the same specifications up to 18GHz but its response from 18 to 26.5GHz follows a 4dB slope within ±1dB and the s.w.r. is no greater than 2.

At the input of each of the above detectors is an APC3.5 precision connector which is compatible with SMA-series hardware and is claimed to be capable of reliable reconnection even after 1000 connections.
WW 316 for further details

Schottky l.s.i. devices

The AM2901 and the AM2909 are low-power Schottky l.s.i. devices from Raytheon Semiconductor. Each device in the AM2900 series has a 100ns cycle time and is fully compatible with the AMD series.

The AM2901, which is a 4-bit slice c.p.u. that is expandable in 4-bit increments, consists of a 16-word by 4-bit two-part r.a.m., a high-speed arithmetic logic unit with 8 functions and associated shifting, decoding and multiplexing circuitry. A 9-bit instruction word is organized into three groups of 3-bits each and selects the source operators, the logic function and the destination register. The device has 3-state outputs and provides various status flag outputs from the logic unit.

The AM2909 is a 4-bit expandable address controller intended for sequencing through a series of instructions contained in r.o.m. or p.r.o.m. The present address can be taken from the address register, direct data inputs, a four-word deep stack or from the programme counter. Each of the four 3-state outputs can be ORed with an external input and a separate line can force all of the outputs to zeros.
WW 317 for further details

C.m.o.s. analogue switches

A family of monolithic c.m.o.s. analogue switches, from Analog Devices Ltd, eliminates s.c.r. latching phenomena by dielectric isolation and provides over-voltage protection for analogue inputs up to ±25V greater than the power supply voltages by switching in a series 1kΩ resistor. Automatic removal of this resistance allows the switch to operate normally and exhibit a low on-resistance. Types AD7510DI and AD7511DI have inverter logic inputs and are quad independent s.p.d.t. switches and type AD7512DI is a dual s.p.d.t. switch. Each type features an on-resistance of 75Ω, a low leakage current of 400pA, a switching speed of 350ns, a low power dissipation of 3mW and t.t.l./c.m.o.s. interfacing.
WW 318 for further details

WW 314

Real and Imaginary

by "Vector"

OUR RESPONSIBILITY

AS I write, the time of the end-of-term school report is upon us; that moment of truth when a battered envelope is resurrected from Junior's satchel and torn open to reveal the candid comments of those who labour mightily towards the education of our young.

We deal with our erring offspring according to our several lights, ranging from the eyeball-to-eyeball frank exchange of views to the more direct slipper-on-the-posterior approach and thereby we assuage to some extent our injured pride at having begotten such dullards. But when we ourselves arrive at our own end-of-term and the gold watch for long service has been presented, what, I wonder, will our own report be like? I don't mean the deputy-manager's laudatory little speech as the timepiece is handed over. All of us who, as subscribers, have been invited to these macabre little ceremonies, know the poetic licence that can be taken on these occasions. No — I mean the report which is written only in our own consciences.

Who can say? For, being individuals, we have differing standards. All of us, from primary school onwards, are conditioned to the unwritten law that material gain is the metre-stick of success and those who have never thrown off those particular blinkers will consider their report written in terms of their bank balance.

Others may rest content in the contemplation of a lifetime spent in honest effort at whatever tasks have been set them. But I know of a growing number — many far from retiring age — who, possessed of social consciences, are expressing disquiet at the uses to which the equipments they handle are being put.

Guglielmo Marconi, towards the end of his life, put his finger exactly on the pulse when he asked "Have I done the world good or have I added a menace?" For wireless, which had begun life as a saviour of life at sea, had, even by the 1930s, diversified into many other channels of application, notably in terms of warfare. Marconi, even at that time, could see that the whole thing was getting out of hand.

Today the use of electronics for lethal purposes has increased by several orders of magnitude. Seven countries are now thought to possess a nuclear capability in their own right, while many more have nuclear warheads supplied to them. There are other even more terrible weapons, lying under their security wraps against the day, the whole brood being contained in the generic title ABC (Atomic, Biological and Chemical). All of them depend on electronics in their delivery systems at least and we may have been involved in their manufacture unwittingly, for the ultimate purpose of such black boxes is not noised abroad.

The problem of engineering conscience can become acute in areas of manufacture where the bulk of the company's contracts are for military equipment — radars, gun-laying devices, complete weapon-control systems and so on. The obvious argument is that anyone who feels guilty at working on such devices has no business to be there anyway. But the issue is by no means as simple as that; he may, for instance, have been transferred from some innocuous area within a company to one where military work is performed.

Again, a man may have joined the company at a period when he had no scruples about the nature of the work. Then, maybe many years later, something happens — a religious experience perhaps, but not necessarily so — to alter his outlook radically. By this time he has probably acquired a wife, children, a mortgage, a car and sundry h.p. commitments. Jobs are not so easily come by and, if he is over forty, virtually impossible to obtain. So where does his duty lie? Towards his family? Or towards his convictions? It is not for us to pass judgement on whether he should bring his family to poverty and preserve his moral integrity or continue at his work and try to stifle his conscience. Whichever decision he takes he will involve acute mental stress and probably a breakdown.

But the majority of us somehow continue to live with the situation, probably because everyday problems keep us so occupied that we have no time to think of anything else. Or if we do, we console ourselves with the thought that the "Other Side" (whoever they might be) are turning out weapons, so it is our duty to do likewise. Certainly we would not dream of pressing the button to send thousands of men, women and children to smithereens, but then, we're sitting in a factory or peaceful research lab. assembling or redesigning a black box, so we don't have to.

Some of us may not even think as far as that. To many, research, in particular, is a game of wits. You are presented with a technical problem which, at first thought, seems impossible of solution. You exercise all your ingenuity and sometimes you win and sometimes you don't. The ultimate purpose of whatever you're trying to design is of minor consequence. It's whether you bring it off or not that counts. The situation in both instances is analogous to a domestic vignette. Relatively few of us would eat steak if we had to split open a steer and watch its life's blood pouring down a drain. By the same token a lot of us would become queasy about those clever little black boxes we hatch up if we were forcibly taken to view at first hand the carnage and to smell the stench which are the logical end products of a weapon-delivery system.

There is a growing conviction that scientists, physicists and engineers must bear full responsibility for their actions and for the devices they perpetrate. Which is as it should be, for the electronic engineering profession is one of the world's greatest forces for good as well as evil. The recent landing on Mars is an example of electronicis at its best; the ABC weapons an example of it at its worst. Probably the circuitry used in both cases is not all that dissimilar; the problem, perhaps not yet fully grasped, is that technology represents the ultimate in anarchy for there is nothing or no-one at its head to say "yea" in the one instance and "nay" in the other.

Some years ago now the world screamed in horror at the drug Thalidomide being put on the market without adequate investigation into its possible side effects. The outcome was horrible enough in all conscience. Yet, daily, new electronic devices are introduced which, although innocuous in themselves, can form an integral part of mechanisms for world annihilation, against which the Thalidomide disaster seems insignificant.

So what is to be done? I'll throw that to the meeting while I duck out, leaving you with one or two tentative thoughts. One is that the modern world is completely and utterly dependent upon electronics for its functioning and an international federation of electronics engineers would exercise considerable authority. Unfortunately, no such world brotherhood exists and it seems unlikely that it ever will. The other thought is that the United Nations, and particularly the USSR and the USA, have spent years haggling over which categories of weapons should be banned and which should not. It seems to me if they would prohibit the use of electronic circuitry in all ABC weapons systems the matter would solve itself, for without these the whole arsenal would be just so much ironmongery. Life could be much simpler and, no doubt, considerably longer.

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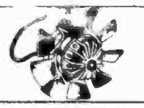

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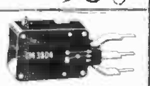

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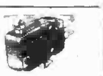

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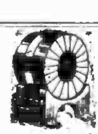

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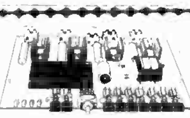

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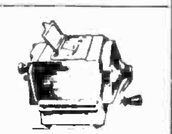

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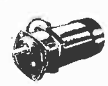

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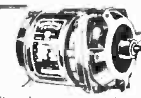
100 R.P.M. 115 lbs. ins.!! 115 lb. ins. 110 volt. 50Hz. 2.8 amp. single phase, split capacitor motor. Immense power. Continuously rated. Totally enclosed. Fan cooled. In-line gearbox. Length 250mm. Dia. 135mm. Spindle Dia. 15.5mm. Length 145mm. ex-equipment tested **£12.00.** Post £1.50. Suitable transformer 230/240 volt **£8.00.** Post 75p.

15 R.P.M. Type SD48 15 r.p.m. 80 lb. ins. Input 100/120 volt A.C. Length incl. gearbox 270mm. Height 135mm. Width 150mm. Shaft drive 16mm. Weight 8.5 Kilos. BRAND NEW. Price **£10.00,** carr. £1.00. Suitable transformer for use on 220/240 volt A.C. **£3.85.** Post 50p.

60 R.P.M. REVERSIBLE 220/240 volt A.C. Small, powerful, continuously rated motor. Mfg. BERGER (Germany). Size 80mm x 65mm x 65mm. Spindle dia. 6mm. Length 15mm. Weight 725 grams. **£6.50.** Post 50p.



BODINE TYPE N.C.I. GEARED MOTOR **(Type 1) 71 r.p.m.** torque 10 lb. in. **Reversible** 1/70th h.p. cycle 38 amp. **(Type 2) 28 r.p.m.** torque 20 lb. in. **Reversible** 1/80th h.p. 50 cycle 28 amp. The above two precision made U.S.A. motors are offered in as new condition. Input voltage of motor 115v **A.C.** Supplied complete with transformer for **230/240v A.C. input.** Price either type **£6.25.** Post 75p or less transformer **£3.75.** Post 65p.

