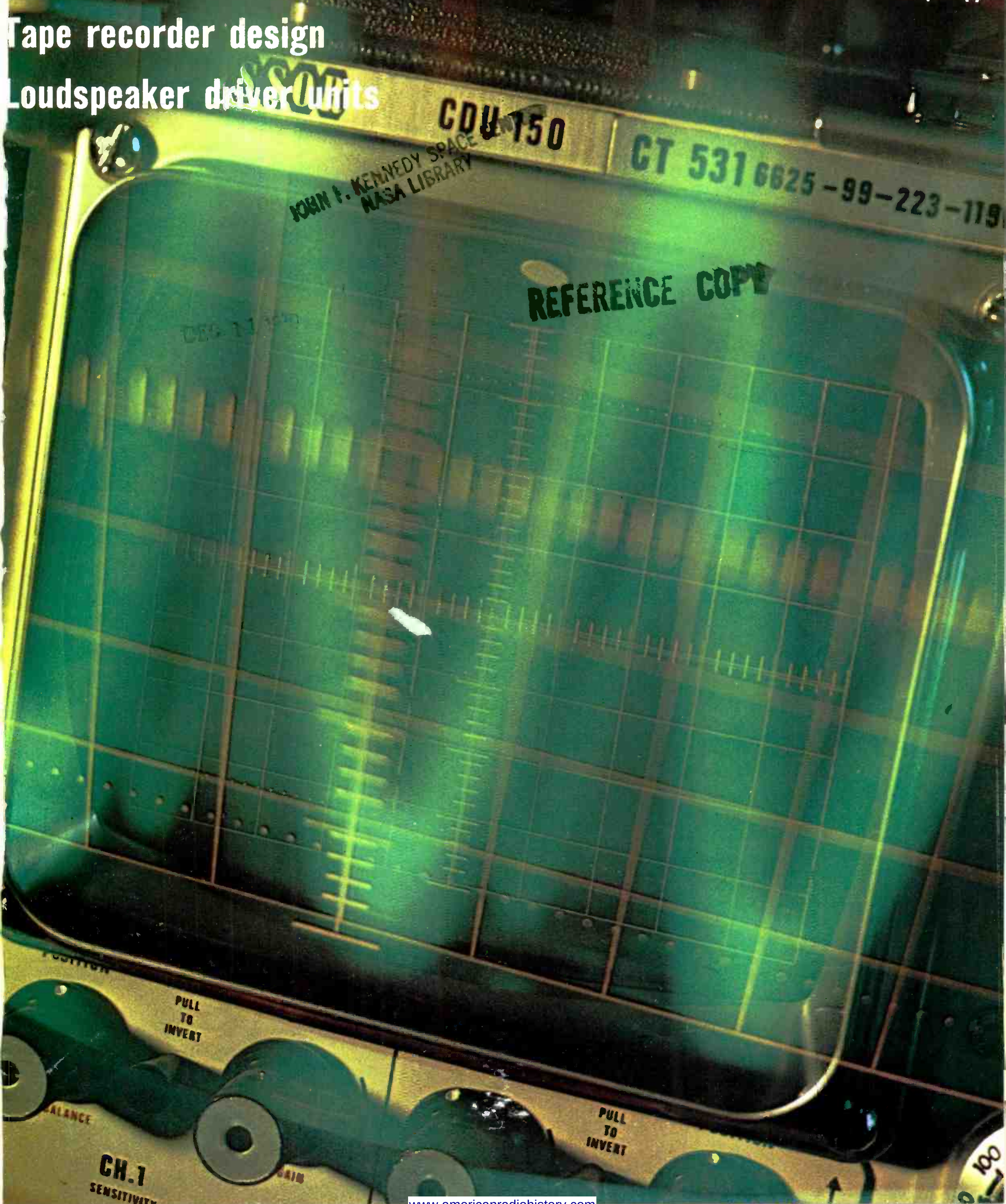
Wireless World

November 1970 3s 6d (17½p)

Tape recorder design

Loudspeaker driver units



Wireless World

Electronics, Television, Radio, Audio

Sixtieth year of publication

November 1970 **Volume 76 Number 1421**

Contents

This month's cover picture has been produced by superimposing an oscillograph on a photograph of the instrument on which it was displayed.

IN OUR NEXT ISSUE

The **boxcar detector** is an instrument for retrieving repetitive signals which are buried in noise. An article will explain how the boxcar detector works and how it is used.

An ultra linear **a.c. millivoltmeter** will be described which is not expensive to build and overcomes the problem of non-linear rectifying diodes by using a constant current source.