(Type 3) 71 r.p.m. 230 Volt A.C. **Continuously rated. Non reversible. £6.50** Post 75p.

6/9 VOLT D.C. GOVERNED 40mm x 40mm. Spindle 10mm. Dia. 2 mm. **£1.00** Post Paid. Two for **£1.65** Post Paid

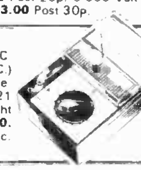
24 R.P.M. 230 volt A.C. Continuously rated. Mfg. Mycalex Ex-equip. Fully tested **£3.85** Post 75p.

1 R.P.M. 230/240 VOLT A.C. SYNCHRONOUS!! Ex-equipment. Thoroughly tested and guaranteed. **ONLY £1.50** Post 20p.

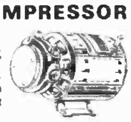
20 r.p.m. GEARED MOTOR 230/240 volt 20 r.p.m. motor **£1.00.** Post 20p.

REVERSIBLE MOTOR 230V A.C. General Electric 230v A.C. 1,600 r.p.m. 0.25 amp. Complete with anti-vibration mounting bracket and capacitor. O/A size 110mm x 95mm. Spindle 5/16" dia. 20mm long. Ex-equipment tested. **£3.00.** Post 50p

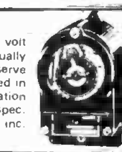
METERS NEW 90mm Diameter **Type: 65CS** D.C. M/C. 2, 5, 10, 20, 50 amp. **£2.75.** Post 20p. 100 amp **£3.25.** Post 20p. **Type: 62T2** A.C. M/I. 1, 20, 50 amp. **£2.50** Post 20p. 0-300 Volt A.C. M/I **£2.75** and 300 Volt A.C. R/M/C. **£3.00** Post 30p.



WHY PAY MORE?! MULTI RANGE METER. A.C. volts 2.5-500 D.C. volts 2.5-500 (Sensitivity 2000Ω/V D.C. & A.C.) D.C. current 0/1/10/100 mA. Ohms range. Sturdy compact moving coil instrument with 21 ranges, dimensions 120 x 80 x 44mm. Weight 0.32 kg. SERVICE TRADING CO. Price **£5.00.** Incl. leads and battery. Post 50p (Total price inc. VAT & Post **£5.94**).



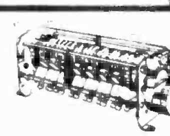
ROTARY VACUUM AIR COMPRESSOR AND PUMP Carbon vane, oil-less 100/115V A.C. 1/12 h.p. motor 50/60 cycle. 2875/3450 r.p.m. 20" vacuum 1.25 c.f.m. 10 p.s.i. (approx figures). New unused surplus stock with elect connection data. Fraction of maker's price. **£12.00.** Post £1.00. Suitable transformer **£3.50.** Post 50p.



TIME SWITCH Horstmann Type V Mk II Time Switch. 200/250 volt A.C. Two on/two off every 24 hours, at any manually pre-set time. 30 amp contacts. 36-hour spring reserve in case of power failure. Day omitting device. Fitted in heavy high impact case, with glass observation window. Built to highest Electricity Board spec. Individually tested. Price **£7.75.** Post 50p (Total inc. VAT £8.91).

A.C. MAINS TIMER UNIT Based on an electric clock, with 25 amp. single-pole switch, which can be preset for any period up to 12 hrs. ahead to switch on for any length of time, from 10 mins. to 6 hrs. then switch off. An additional 60 min. audible timer is also incorporated. Ideal for Tape Recorders, Lights, Electric Blankets etc. Attractive satin copper finish. Size 135 mm x 130 mm x 60 mm. Price **£2.25.** Post 40p. (Total inc. VAT & Post **£2.87**).

POWER RHEOSTATS New ceramic construction, vitreous enamel embedded winding, heavy duty brush assembly, continuously rated.
25 WATT 10, 25, 100, 150, 250, 500, 1k, 1.5k ohm **£1.90.** Post 20p. **50 WATT** 1, 5, 10, 25, 50, 100, 500, 1k ohm **£2.40.** Post 25p. **100 WATT** 1/5/10/25/50/100/250/500/1k, 1.5k/2.5k/5k ohm. **£3.70.** Post 35p.
Black Silver Skirted knob calibrated in Nos. 1-9. 1½ in. dia brass bush. Ideal for above Rheostats **22p ea.**



PROGRAMME TIMERS 230 Volt AC Operation. 15 or 20 r.p.m. Each cam operates a c/o micro switch. Ideal for lighting effects, displays, etc. Ex equip tested. Similiar to illustration.
9 CAM model **£5.00**
9 CAM model **£6.50**
12 CAM model **£7.50**
Post 60p. Also available for 50 volt A.C. operation. Prices as above.

SERVICE TRADING CO.

ALL MAIL ORDERS, ALSO CALLERS AT: 57 BRIDGMAN ROAD, CHISWICK, LONDON, W4 5BB. Phone: 01-995 1560 *Closed Saturdays.*

SHOWROOMS NOW OPEN. AMPLE PARKING

PERSONAL CALLERS ONLY 9 LITTLE NEWPORT STREET LONDON, WC2H 7JJ. *Tel.: 01-437 0576*

RETURN OF POST MAIL ORDER SERVICE

BSR HI-FI AUTOCHANGER

STEREO AND MONO

Plays 12", 10" or 7" records. Auto or Manual. A high quality unit backed by BSR reliability with 12 months' guarantee. A.C. 200/250V. Size 13½-11¼in. 3 speeds. Above motor board 3¾in. Below motor board 2½in. with STEREO and MONO CARTRIDGE **£10.25** Post 75p

B.S.R. SINGLE PLAYER similar to MP60 with stereo cartridge and cueing device **£15.50**

PORTABLE PLAYER CABINET

Modern design. Rexine covered. Vynair front grille. Chrome fittings Size 17 x 15 x 8in. approx. **£4.50** Post 50p

Motor board cut for BSR or Garrard deck

HEAVY METAL PLINTHS

With P.V.C. Cover. Cut out for most B.S.R or Garrard decks. Silver grey finish

Model "A" Size 12½ x 14¾ x 7½in. **£5.50**

Model "B" Size 16 x 13¾ x 7in. **£6.95.** Post 75p.

COMPLETE STEREO SYSTEM

Two full size loudspeakers 13¾ x 10 x 3¾in Player unit clips to loudspeakers making it extremely compact, overall size only 13¾ x 10 x 8½in., 3 watts per channel, plays all records 33 r.p.m., 45 r.p.m. Separate volume and tone controls. Attractive teak finish. 240V a.c. mains. **£22.50** £1 carriage

SPECIAL OFFER!
SMITH'S CLOCKWORK 15 AMP TIME SWITCH
0—60 MINUTES £2.95 Post 35p

Single pole two-way. Surface mounting with fixing screws. Will replace existing wall switch to give light for return home, garage, automatic anti-burglar lights, etc. Variable knob. Turn on or off at full or intermediate settings. Brand new and fully guaranteed.

TEAKWOOD LOUDSPEAKER GRILLES will easily fit to baffle board. Size 10½ x 7⅞in—**45p.**

R.C.S. "MINOR" 10 watt AMPLIFIER KIT

This kit is suitable for record players, guitars, tape playback, electronic instruments or small P.A. systems. Two versions available: Mono, **£11.25**; Stereo, **£18.** Post 45p. Specification 10W per channel; input 100mV; size 9½ x 3 x 2in. approx. S.A.E. details. Full instructions supplied. AC mains powered.

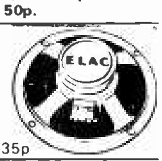
VOLUME CONTROLS

5kΩ to 2MΩ LOG or LIN.
L/S **25p.** D.P. **40p**
STEREO **L/S 55p.** D.P. **75p**
Edge 5K S.P. Transistor **30p**

80 Ohm Coax 8p yd.

STANDARD TYPE VHF FRINGE LOW LOSS **15p yd.** Ideal 625 and colour
PLUGS **10p.** SOCKETS **10p.**
LINE SOCKETS **18p.** OUTLET BOXES **50p.**

ELAC HI-FI SPEAKER 8in. TWIN CONE



Dual cone plasticised roll surround Large ceramic magnet. 50-16,000 c/s Bass resonance 55 c/s 8 ohm impedance. 10 watts. music power. **£3.95** Post 35p

E.M.I. 13½ x 8in. SPEAKER SALE!

With tweeter and crossover 10 watt State 3 or 8 ohm As illustrated. **£5.25** Post 35p

Bass Woofer. 15 watts. 8 or 15 ohm **£6.95** Post 45p

With tweeter and cross-over 20 watt Bass res 25 c p s Flux = 11,000 gauss. 8 or 15 ohm 20 to 20,000 c.p s **£8.95** Post 45p

Bookshelf Cabinet

Teak finish, for EMI 13 x 8 speakers **£6.95** Post 75p

THE "INSTANT" BULK TAPE ERASER AND HEAD DEMAGNETISER. Suitable for cassettes, and all sizes of tape reels A C mains 200/250V Leaflet S A E Will also demagnetise small tools **£4.35** Post 30p

BLANK ALUMINIUM CHASSIS. 6 x 4 **-70p**; 8 x 6**--90p**; 10 x 7**—£1.15**; 12 x 8**—£1.35**; 14 x 9**—£1.50**; 16 x 6**—£1.45**; 16 x 10**—£1.70.**

ALUMINIUM PANELS. 6 x 4**—17p**; 8 x 6**—24p**; 14 x 3**—25p**; 10 x 7**—35p**; 12 x 8**—43p**; 12 x 5**—30p**; 16 x 6 **-43p**; 14 x 9**—52p**; 12 x 12**—68p**; 16 x 10**—75p.**

ELAC 9 x 5in HI-FI SPEAKER TYPE 59RM **£3.45** Post 35p
This famous unit now available. 10 watts. 8 ohm

RCS LOW VOLTAGE STABILISED POWER PACK KITS

All parts and instructions with Zener diode, printed circuit rectifiers and double wound mains transformer. Input 200/240V a.c Output voltages available, 6 or 7.5 or 9 or 12V d.c. up to 100mA or less. Size 3 x 2½ x 1½in. Please state voltage required. **£2.95** Post 45p

RCS POWER PACK KIT **£3.35**
12 VOLT, 750mA. Complete with printed circuit board and assembly instructions. Post 30p
12 VOLT 300mA KIT. **£3.15.** 9 VOLT 1 AMP KIT, **£3.35.**

R.C.S. GENERAL PURPOSE TRANSISTOR PRE-AMPLIFIER — BRITISH MADE

Ideal for Mike, Tape, P.U., Guitar, etc Can be used with Battery 9-12V or H T. line 200-300V d.c. operation. Size: 1¾ x 1¼ x ¾in. Response 25 c/s to 25 kc/s 26 dB gain For use with valve or transistor equipment Full instructions supplied. Details S.A.E. **£1.45** Post 30p

ELECTRO MAGNETIC PENDULUM MECHANISM

1.5V d c. operation over 300 hours continuous on SP2 battery, fully adjustable swing and speed Ideal displays, teaching electro magnetism or for metronome, strobe, etc. **95p** Post 30p

MAINS TRANSFORMERS

ALL POST 50p

250-0-250V 70mA, 6.5V, 2A	**£3.45**
250-0-250 80mA, 6.3V 3.5A, 6 3V 1A or 5V 2A	**£4.60**
350-0-350 80mA, 6.3V 3.5A, 6.3V 1A or 5V 2A	**£5.80**
300-0-300V 120mA, 6 3V 4A C T ; 6 3V 2A	**£7.00**
MIDGET 220V 45mA, 6.3V 2A	**£1.75**
HEATED TRANS. 6.3V ½ amp **£1**; 3 amp	**£1.40**

GENERAL PURPOSE LOW VOLTAGE. Tapped outputs at 2 amp. 3, 4, 5, 6, 8, 9, 10, 12, 15, 18, 25 and 30V **£4.60.** 1 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60 **£4.60.** 2 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60 **£7.00.** 3 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60 **£8.70.** 5 amp. 6, 8, 10, 12, 16, 18, 20, 24, 30, 36, 40, 48, 60 **£11.25.** 6.06V 500mA **£1**, 9V 1 amp. **£1**, 12V 300mA, **£1**, 12V 500mA, **£1**, 12V 750mA, **£1**, 10V, 30V, 40V, 2 amp., **£2.75**, 20V, 3 amp, **£2.45**, 40V, 2 amp., **£2.95**, 30V 5A and 34V 2ACT **£3.45**, 16V, ½ amp. **£1**, 16V, 2 amp., **£2.20**, 0, 5, 8, 10, 16V. ½ amp , **£1.95**, 20V ½ amp , **£1.75**, 20V. 1 amp **£2.20**, 20V 3 amp , **£2.50**, 20-0-20V 1 amp **£2.95**, 30V 1½ amp. **£2.75.** 20v, 40v, 60v, 1A, **£3.50**

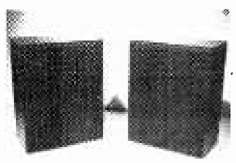
AUTO TRANSFORMERS, 115V to 230V or 230V to 115V 150W **£5**; 250W **£6**; 400W **£7**; 500W **£8.**

FULL WAVE BRIDGE CHARGER RECTIFIERS 6 or 12V outputs, 1½ amp **40p**; 2 amp **55p**; 4 amp **85p.**

CHARGER TRANSFORMERS. 1½ amp **£2.75**; 4 amp. **£4.60.**

12V. 1½A HALF WAVE Selenium Rectifier. **25p.**

R.C.S. ROSEWOOD SPEAKERS



Size 12½in. x 9¾in. x 5½in. Response 50 to 14,000 cps 8 watts rms 3, or 8, or 16 ohms.
£12 pair Post 75p.

KUBA - KOPENHAGEN STEREO

TUNER-AMPLIFIER CHASSIS AM-FM 5+5 WATT

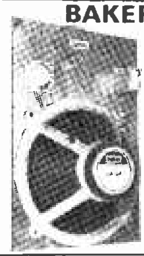
This Continental 4-band radiogram chassis uses first class quality components throughout Features Large facia panel with 7 push buttons for medium, long, short, VHF-FM, AFC, phono, mains on-off. 4-rotary controls, tuning, volume, tone, balance. Facia size 17 x 4½ inches. Chassis size 17 x 4½ x 5½ inches. DIN-connector sockets for tape record/playback, loudspeakers, phono pick-up, external FM-AM aerials. Automatic stereo beacon light. Built-in ferrite rod aerial for medium/longwave. A.C. 240V. mains. Circuit supplied. **£38.50** Post £1.50

LOW VOLTAGE ELECTROLYTICS

1, 2, 4, 5, 8, 16, 25, 30, 50, 100, 200mF 15V **10p.**
500mF 12V **15p**; 25V **20p**; 50V **30p.**
1000mF 12V **17p**; 25V **35p**; 50V **47p**; 100V **70p.**
2000mF 6V **25p**; 25V **42p**; 50V **57p.**
2500mF 50V **62p**; 3000mF 25V **47p**; 50V **65p.**
5000mF 6V **25p**; 12V **42p**; 25V **75p**; 35V **85p**; 50V **95p.**

SHORT WAVE 100pF air spaced gangable tuner. **95p.**
TRIMMERS 10pF, 30pF, 50pF, **5p.** 100pF, 150pF, **15p.**
CERAMIC, 1pF to 0.01mF, **5p.** Silver Mica 2 to 5000pF. **5p.**
PAPER 350V-0.1 **7p**; 0.5 **13p**; 1mF 150V **15p**; 2mF 150V **15p**; 500V-0.001 to 0.05 **5p**; 0.1 **10p**; 0.25 **13p**; 0 47 **25p.**
MICRO SWITCH SINGLE POLE CHANGEOVER 20p.
SUB-MIN MICRO SWITCH, 25p. Single pole change over
TWIN GANG, 385 + 385pF **50p**; 500pF standard **75p**; 365 + 365 + 25 + 25pF Slow motion drive **65p.**
120pF **TWIN GANG, 50p**; 365pF **TWIN GANG, 50p.**
NEON PANEL INDICATORS 250V. Amber or red **30p.**
RESISTORS. ¼W, ½W, 1W, 20% **2p**; 2W, **10p**; 10Ω to 10M
HIGH STABILITY. ½W 2% 10 ohms to 6 meg **12p.**
Ditto 5% Preferred values 10 ohms to 10 meg . **5p.**
WIRE-WOUND RESISTORS 5 watt, 10 watt, 15watt, 10 ohms to 100K **12p** each.
TAPE OSCILLATOR COIL. Valve type, **35p.**
BRIDGE RECTIFIER 200V PIV ½ amp **50p.**
TOGGLE SWITCHES S.P **20p.** D P S.T **25p.** D P D T **30p.**
MANY OTHER TOGGLES IN STOCK.

BAKER MAJOR 12" £10.35



30-14,500 c/s, 12in. double cone, woofer and tweeter cone together with a BAKER ceramic magnet assembly having a flux density of 14,000 gauss and a total flux of 145,000 Maxwells. Bass resonance 40 c/s. Rated 25W. NOTE 3 or 8 or 15 ohms must be stated.

Module kit, 30-17,000 c/s with tweeter, crossover, baffle and instructions. **£13** Post 60p each
Please state 3 or 8 or 15 ohms.

BAKER "BIG-SOUND" SPEAKERS. Post 50p each.

'Group 25'	'Group 35'	'Group 50/15'
12in 30W **£8.95**	12in. 40W **£10.50**	15in. 75W **£19.50**
3 or 8 or 15 ohm	3 or 8 or 15 ohm	8 or 15 ohm

BAKER LOUDSPEAKER, 12IN. 60 WATT GROUP 50/12, 8 OR 15 OHM HIGH POWER.
FULL RANGE PROFESSIONAL QUALITY. 30-16,000 CPS MASSIVE CERAMIC MAGNET WITH ALUMINIUM PRESENCE CENTRE DOME **£14.50** Post 80p

TEAK VENEERED HI-FI SPEAKERS AND CABINETS
For 12in. or 10in speaker 20x13x12in. **£12.50** Post 95p
For 13 x 8in. or 8in. speaker . . . . . . **£6.95** Post 75p
For 8x5in. speaker 12x8x6in. . . . . **£4.95** Post 50p
LOUDSPEAKER CABINET WADDING 18in. wide . . **20p** ft.