Attenuators: some notes on the calculation and uses of resistance networks.

ibpa International Business Press Associates

I.P.C. Electrical-Electronic Press Ltd
Managing Director: George Fowkes
Publishing & Development Director: George H. Mansell
Advertisement Director: Roy N. Gibb
Dorset House, Stamford Street, London, SE1

PUBLISHED MONTHLY (3rd Monday of preceding month). *Telephone:* 01-928 3333 (70 lines). *Telegrams/Telex:* Wiworld Bisnespres 25137 London. *Cables:* "Ethaworld, London, S.E.1." *Annual Subscriptions: Home;* £3 0s 0d. *Overseas:* 1 year £3 0s 0d. (*Canada and U.S.A.;* $7.50). 3 years £7 13s 0d. (*Canada and U.S.A.;* $19.20). Second-Class mail privileges authorised at New York N.Y. Subscribers are requested to notify a change of address four weeks in advance and to return wrapper bearing previous address. BRANCH OFFICES: *BIRMINGHAM:* 202, Lynton House, Walsall Road, 22b. *Telephone:* 021-356 4838. *BRISTOL:* 11, Elmdale Road, Clifton, 8. *Telephone:* OBR2 21204/5. *GLASGOW:* 2-3 Clairmont Gardens, C.3. *Telephone:* 041-332 3792. *MANCHESTER:* Statham House, Talbot Road, Stretford, M32 OEP. *Telephone:* 061-872 4211. NEW YORK OFFICE U.S.A.: 205 East 42nd Street, New York 10017. *Telephone:* (212) 689-3250.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Wireless World

Symbols for Active Devices

Active devices in common use now include valves, bipolar transistors and field-effect transistors. As far as their normal use is concerned all these can be considered as triodes. The valve, of course, exists in tetrode, pentode, hexode, heptode, octode and even nonode forms. Except for certain special applications where signals are applied simultaneously to more than one grid (e.g. frequency changers), most valves have only three signal electrodes, an emitting cathode, a collecting anode and a control grid.

In the case of the bipolar transistor the three electrodes corresponding to cathode, grid and anode of the triode valve are called emitter, base and collector, while the equivalents of the f.e.t. are source, gate and drain.

The standard symbols for 'electrode' voltages for the valve are V_{gk} and V_{ak} (often abbreviated to V_g and V_a , since the cathode as reference point is usually understood). For the bipolar transistor, they are V_{BE} and V_{CE}, while for the f.e.t. they are V_{GS} and V_{DS}. Currents are I_g and I_a (valve), I_B, I_C and I_E (bipolar) and I_G, I_D and I_S (f.e.t.). Notice that the convention of using capital letters for the subscripts to semiconductor quantities to indicate d.c. values, is not common with valves.

However different physically these devices may be and however different may be their internal operation, they are all fundamentally the same when considered as a three-terminal 'black box'. They can all be represented by the same equivalent circuit and the same set of equations. Why, then, should we have three sets of symbols for what are similar quantities from the point of view of the external circuit? Would it not be much simpler to have a common set for all?

This would probably have happened from the start had it not been that early transistors were p-n-p types. For an n-p-n transistor cathode and anode are as correct for the emitter and collector as they are for the valve, but since they mean the negative and positive electrodes to apply them to a p-n-p type would cause endless confusion.

What is really needed are three words, one to denote cathode (valve), emitter (bipolar) and source (f.e.t.); one to denote anode (valve), collector (bipolar) and drain (f.e.t.); and a third for control grid (valve), base (bipolar) and gate (f.e.t.).

Emitter and collector are equally suited to the valve and to the bipolar transistor. They may not appear so applicable to the f.e.t. However, in this device there is a source, which is the end of the semiconductor at which electrons or holes start to flow through it, and there is a drain at which their internal flow ceases. There is, of course, no emission as there is in a valve, but neither is there in a bipolar transistor. Emitter is really a misnomer for the latter, but eminently suitable for the valve!

At first sight 'source' would seem suitable for all three devices, but the term is commonly used in circuit theory for a signal source. To use the same word for an 'electrode' of an active device is to invite confusion. In our view, therefore, emitter and collector are the best words to use for all three devices.