R.C.S. 100 watt VALVE AMPLIFIER CHASSIS

Four inputs. Four way mixing, master volume, treble and bass controls. Suits all speakers This professional quality amplifier chassis is suitable for all groups, disco, P A , where high quality power is required. 5 speaker outputs. A/C mains operated. Slave output socket. Produced by demand for a quality valve amplifier. 100V line output to order. Send for leaflet. Suitable carrying cab **£14.** Price **£85** carr. £2.50

SPEAKER COVERING MATERIALS. Samples Large S.A.E.
Horn Tweeters 2-16kc/s. 10W 8 ohm or 15 ohm **£3.60**
De Luxe Horn Tweeters 3-18kc/s, 30W, 8 ohm, **£7.50.**
CROSSOVERS. TWO-WAY 3000 c/s 3 or 8 or 15 ohm **£1.90.** 3-way 950 cps/3000 cps, **£2.20.**
LOUDSPEAKERS P.M. 3 OHMS. 7x4in. **£1.50**; 6½in., **£1.80**; 8x5in., **£1.90**; 8in , **£1.95.**
SPECIAL OFFER: 80 ohm 2¼in , 2¾in., 35 ohm, 3in., 25 ohm, 2½in dia , 3in dia , 5x3in. 8 ohm, 2½in., 3in., 3½in., 5in , 15 ohm, 3½in. dia, 6x4in., 7x4in., 5x3in , 3 ohm , 2½in., 2⅝in., 3½in , 5in. dia. **£1.25 each.**
PHILIPS LOUDSPEAKER, 8in , 4 ohms, 4 watts, **£1.95**
RICHARD ALLAN TWIN CONE LOUDSPEAKERS
8in. diameter 4W **£2.50.** 10in. diameter 5W **£2.95**; 12in diameter 6W **£3.50.** 3/8/15 ohms, please state.
VALVE OUTPUT TRANS. 40p; MIKE TRANS. 50 1, **40p.**
Mike trans mu metal 100 1 **£1.25.**

Loudspeaker Volume Control 15 ohms 10W with one inch long threaded bush for wood panel mounting. ¼in spindle. **65p.**

BAKER 150 WATT PROFESSIONAL MIXER AMPLIFIER

All purpose transistorised Ideal for Groups, Disco and P A. 4 inputs speech and music. 4 way mixing. Output 4 8/15 ohms, a.c. Mains. Separate treble and bass controls. Master volume control. Guaranteed Details S A.E **£68** £1 00 Carr.

NEW MODEL MAJOR—50 watt. 4 input. 2 vol Treble and bass. Ideal disco amplifier. **£49.95**

100 WATT DISCO AMPLIFIER CHASSIS
volume, treble, bass controls, 500 M.V. or 1 volt input. Four loudspeaker outputs 4 to 16 ohm. All transistor. **£52**

BARGAIN 4 CHANNEL TRANSISTOR MONO MIXER
Add musical highlights and sound effects to recordings. Will mix Microphone, records, tape and tuner with separate controls into single output. 9V **£5.20**

TWO STEREO CHANNEL VERSION **£6.85**

BARGAIN 3 WATT AMPLIFIER. 4 Transistor Push-Pull Ready Built, with volume, Treble and bass controls 18 volt d.c Mains Power Pack **£3.45** **£3.95**

BALANCED TWIN RIBBON FEEDER 300 ohms. 7p yd.
JACK SOCKET Std. open-circuit 20p, closed circuit 25p; Chrome Lead-Socket 45p. Mono or Stereo.
Phono Plugs 8p. Phono Socket 8p.
JACK PLUGS Std. Chrome 30p; Plastic 25p; 3.5mm 15p.
STEREO JACK PLUG 30p. SOCKET 25p.
DIN SOCKETS Chassis 3-pin 10p. 5-pin 10p.
DIN SOCKETS FREE 3-pin 25p; 5-pin 25p. DIN PLUGS 3-pin 25p; 5-pin 25p. VALVE HOLDERS, 10p; CANS 10p.

R.C.S. SOUND TO LIGHT KIT
Kit of parts to build a 3 channel sound to light unit 1,000 watts per channel **£12.50.** Post 35p.
Easy to build Full instructions supplied Cabinet **£3.**
As featured in December Practical Wireless

E.M.I. TAPE MOTORS. 120V a c., 1,200 r p m 4 pole Spindle 0.187 x 0.75in. Size 3¼ x 2½ x 2¼. **£1.** Post 40p.
Collaro gram motor 120V **75p.**

RADIO COMPONENT SPECIALISTS

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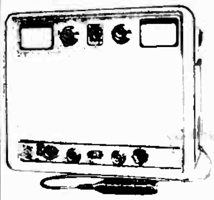

MARCONI TF 867 SIGNAL GENERATOR
Range: 15KHz to 30MHz Output 0.4µV to 4V at 13 or 75 ohms. Impedance with termination (supplied). Built in crystal check facility with handbook. **£138** including carriage.

HEWLETT-PACKARD AUDIO GENERATOR MODEL 206-A. Freq 20c to 20.000c. matching impedance 50. 150. 600 ohms. Price **£85.00** carriage £4.00
OSCILLOSCOPES 175A with 1750A dual trace vertically plug-in and 1781B delay time base plug-in. 50MHz mini-meter band switch at 50 Mv/CM Modes of operation. Single, mixed. delaying. Full spec and price on application

DIVERSITY SWITCH TYPE MA168B. Solid state **£45.00.**
REDIFON SSB TRANSMITTER/RECEIVER TYPE GR410. Full particulars and price on request
SOLOTRON REGULATED PSU MODEL SRS 152. 0 170v DC to 200mA. 160-340v 330-500v and AC 6.3v 5 amp **£35.00.** Carriage £5.00.

RACAL RECEIVERS MODELS. RA17. in fully working and tuned condition. Prices on application RA98A ADAPTOR **£85.00.**
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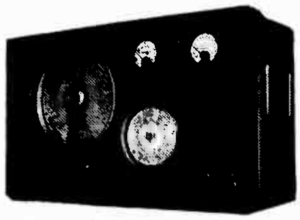

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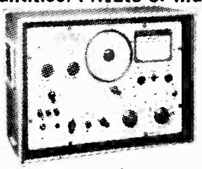

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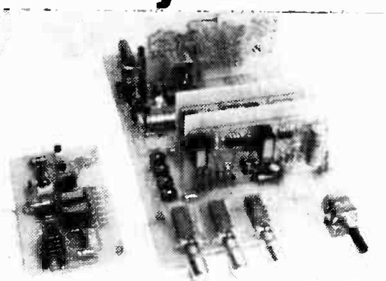

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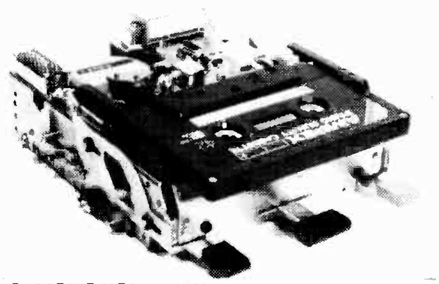

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BF198	23	2N3702	12
BF199	25	2N3703	12
BF200	28	2N3704	10
BF218	40	2N3705	10
BF224	20	2N3706	10
BF240	17	2N3819	38
BF241	17	2N5296	40
BF257	28	2N5496	53
BF258	26	OC71	29
BF259	30	OC72	29
BF336	37	R2008B	£1.90
BF337	35	R2010B	£1.90
BF338	34	RCA16334	80
BF355	50	RCA16335	80

Semi Conductors

Type	Price (p)	Type	Price (p)
S2802	£2.99	TIP32A	62
S6080 A KIT		TIP41A	60
	£4.90	TIP42A	75
TIP31A	52	TIS91	27

★20p or less. Minimum 5 items

Diodes

Type	Price (p)	Type	Price (p)
BA115	9	OA47	8
BA145	16	OA90	6
BA148	16	OA95	5½
BA154/201	12	OA202	8
BA155	15	IN60/OA91	7
BAX13	6	IN914	6
BAX16	6	IN4001	4
BY126	11	IN4002	5
BY127	10	IN4003	5
BY199	25	IN4004	5
BY206	17	IN4005	5
BY238	25	IN4007	6
BYX10	14	IN4148	4

★20p or less. Minimum 5 items

EHT Multipliers

Type	Chassis	Price
2DAK	1500 (17" x 19")	£1.85
2TQ	950MK2 1400	£2.05
2TAK	1500 (23" x 24")	£2.05
11TAQ	ITT CVC 1, 2 & 3	£5.10
ITN	GEC Sobell	£4.50
IITAZ	GEC 2110	£4.50
IITAM	Philips G8	£4.50
IITBD	Philips 550	£4.65
3TCW	Pye 691/693	£3.49
ITH	Decca 30 Series	£4.60
3TCU	Thorn 3000/3500	£5.00
11HAA	Thorn 8000	£1.99
11HAB	Thorn 8500	£4.31
IITCP	Bush 823	£5.50
TVKI	Korting	£4.39

New B & W Tubes

Screen Size	Type	Price
12"	Toshiba E2117A	£17.75
14"	Toshiba M6529 FZP	£17.95
20"	CME 2013	£15.50
24"	CME 2413	£17.30

New Colour Tubes

Screen Size	Type	Equivalent	Price
19"	A49-191X,	A49-192 and A49-120X	£57.70
20"	510DJB22,	A51-110X	£61.35
22"	A56/120X		£61.50

Distributors

Contact your local distributor for fast local service.

Regular calls arranged to meet your requirements.

SCOTLAND

Elcomatic Ltd.
Kirktonfield Road,
Neilston, Glasgow GT8 3PL
Tel. 041-881 5825

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Electronic Sales
(Ulster) Limited,
4 Tates Ave., Lisburn Road,
Belfast BT9 7BY
Tel. Belfast (0232) 668718

LANCASHIRE

Moorside Electrical Co.,
70 Moorside Avenue,
Smithills
Bolton. Tel. 0204 40918

MERSEYSIDE, CHESHIRE SALOP, STAFFS.