The third electrode is more difficult. The 'grid' of a valve describes the physical form of the electrode. The 'base' of a bipolar transistor describes the physical form of the point-contact transistor but not that of the junction type. The 'gate' of an f.e.t. does in some measure attempt to describe what it does. Unfortunately, it implies an on-off type of control for one thinks of a gate as being open or closed, not as a regulator of flow. But for this, 'gate' could be used for all three devices. 'Control' is ruled out if collector is used, because it must have a different initial letter if the resulting symbolism is to follow. A word beginning with 'g' is also undesirable because 'c' and 'G' are easily confused; lower case 'c' and 'e' are bad enough in handwriting. One possibility is 'regulate'. Our suggestion therefore is that we should standardize on emitter, regulator and collector for the three electrodes of valves, bipolar transistors and field-effect transistors, but readers may have other ideas.

High-quality Tape Recorder

1. Specification and design

*by J. R. Stuart**, B.Sc.

Tape recorder construction has received relatively little attention over the years, and presumably one reason is the apparent complexity of the circuitry and alignment, compared with other items of domestic audio equipment. Two tape recorders have been described in these pages in a period of ten years, whereas several power amplifiers have been described in the last few months.

In view of the large interest in the construction of domestic audio equipment, it was decided to produce a design for a tape link which would be simple and cheap to build and easy to set up.

Reel-to-reel or cassette?

Continuing tape recorder development has resulted in commercial machines, using standard reeled tape, which give excellent performance at low speeds with or without crossfield bias.

Probably the most significant developments have been the large improvement in high-speed tape copying techniques, widespread acceptance of the Dolby noise reduction process, and the rapid growth of interest in four-channel stereo. These combine to create a situation in which tape will take over from disc as the major programme source particularly as no compatible coding can record four independent channels on a disc—although it can be done at the expense of crosstalk.[1]

It is now possible to manufacture a cassette tape to run at $1\frac{7}{8}$ i.p.s. which, with Dolby, gives a performance better than disc. However, at present no cassette tape transport is available which can offer the necessary low wow and flutter performance nor the retrieval capability of a high-quality deck of the conventional form.

The choice of a conventional deck for this design was made without hesitation, for the use of such a machine will not decline

*Marconi Instruments Ltd.

TABLE 1
Specification of the complete recorder

Bandwidth measured at −9 dB, C.C.I.R. replay:

15 i.p.s.	25 Hz	− 30 kHz	±1 dB
$7\frac{1}{2}$ i.p.s.	25 Hz	− 17 kHz	±1 dB
$3\frac{3}{4}$ i.p.s.	25 Hz	− 11 kHz +1	−2 dB
$1\frac{7}{8}$ i.p.s.	25 Hz	− 6 kHz +1	−3 dB

Distortion (at 1 kHz)

$7\frac{1}{2}$ i.p.s.	0 dB	1%	third harmonic	(reference level)
	+2.3 dB	2%	third harmonic	
15 i.p.s.	0 dB	0.7%	third harmonic	
	+2.3 dB	1.5%	third harmonic	

Dynamic range

56 dB	15 i.p.s. and $7\frac{1}{2}$ i.p.s.	(weighted)
54 dB	$3\frac{3}{4}$ and $1\frac{7}{8}$ i.p.s.	(weighted)

Crosstalk
−60 dB mono
−45 dB stereo

Amplifier hum and noise
below −66 dB

Input sensitivity
7 mV rms into 45kΩ or 600Ω
or 25 mV rms into 150kΩ or 600Ω
or 250 mV rms into 1.5MΩ or 600Ω

Output
25mV rms. Output Impedance < 100Ω
and 250mV rms. Output Impedance < 100Ω

Peak-programme meter
Switchable to measure record, replay and bias levels.

Cost
£20 + £85 14s 7d for the Brenell Mk 6 deck.

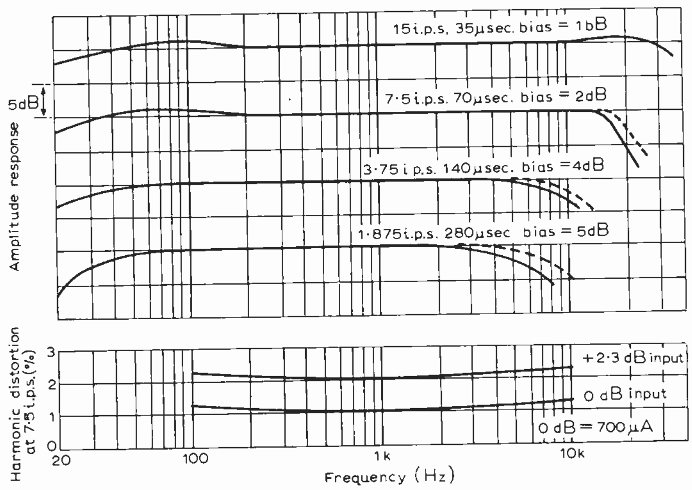


Fig. 1. Maximally flat frequency response.

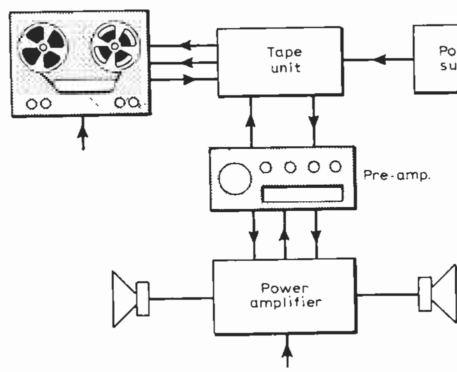


Fig. 2. Expected arrangement of the tape unit.

when live recordings are made for either amateur or professional applications, particularly those requiring editing. Further, many decks of this type are in use and may be adapted to this design.

Crossfield biasing was not considered in view of the extreme mechanical problems this would create for the constructor.

This tape recorder has been designed around the Brenell Mk 6 deck. Brenell Engineering Ltd have agreed to make this deck available in the required form.

Evolving a specification

Table 1 shows the performance of this tape recorder for the conditions described and Fig. 1 shows the frequency response for constant current record, C.C.I.R. play back at $7\frac{1}{2}$ i.p.s. and 15 i.p.s. adjusted for a maximally flat response.

Equalization is described in detail later along with the corresponding setting-up and performance details.

In evolving a design the primary considerations were

(a) simplicity of design consistent with high performance

(b) non-critical construction
(c) the use of readily available components
(d) a minimum number of adjustments (the circuits deliberately leave very few parameters undefined and all calibration can be done with a multi-meter, although the full procedure is described)
(e) design flexibility to enable ready extension to four-channel and cassette applications when such decks are available.

The unit described is a mains-powered tape link and is intended for use with an existing audio system of pre- and power-amplifiers, and mixer if required. Such a recorder receives its signal from the pre-amplifier or mixer and replays through the same system. Three tape heads are fitted to allow simultaneous recording and playback; this affords better performance and much extended monitoring facilities.

The unit is readily compatible with the designs published in *Wireless World;* in particular the signal levels have been chosen to match the Bailey[2] and Nelson-Jones[3] pre-amplifiers. Fig. 2 shows the expected arrangement.

It was decided that the standard tape recorder should be a stereo unit capable of recording or replaying mono on either of the channels, with extensive monitoring facilities.

In addition to the considerations above, the particular performance parameters are cost, bandwidth, dynamic range and simplicity, and to achieve a good overall performance these must be carefully examined at each stage of the design.

To achieve simplicity it has been necessary to produce non-critical alignment with the full manufacturers' spread of devices, and the construction is no more complex than a power-amplifier. A block diagram of the tape unit is shown in Fig. 3.

Bandwidth

The bandwidth of a tape recorder is determined by the tape transport mechanism at low frequencies, and at high frequencies, to a first order, by