Ribble Electronics,
Rear 331 Squires Gate Lane,
Blackpool FY4 3RG.
Tel. Blackpool 0253 43612

WALES

Swansea Aerial Co. Ltd.,
Siloh Road,
Landore,
Swansea SA1 2NT
Tel. Swansea 50393/54836

Distributors

WEST MIDLANDS

Geetavision
116 The Park Paling,
Cheylesmore,
Coventry CV3 5LL
Tel. Coventry 56476-503598

EAST ANGLIA

Norwich Electronic Components
16 Denbigh Road,
Norwich. NR2 3AA
Tel. 0603 28625

LONDON & SOUTH EAST

Paul Electrical Ltd.,
250/252 Grand Drive,
Raynes Park,
London. SW20
Tel. 01 542 6546

DORSET HANTS, ISLE OF WIGHT

Double D. Distributors,
16 Highfield Road,
Bournemouth BH9 2SG
Tel. 0202 519562

SOUTH WEST

D. B. Components,
1 Devonshire Street,
Greenbank, Plymouth, Devon
Tel. (0752) 24369

Distributors are still required for the following areas-

1 Yorkshire West & North Humberside Area
2 Yorkshire South Nottingham, Lincoln
3 Leicester, Northants Warwickshire
4 North East
5 Somerset, Avon Gloucester, Wilts.
6 Oxford, Berkshire Buckinghamshire
7 Bedfordshire, Herts

Good people to deal with

COMBINED PRECISION COMPONENTS LTD.

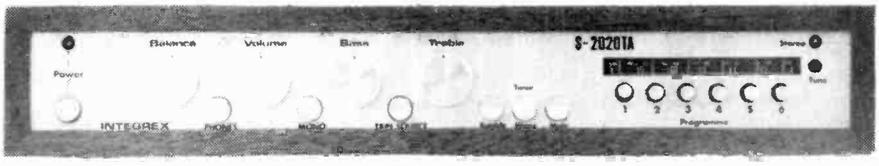
C.P.C., Dept. W. 194-200 NORTH ROAD, PRESTON, LANCASHIRE, ENGLAND
Phone: Preston (STD 0772) 55034. Telex 677122

AROUND THE WORLD EXPORT SERVICE- ask for Robin Pratt **New price list 1.10.76**

INTEGREX

S-2020TA STEREO TUNER/AMPLIFIER KIT

SOLID MAHOGANY CABINET



A high-quality push-button FM Varicap Stereo Tuner combined with a 24W r.m.s. per channel Stereo Amplifier.

Brief Spec. Amplifier: Low field Toroidal transformer, Mag. input, Tape In/Out facility (for noise reduction unit, etc), THD less than 0.1% at 20W into 8 ohms. All sockets, fuses, etc., are PC mounted for ease of assembly. Tuner section: uses Mullard LP1186 module requiring no RF alignment, ceramic IF, INTERSTATION MUTE, and phase-locked IC stereo decoder. LED tuning and stereo indicators. Tuning range 88—104MHz. 30dB mono S/N @ 1.8μV.THD typ. 0.4%

PRICE: £53.95+VAT

NELSON-JONES STEREO FM TUNER KIT

A very high performance tuner with dual gate MOSFET RF and Mixer front end, triple gang varicap tuning, and dual ceramic filter/dual IC IF amp.

Brief Spec. Tuning range 88—104MHz. 20dB mono quieting @ 0.75μV. Image rejection — 70dB. IF rejection—85dB. THD typically 0.4%
IC stabilized PSU and LED tuning indicators. Push-button tuning and AFC unit. Choice of either mono or stereo with a choice of stereo decoders.

Compare this spec. with tuners costing twice the price

Mono £29.15+VAT
With ICPL Decoder £33.42+VAT
With Portus-Haywood Decoder £35.95+VAT

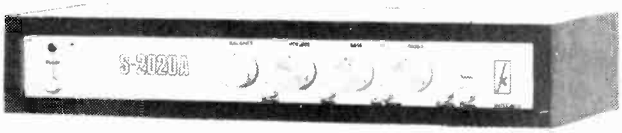
STEREO MODULE TUNER KIT

A low-cost Stereo Tuner based on the Mullard LP1186 RF module requiring no alignment. The IF comprises a ceramic filter and high-performance IC Variable INTERSTATION MUTE. PLL stereo decoder IC

Sens. 30dB S/N mono @ 1.8μV
THD typically 0.4%
Tuning range 88—104MHz
LED sig. strength and stereo indicator

PRICE: Mono £26.85+VAT
Stereo £29.95+VAT

S-2020A AMPLIFIER KIT



Developed in our laboratories from the highly successful "TEXAN" design. PC mounting potentiometers, switches, sockets and fuses are used for ease of assembly and to minimize wiring

Type Spec. 24+24W r.m.s into 8-ohm load at less than 0.1% THD. Mag. PU input S/N 60dB. Radio input S/N 72dB. Headphone output. Tape In/Out facility (for noise reduction unit, etc.). Toroidal mains transformer.

PRICE: £31.95+VAT

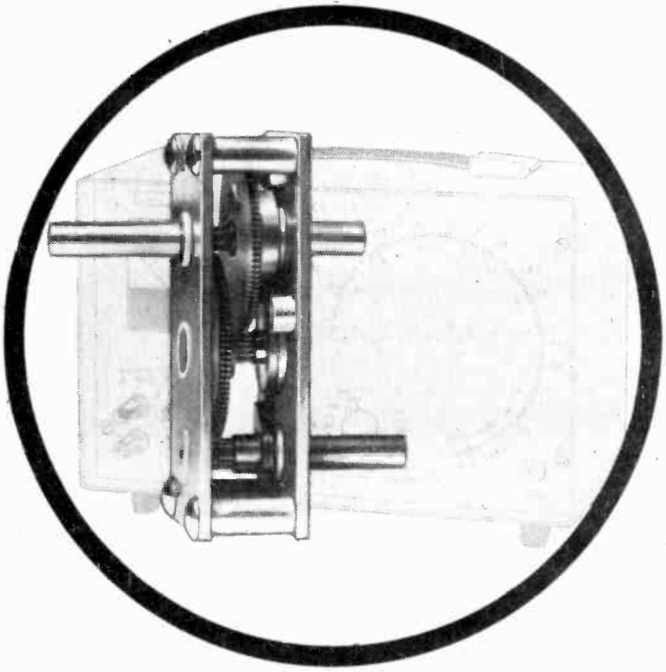
ALL THE ABOVE KITS ARE SUPPLIED COMPLETE WITH ALL METALWORK, SOCKETS, FUSES, NUTS AND BOLTS, KNOBS, FRONT PANELS, SOLID MAHOGANY CABINETS AND COMPREHENSIVE INSTRUCTIONS

BASIC NELSON-JONES TUNER KIT . £14.28+VAT
BASIC MODULE TUNER KIT (Mono) . £14.75+VAT
BASIC MODULE TUNER KIT (stereo) £16.75+VAT

PHASE-LOCKED IC DECODER KIT . . £4.47+VAT
PUSH-BUTTON UNIT . . . . £4.50+VAT

PORTUS-HAYWOOD PHASE-LOCKED STEREO DECODER KIT . . . . **£8.00**+VAT

Ten into one will go.

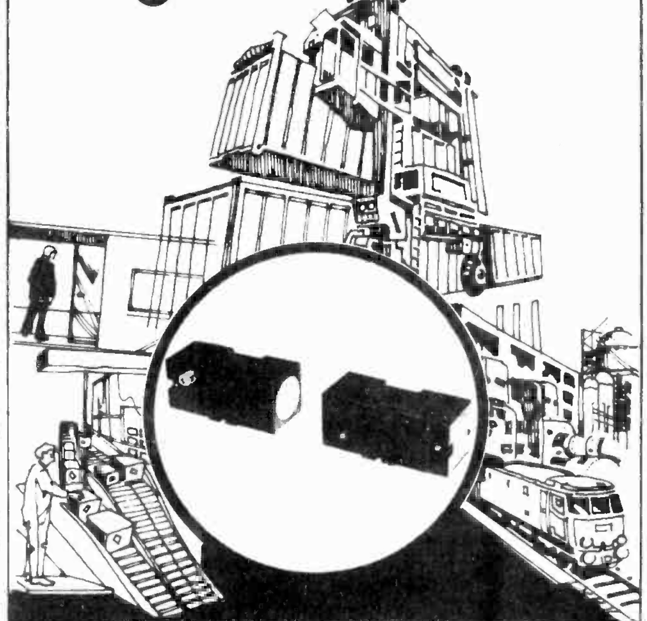


With the precision of the Jackson G10 Gearbox, you get ten turns of input equalling one effective turn of output. This makes the G10 ideal for decimal presentation for analog control. The Gear Box itself is packaged within 70mm by 35mm by 19mm. The output shaft drive torque is greater than 700 gm cms. Input shaft diameters are 6mm. All the gears are fully anti-backlash loaded. The Jackson G10, the compact, versatile gearbox.
All Jackson Products are backed by 50 years' experience in the communications field. Highly skilled men, and Jackson Brothers' good name.

Write for further information to:
JACKSON BROTHERS (LONDON) LIMITED
Kingsway, Waddon, Croydon CR9 4DG
Tel: 01-681 2754/7 Telex 946849
U.S. Office: Swedgal Electronics Inc., 258 Broadway, New York, N.Y. 10007
B.S. 9000 Approved. DEF STAN 05-21.

WW — 066 FOR FURTHER DETAILS

Industrial Action with the JAMES SCOTT INDUSTRIAL microwave range of equipment



The James Scott range of Microwave equipment now offers industrial users a greater choice of alternative systems in robust, industrial, cast aluminium housings, for a wide variety of applications.
The range is made up of standard sub-assemblies which can be permutated to suit Individual application requirements.

Some Suggested Applications for these Units
Level controllers; Proximity alarms; Small object counters; Process control systems; Positioning systems; Door opening systems; Safety barriers; Presence/detectors; Train control systems; Vibration sensing systems; Intruder alarms; Road vehicle systems.
If any of the above are your problems or if you have a particular problem for which we could adapt a system please write or telephone for further information and technical literature to.

JAMES SCOTT (Electronic Engineering) Ltd
CARNTYNE INDUSTRIAL ESTATE
GLASGOW G32 6AB
Tel: 041-778 4206

WW — 029 FOR FURTHER DETAILS

The magnificent nine... an open and closed case for selecting Celestion.

Model	Measurements: Centimetres			Measurements: Inches			Sensitivity Pink Noise W at 1M 90 dB	Power Handling Peak Music	Suggested Amp Watts RMS: Min	Suggested Amp Watts RMS: Max	Frequency Response	
Ditton 11	35	20	25	14	8	10	9.9	25 W	15	30	35 Hz	28 KHz
Ditton 15	53	24	23	21	9	9	4.2	30 W	10	30	30 Hz	15 KHz
Ditton 33	61	35	26	24	14	10	5.5	40 W	20	60	40 Hz	28 KHz
Ditton 44	76	37	25	30	14	10	4.0	44 W	20	50	30 Hz	40 KHz
Ditton 25	81	36	28	32	14	11	2.9	60 W	15	60	20 Hz	40 KHz
Ditton 66	100	38	29	40	15	11	4.8	80 W	20	[illegible]	16 Hz	40 KHz
UL 6	29	41	22	11	16	8	13.0	40 W	20	[illegible]	35 Hz	28 KHz
UL 8	58	28	23	23	11	9	8.4	50 W	15	[illegible]	30 Hz	28 KHz
UL 10	67	31	38	26	12	15	18.0	100 W	25	[illegible]	20 Hz	40 KHz

Celestion

W13

Send this coupon for literature or ask your dealer for a demonstration. I am interested in large, medium, small speakers.

Name ____________________

Address ____________________

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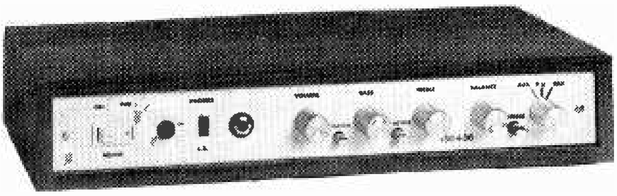
Rola Celestion Ltd., Ditton Works, Foxhall Road, Ipswich, Suffolk IP3 8JP
Telephone: Ipswich (0473) 73131. Cables: Voicecoil Ipswich. Telex: 98365

the sound to be experienced!

Hong Kong Jersey Australia St. Lucia India Barbados Antigua Jordan Spain Israel Mauritius St. Vincent Uganda Ascension Island Malta Sierra Leone Somalia New Guinea Italy Kuwait Netherlands Canada Trinidad Malaya Austria

AUDIO KIT SUPPLIERS TO THE WORLD



T20+20 and our new T30+30 20W, 30W AMPLIFIERS

Designed by Texas engineers and described in Practical Wireless the Texan was an immediate success Now developed further in our laboratories to include a Toroidal transformer and additional improvements, the slimline T20 + 20 delivers 20W per channel of true Hi-Fi at exceptionally low cost The design is based on a single F/Glass PCB and features all the normal facilities found on quality amplifiers, including scratch and rumble filters, adaptable input selector and head phones socket. In a follow up article in Practical Wireless further modifications were suggested and these have been incorporated into the T30 + 30. These include RF interference filters and a tape monitor facility Power output of this new model is 30W per channel.

Pack	T20	T30
1. Set of low noise resistors	1.40	1.50
2. Set of small capacitors	2.20	2.80
3. Set of power supply capacitors	1.90	2.30
4. Set of miscellaneous parts	3.20	3.20
5. Set of slide, mains, P.B. switches	1.20	1.20
6. Set of pots, selector switch	2.80	2.80
7. Set of semiconductors, ICs, skts.	7.25	7.75

Pack	T20	T30
8. Toroidal transformer – 240V prim. e.s. screen	4.95	6.80
9. Fibreglass PCB	3.20	3.60
10. Set of metalwork, fixing parts	4.20	4.80
11. Set of cables, mains lead	0.40	0.40
12. Handbook (free with complete kit)	0.25	0.25
13 Teak cabinet 15.4" x 6.7" x 2.8"	4.50	4.50

SPECIAL PRICES

FOR COMPLETE KITS!

T20+20
KIT PRICE only **£28.25**

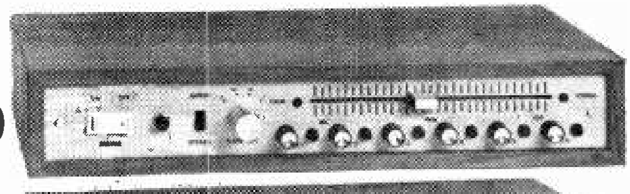
T30+30
KIT PRICE only **£32.95**

2 NEW TUNERS!

WW SFMT II

Following the success of our Wireless World FM Tuner kit we are now pleased to introduce our new cost reduced model, designed to complement the T20 and T30 amplifiers The frequency meter of the more advanced model has been omitted and the mechanics simplified, however the circuitry is identical and this new kit offers most exceptional value for money. Facilities included are switchable afc, adjustable, switchable muting, channel selection by slider or readily adjustable pre-set push-button controls and LED tuning indication Individual pack prices in our free list.

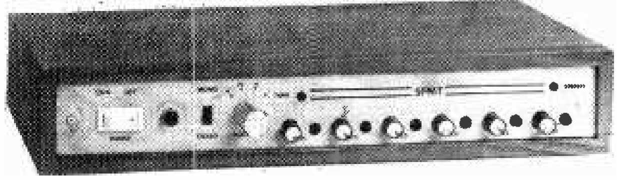
KIT PRICE **£45.50**



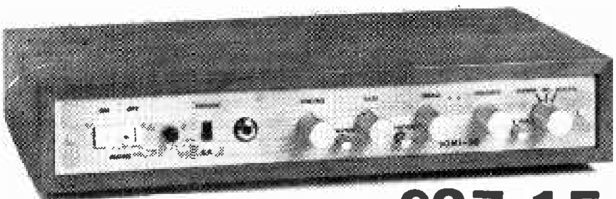
POWERTRAN SFMT

This easy to construct tuner using our own circuit design includes a pre-aligned front end module, PLL stereo decoder, adjustable, switchable muting, switchable afc and push-button channel selection As with all our full kits, all components down to the last nut and bolt are supplied together with full constructional details

KIT PRICE **£32.60**



CONVERT NOW TO QUADRAPHONICS!



SQM1 — 30 KIT PRICE £37.15

With 100s of titles now available no longer is there any problem over suitable software. No problems with hardware either. Our new unit the SQM1-30 simply plugs into the tape monitor socket of your existing amplifier and drives two additional speakers at 30W per channel. A full complement of controls including volume, bass, treble and balance are provided as are comprehensive switching facilities enabling the unit to be used for either front or rear channels, by-passing the decoder for stereo-only use and exchanging left and right channels. The SQ matrix decoder is based upon a single integrated circuit and was designed by CBS whilst the power and tone control sections are identical to those used in our T30 + 30 amplifier which the SQM1-30 matches perfectly Kit price includes CBS licence fee

SQ is a trade mark of CBS Inc

Special offer to T20 + 20 and Texan owners!
Owners of T20 + 20 and Texan amplifiers, which have no tape monitor outlet, purchasing an SQM 1-30 will be supplied on request, a free conversion kit to fit a tape monitoring facility to the existing amplifier. This makes simple the connection to the highly adaptable SQM 1-30 quadrophonic decoder/rear channel amplifier.

Wireless World Amplifier Designs. Full kits are not available for these projects but component packs and PCBs are stocked for the highly regarded Bailey and 20W class AB Linsley Hood designs, together with an efficient regulated power supply of our own design. Suitable for driving these amplifiers is the Bailey Burrows pre-amplifier and our circuit board, for the stereo version of it features 6 inputs, scratch and rumble filters and wide range tone controls which may be either rotary or slider operating For those intending to get the best out of their speakers, we also offer an active filter system, described by D C Read, which splits the output of each channel from the pre-amplifier into three channels each of which is fed to the appropriate speaker by its own power amplifier The Read/Texas 20W, or any of our other kits are suitable for these. For tape systems a set of three PCBs have been prepared for the integrated circuit based, high performance stereo Stuart design Details of component packs are in our free list

30W Bailey Amplifier	
BAIL Pk 1 F/Glass PCB	£1.00
BAIL Pk. 2 Resistors, Capacitors, Potentiometer set	£2.35
BAIL Pk. 3 Semiconductor set	£4.70
20W Linsley Hood Class AB	
LHAB Pk. 1 F/Glass PCB	£1.05
LHAB Pk 2 Resistor, Capacitor, Potentiometer set	£3.20
LHAB Pk 3 Semiconductor set	£3.35
Regulator Power Sypply	
60VS Pk. 1 F/Glass PCB	£0.85
60VS Pk. 2 Resistor, Capacitor set	£2.20
60VS Pk. 3 Semiconductor set	£3.10
60VS Pk 6A Toroidal transformer (for use with Bailey)	£8.80
60VS Pk. 6B Toroidal transformer (for use with 20W LH)	£7.25
Bailey Burrows Stereo Pre-Amp	
BBPA Pk 1 F/Glass PCB	£2.80
BBPA Pk. 2 Resistor, capacitor semiconductor set	£6.70
BBPA Pk 3R Rotary Potentiometer set	£2.85
BBPA Pk. 3S Slider Potentiometer set with knobs	£3.10
Active Filter	
FILT Pk. 1 F/Glass PCB	£1.40
FILT Pk. 2 Resistor, Capacitor set (metal oxide 2%, polystyrene 2½%)	£4.20
FILT Pk 3 Semiconductor set	£2.25
2 off Pks 1, 2, 3 rqd for stereo sctive filter system	
Read/Texas 20W Amp	
READ Pk. 1 F/Glass PCB	£1.00
READ Pk. 2 Resistor, Capacitor set	£1.20
READ Pk. 3 Semiconductor set	£2.30
6 off pks 1, 2, 3 required for stereo active filter system	£2.30
Stuart Tape Recorder	
TRRP Pk 1 Replay Amp F/Glass PCB	£1.30
TRRC Pk 1 Record Amp F/Glass PCB	£1.70
TROS Pk 1 Bias/Erase/Stalilizer F/Glass PCB	£1.20

Further details of above and additional packs given in our FREE LIST

SQ QUADRAPHONIC DECODERS

Feed 2 channels (200-1000mV as obtainable from most pre-amplifiers or amplifier tape monitor outlets) into any one of our 3 decoders and take 4 channels out with no overall signal level reduction. On the logic enhanced decoders Volume, Front-Back, LF-RF balance, LB-RB balance and Dimension controls can all be implemented by simple single gang potentiometers.