(a) recording speed

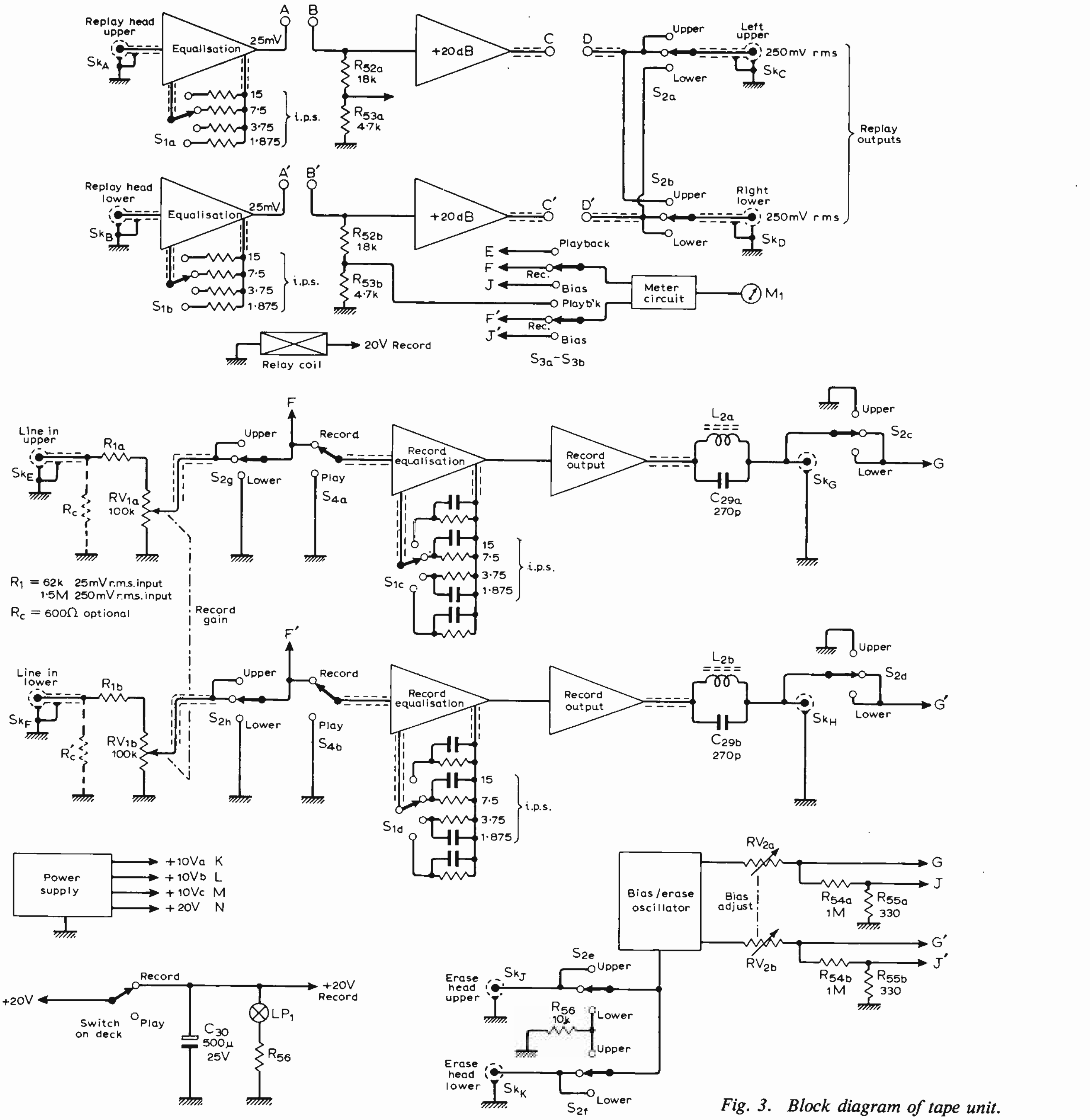


Fig. 3. Block diagram of tape unit.

(b) h.f. bias level
(c) replay head gap
(d) alignment of record and replay gaps
(e) equalization standard (I.E.C., N.A.B., D.I.N., C.C.I.R., N.A.R.T.B.)
(f) magnetic domain size on tape
(g) head losses (copper, and iron, and leakage).

Second order effects include the recording-head gap.

The Brenell Mk 6 uses Bogen heads which have a hyperbolic face to ensure good tape-head contact. They also have pressure pads which nevertheless seem to allow good low-frequency response as is seen from Fig. 1.

In a given system the parameters which the designer may control are a, b, and e, and to some extent d.

Great care must be exercised in producing a bandwidth specification; it seems dangerous to rely as much as we do on these figures. The problem is that in most cases it is the published specification for bandwidth and noise which sells a tape recorder. The author feels that it is of limited value to reject a model with an upper −2dB point of 15 kHz in favour of one which has the same point at 22 kHz; the reasons are as follows.

The sensitivity of the human ear at 17 kHz is a mean of 10 dB below 4 kHz at listening level of 60 phons, and the 1% duration peak content in an orchestral piece at 15 kHz is 10 dB below 500 Hz[4]. It would seem that a variation of ± 2dB at 20 kHz should have little effect, particularly as the threshold of hearing at 20 kHz is at a loudness of 80 phons (Robinson & Dadson) and in the upper octave just noticeable distortion is greater than 1 phon.

The ear is however sensitive to transient 'slewing-rate' and to inharmonic products.

No recording system can easily retain the phase information required to reproduce the transient information in the way required; however a lot can be done to reduce the intermodulation products which are generated in the upper band. It seems evident that the perceived difference between the systems of different bandwidth, is due to distortion produced by the method of bandwidth reduction, causing intermodulation products to appear in the region 1–6 kHz, with obvious effect. Because the major control of bandwidth of a tape recorder is the high-frequency pre-emphasis, and since harmonic products in the upper octave are not retained, the intermodulation products here, and the bandwidth, are determined by the recording characteristic.

Dynamic range

In a well designed tape recorder the dynamic range is determined by the tape and defined by tape overload and inherent background noise.