These state-of-the-art circuits used under licence from CBS are offered in kits of superior quality with close tolerance capacitors, metal oxide resistors and fibre-glass PCBs designed for edge connector insertion. All kit prices include CBS licence fee.

M1. Basic matrix decoder with fixed 10-40 blend All components, PCB **£5.90**

L1. Full logic controlled decoder with "wave matching" and "front back logic" for enhanced channel separation. All components PCB **£17.20**

L2A. More advanced full logic decoder with "variable blend" for increased front back separation. All components, PCB **£22.60**

L3A. Decoder similar to L2A but with discreet component front end with high precision 6-pole phase shift networks for increased frequency response. All components (carbon film resistors), PCB **£25.90**

Also available with M.O. resistors, cermet pre-set — add **£4.20**

SEMICONDUCTORS as used in our range of quality audio equipment.

2N699	£0.20	40361	£0.40	BD529	£0.55	MJE521	£0.60	TIP29C	£0.55
2N1613	£0.20	40362	£0.45	BD530	£0.55	MPSA05	£0.25	TIP30C	£0.60
2N1711	£0.25	BC107	£0.10	BDY56	£1.60	MPSA12	£0.35	TIP41A	£0.70
2N2926G	£0.10	BC108	£0.10	BF257	£0.40	MPSA14	£0.30	TIP42A	£0.80
2N3055	£0.45	BC109	£0.10	BF259	£0.47	MPSA55	£0.25	TIP41B	£0.75
2N3442	£1.20	BC109C	£0.12	BFR39	£0.30	MPSA65	£0.35	TIP42B	£0.90
2N3711	£0.09	BC125	£0.15	BFR79	£0.30	MPSA66	£0.40	IN914	£0.07
2N3904	£0.17	BC126	£0.15	BFY51	£0.20	MPSU05	£0.50	IN916	£0.07
2N3906	£0.20	BC182	£0.10	BFY52	£0.20	MPSU55	£0.50	1S920	£0.10
2N4062	£0.11	BC212	£0.12	CA3046	£0.70	SBA750A	£1.90		
2N4302	£0.60	BC182K	£0.10	LP1186	£6.50	SL301	£1.30		
2N5087	£0.25	BC212K	£0.12	MC1310	£2.20	SL3045	£1.20	FILTERS	
2N5210	£0.25	BC182L	£0.10	MC1351	£1.05	SN72741P	£0.40	FM4	£1.00
2N5457	£0.45	BC184L	£0.11	MC1741CG	£0.65	SN72748P	£0.40	SFG10 7MA	£1.50
2N5459	£0.45	BC212L	£0.12	MFC4010	£0.95	TIL209	£0.20		
2N5461	£0.50	BC214L	£0.14	MJ481	£1.20	TIP29A	£0.40		
2N5830	£0.35	BCY72	£0.13	MJ491	£1.45	TIP30A	£0.45		

EXPORT NO PROBLEM

Our Export Department will be pleased to advise on postal costs to any country in the world. Some of the countries to which we sent kits in 1975 are shown surrounding this advertisement.

Kenya France St. Martin, Java New Zealand Borneo South Africa Denmark Nigeria Anguilla Finland

KINNIE COMPONENTS
10 NELMES WAY HORNCHURCH ESSEX RM11 202 HORNCHURCH 45167

CIRCUIT BOARD
P.C.B. 1/16 1 oz. COPPER.

FORMICA
Dim. 8.4 x 7.7 in 3 pcs. **80p.**
Dim. 9.4 x 8.1 in 3 pcs. **90p.**
Dim. 10.1 x 7.9 in 3 pcs. **£1.00.**
Dim. 13.1 x 9.4 in 3 pcs. **£1.20.**
Dim. 17.0 x 9.0 in 2 pcs. **£1.20.**
P.P. 35p on each pack.

BARGAIN PACK
10 pcs. 10.1 x 7.9 in. (Formica) plus free ½lb etching Xtals. **£3.30.**

FIBRE GLASS P.C.B.
Dim. 6 x 6 in. **55p** each.
Dim. 12 x 6 in. **85p** each. P.P 15p
Dim. 12 x 12 in. **£1.40** each.

FIBRE GLASS P.C.B. DOUBLE SIDED
Dim. 6 x 6 in. **45p** each.
Dim. 12 x 6 in. **70p** each. P.P. 15p
Dim. 12 x 12 in. **£1.30** each.

ETCH RESIST PENS (55p, P.P. 5p).

RESIST COATED P.C.B.
10.1 x 7.9 in. **70p** ea. (Formica).
6 x 6 in. **75p** ea. (Fibre glass).

BLUE P.C.B. INK
Etch resist use with any pen. Much cheaper than ready loaded pens. 50 c.c., **55p,** p.p. 10p.

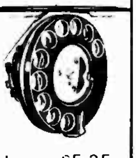
FERRIC CHLORIDE ETCHING XTALS
1lb—1 litre pack, **70p,** p.p. 35p.
5lb—5 litre pack, **£2.20,** p.p. 65p.

PRINTED CIRCUIT KIT
The no-frills-all-value kit containing 4 pcs 8 x 7 Formica laminate. 1 pce 6 x 6 Fibre glass laminate, 1 lb Etching Crystals, 50 c.c. Resist ink with instructions. **£2.40,** p.p. 65p.

BARGAIN PACK FIBRE GLASS P.C.B.
200 sq in all usable pieces, **£1.40.**

EDGE CONNECTORS, 54 WAY.
1 Spacing
Vero size, etc. Can be cut to any length. **65p,** p.p. 10p. Side guides to suit above, **15p** each.

TELEPHONE DIALS
(new), **£1.25,** p.p. 25p



EXTENSION TELEPHONES
(Type 706). Various colours. £5.25, p.p. 75p.

MINIATURE UNISELECTOR
12 volt 11-way, 4 bank (3 non-bridging, 1 homing), **£2.50,** p.p. 35p.
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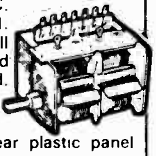

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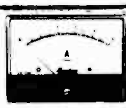

2⅜ in x 1⅞ S8 500mA
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S2 100µA S10 50v a.c.
S3 500µA S11 300v a.c.
S4 1mA S12 50/0/50µA
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L2 100µA — All at **£5,** p.p. 15p.

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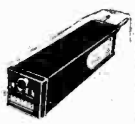

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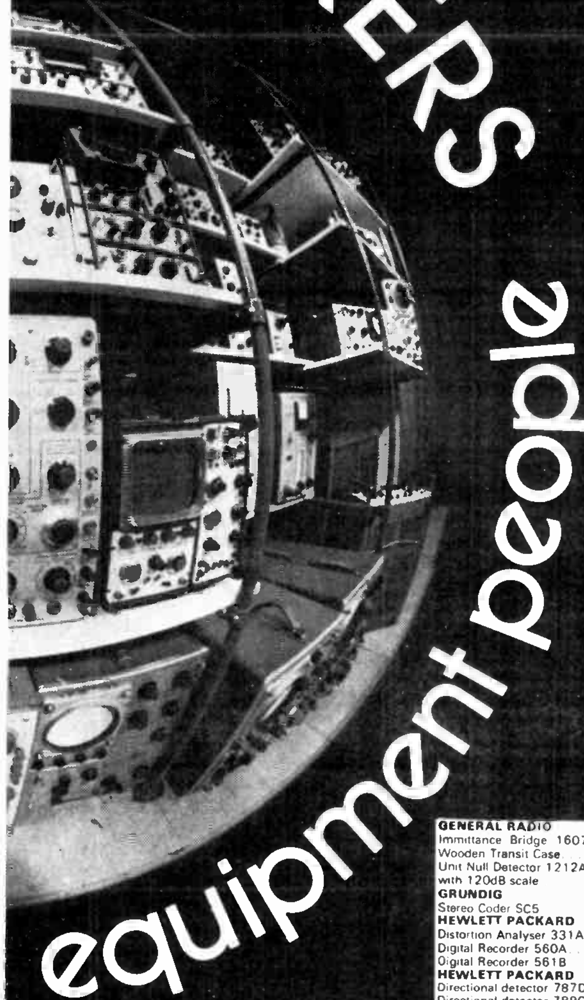

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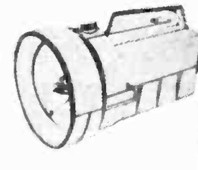

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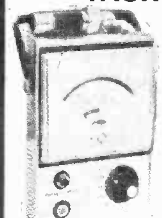

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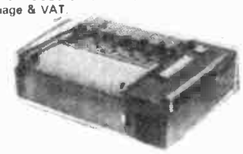

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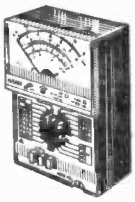

AC/DC Multimeter type U4324 A-DC 0.06-3A — 6 Ranges A-AC 0 3A — 5 Ranges C-DC 0.6-1200V — 9 Ranges V-AC 3.900V—8 Ranges. Freq in the range of 45 to 20kHz Resistance 500 ohm to 5 Mohm — 5 Ranges Decibel — 10 to + 12dB Accuracy ±2 5% DC± 4% AC
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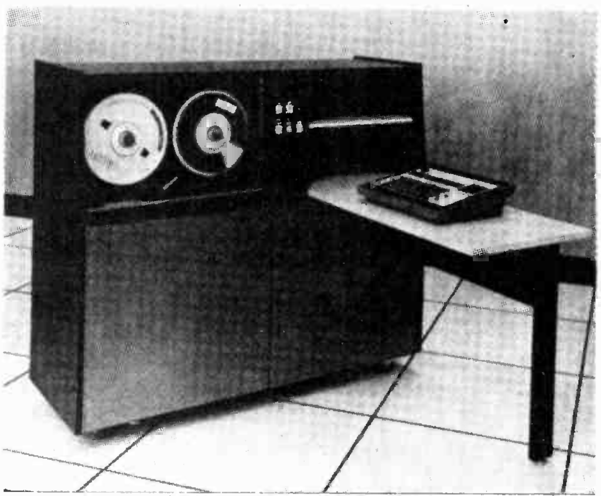

Honeywell Keytape Unit as picture. Checked, tested with Manual, **£215** ea.