Sources of noise in the recorder are the amplifiers (more than 10 dB below tape noise in this design) and recorded noise by the bias and erase waveforms. In order to minimize this the erase waveform must be very pure and free from even-order harmonics.

Another source of noise is hum. However, careful power supply design and overall construction have reduced basic amplifier hum to less than −80 dB. The hum level appears far below the amplifier noise, and is inaudible in the author's set-up at a gain setting equivalent to 40W at a distance of 6 feet from the speakers.

Two-track operation was chosen to give a maximum dynamic range, however the Brenell Mk 6 deck is available with four-track heads and these may be used with no circuit modification giving about 3 dB less dynamic range.

Power supply

It was intended that the recorder should obtain raw d.c. from the power amplifier with which it is used, and a regulator is used to derive the system rail of +20 V. In case this power is not available a simple supply will be described in Part 2.

Choice of devices

The R.C.A. integrated circuit quad-amplifiers CA 3048 and CA 3052 were chosen for this design—which uses one of each. In

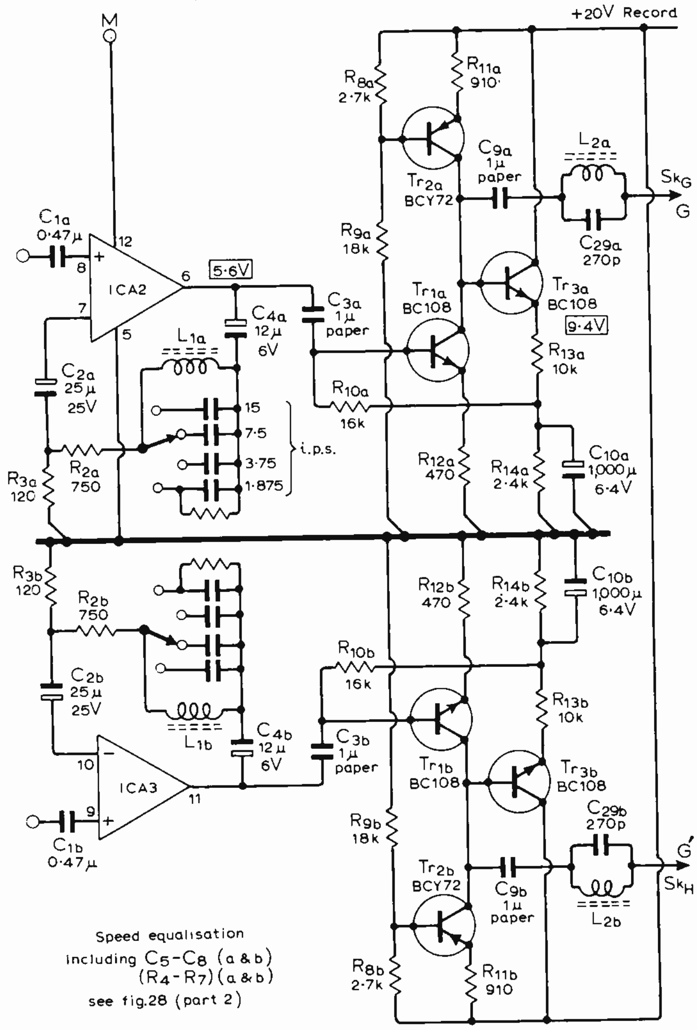


Fig. 5. Circuit diagram of recording stage.

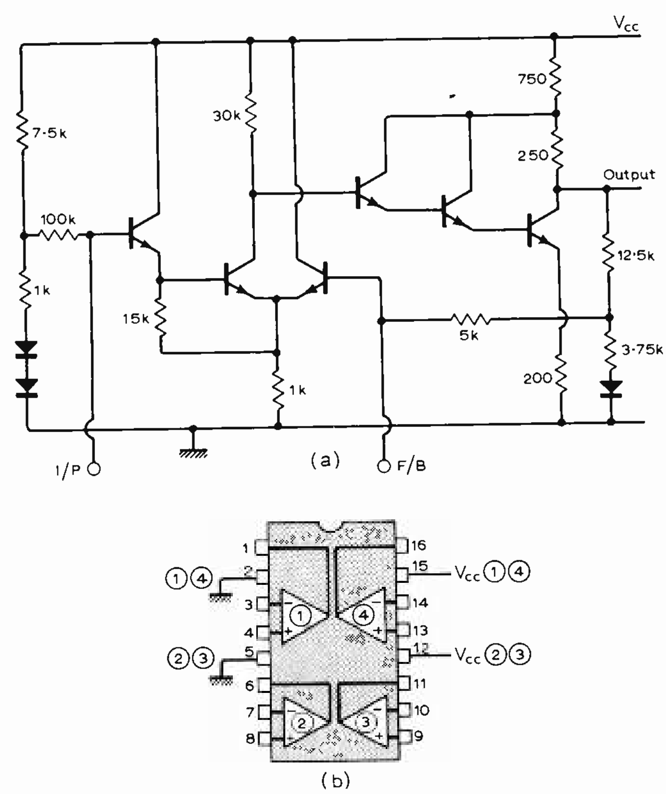


Fig. 4. Data on the i.c. linear amplifiers type CA3048 and CA3052; (a) the circuit diagram of each amplifier section (¼i.c.); (b) pin connections; and (c) performance details of each amplifier.

the author's experience they have a highly predictable, reliable performance and offer a saving of a very large number of discrete components. Although there is no reduction in cost, the reliability of one of these chips for home construction, when compared with the minimum equivalent of twelve transistors and associated components, is high. The circuits should be carefully checked however for the cost of mistakes could be higher. Fig. 4 (a) & (b) show the circuit diagram and specification for these devices. The transistors chosen are cheap silicon-planar devices of ready availability.

Recording section

The essential recording function is to produce a residual flux/input voltage transfer function which is linear with respect to amplitude variations.

In the mid-band residual flux relates linearly to applied flux, which is in turn proportional to the current flowing in the recording head windings, and so it follows that the recording current should be proportional to the signal voltage.

It is also necessary to modify the amplitude/frequency response of the recording stage to obtain the optimum bandwidth as described earlier.

The recording amplifier falls readily into two sections, namely the equalization and output stages.

Fig. 5 shows the circuit diagram for the stereo recording section. Reference to Fig. 3 shows that the record gain control is placed at the input to the equalization stage, i.c.A 2&3, to maintain optimum conditions of dynamic range and distortion. S_2 g & h, and S_4 a&b direct the input signals according to the selected function.

The open loop gain of i.c.A 2 & 3 is set to 45 dB by R_3, and the low-frequency gain of this stage is

$$\frac{R_2 + R_3}{R_3} \approx 7.25$$

This implies a sensitivity of 7 mV r.m.s. for 0 dB output level. Here 0 dB output was set for a flux density of 32 millimaxwells per millimetre of tape at +1 dB bias and $7\frac{1}{2}$ i.p.s.

The parallel tuned circuit formed by L_1, and C_{5-8}, increases the gain at the resonant frequency by an amount determined by R_{4-7}. Several combinations of frequency and boost may be used and these will be described in Part 2. Fig. 6 shows the frequency response of the equalizing stage when set for maximally flat response as in Fig. 1. This rising gain at high frequencies compensates to some extent for the losses in the recording head and tape, and ensures a 'constant induction' characteristic. Noise and distortion are both very low in this stage, distortion at 1 kHz is less than 0.01% at rated input, and the noise is more than 70 dB down.

As the CA 3052 amplifier can give 2V r.m.s. output with 0.65% distortion open loop, this equalizing stage is capable of producing 32 dB boost with less than 0.1% distortion. Because the recording head is a non-ideal inductor, it is an interesting problem to produce a 'constant current' drive at all frequencies in the pass-band; this implies an amplifier whose voltage gain is proportional to the head impedance.

A large number of designs have appeared, to produce this constant current drive for the head, and indeed to arrange this drive with a good 0 dB overload margin, to allow pre-emphasis, is quite difficult.

The Brenell Mk 6 deck is fitted with a Bogen UK202B record head, which has an inductance of 120 mH at 1 kHz and requires a recording current of 110 μA to induce a remanent flux of 32 mMx/mm; this head achieves its maximum impedance of 10 kΩ at about 14 kHz. Without pre-emphasis then the voltage across the head will be 1.1 V r.m.s. and as the output amplifier can provide 5.5 V r.m.s. across the head at this frequency the minimum pre-emphasis which can be applied to allow no overload at the 0 dB level is 14 dB at 14 kHz. It is worthwhile investigating the power-frequency spectrum of the signal source, as many music sources have maximum peaks at 15 kHz 10 dB below 500 Hz[4]. Thus if necessary a further 10 dB boost could be applied with less than 1% duration overload at these frequencies.