As above but less data boards. Tested forward/backward tape movement and control, etc. Data entry/exit via read/write boards. **£105** ea.

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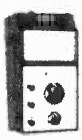

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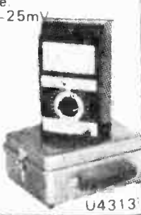

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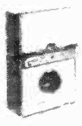

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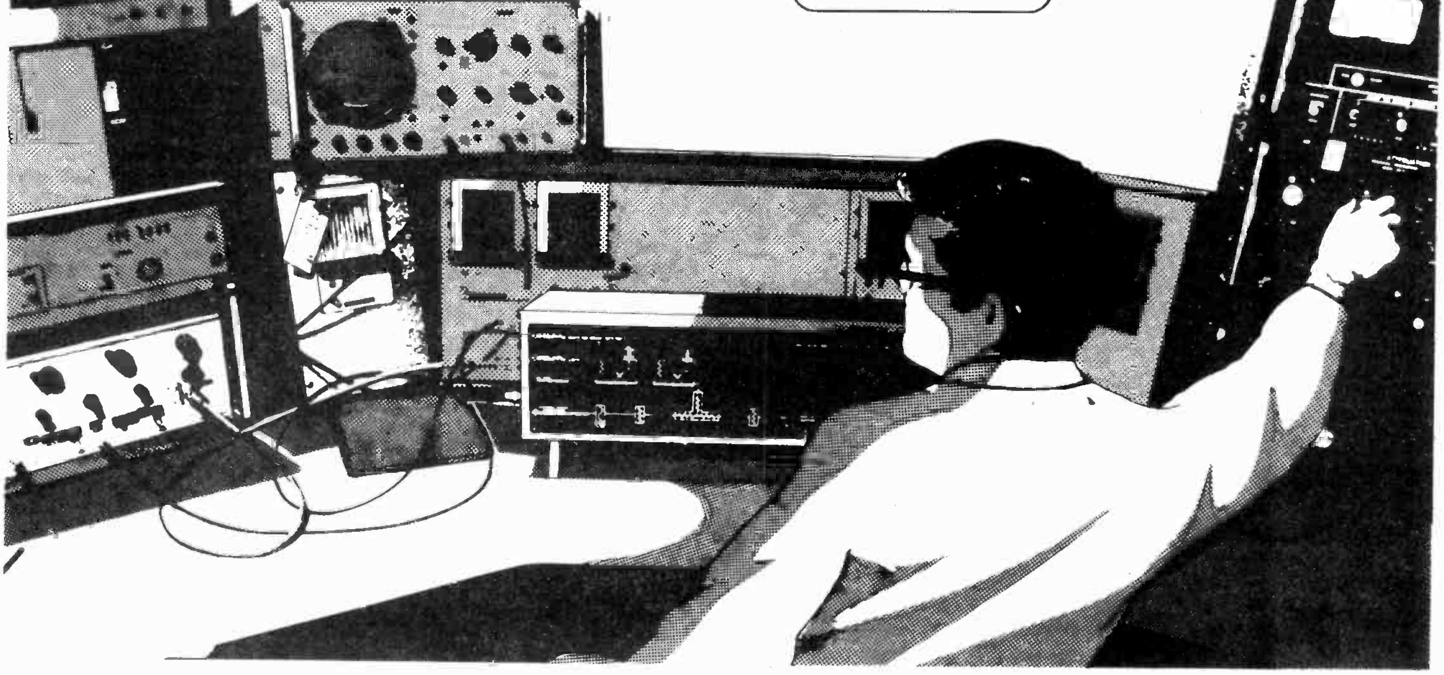

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(6141)

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Electronic and Bio-medical Engineering Department

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Application form and job description to be obtained from.

Area Engineer, Shrewsbury Hospital, Copthorne South, Mytton Oak Road, Shrewsbury, Salop. Tel: Shrewsbury 52244 Ext. 3273.

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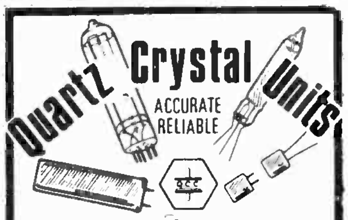

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Miss C. Mulshaw,
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0.22			
0.33	£1.32	77p	51p
0.47			
0.68	£1.44	84p	56p
1.0	£1.56	91p	60p
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2.2	£1.98	£1.32	75p
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4.7	£2.82	£1.88	£1.23
6.8	£3.48	£3.32	£1.47
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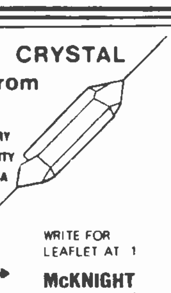

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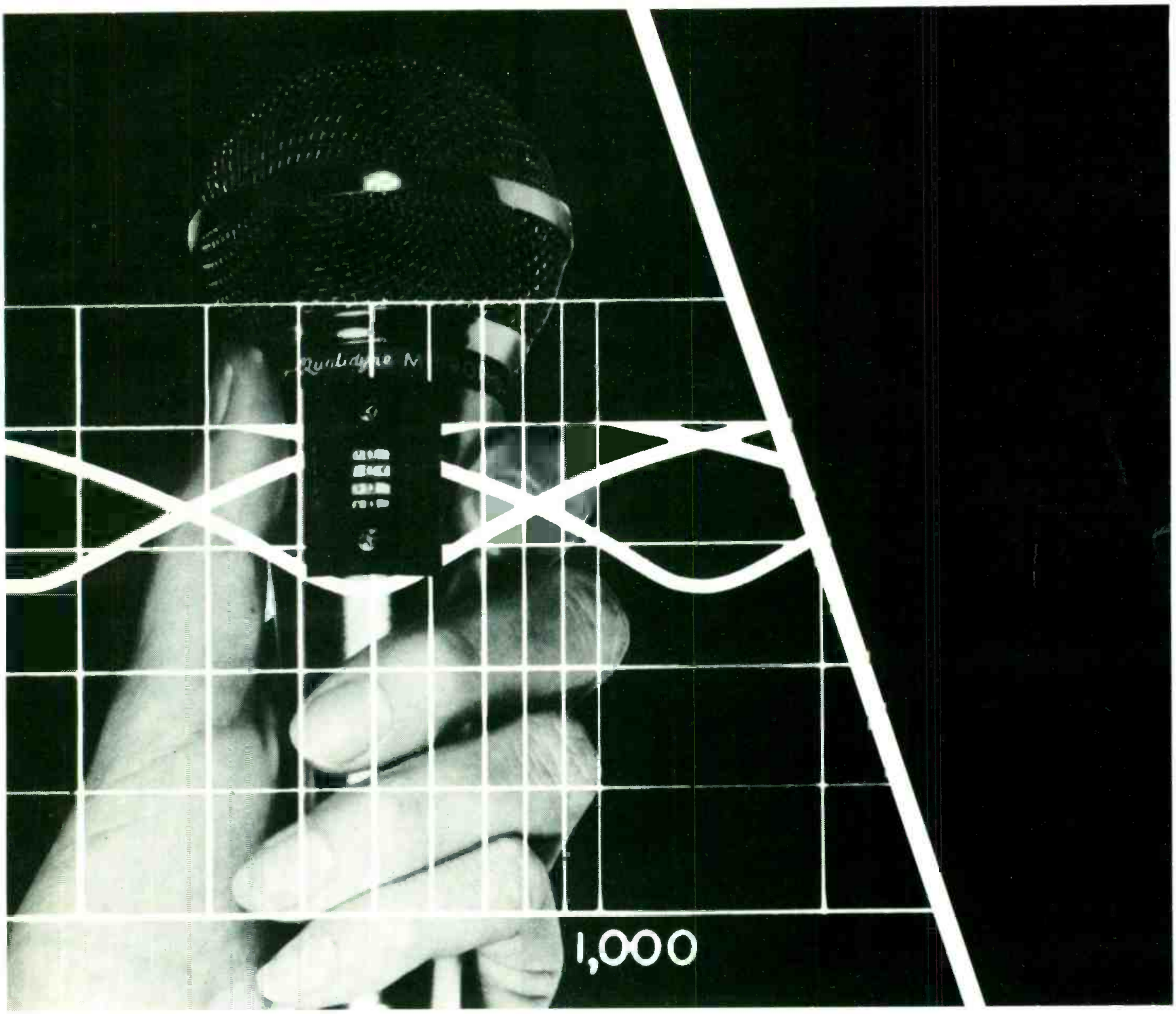
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