Wherever possible the nature of the pre-emphasis has been designed to accept a 0 dB signal without overload. If this is not the case the amount of overload is stated. Traditionally 'constant

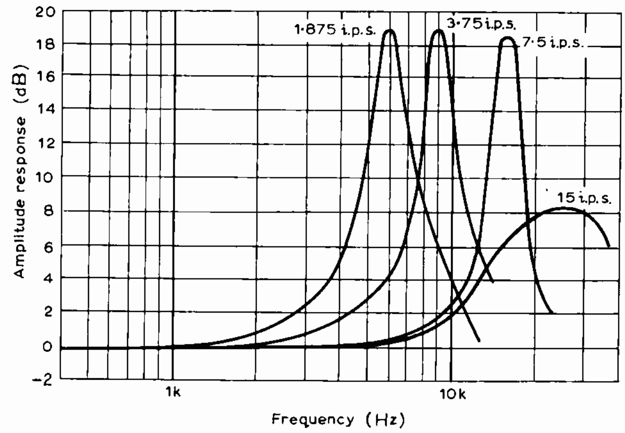
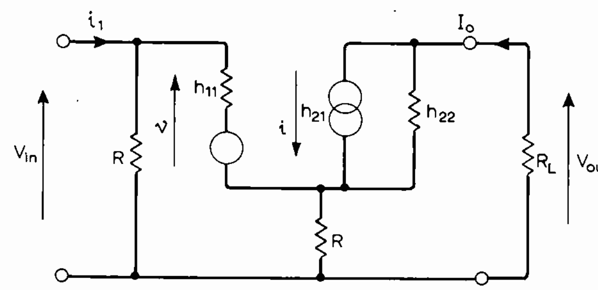


Fig. 6. Frequency response of recording pre-emphasis.



$$V_{in} = \left(1 + (h_{21}+1)\frac{R}{h_{11}}\right)V$$

$$I_o = h_{21}\frac{V}{h_{11}}$$

Then if $(1+h_{21})R \gg h_{11}$ $\quad \frac{I_o}{V_{in}} = \frac{h_{21}}{1+h_{11}} \cdot \frac{1}{R} \simeq \frac{1}{R}$

Fig. 7. Mid-band small-signal equivalent circuit of recording output amplifier.

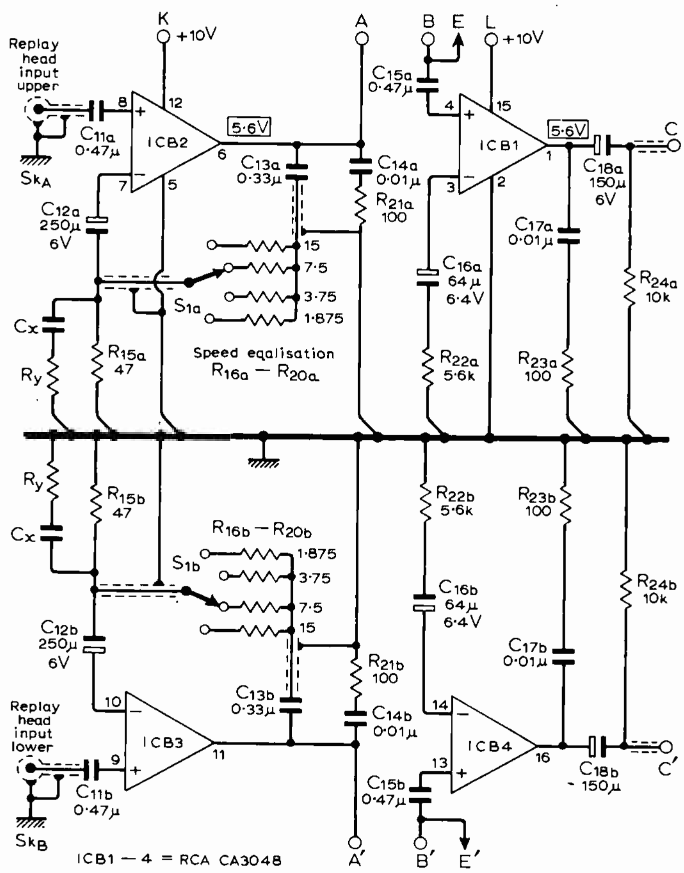


Fig. 8. Circuit diagram of replay amplifier.

TABLE 2 **(Replay equalization details.)**

speed	standard	time constants (µs) t1	t2	gain @ 1kHz (approx)	Cx µF	Ry µF	Rp	Rq	Rs	Rt	Rm kΩ	Cz
15 i.p.s. 38 cm/sec	CCIR/DIN IEC94* BSI (1970)†	35	∞	10	—	—	56	—	—	—	∞	s/c
	NAB, IEC (USA)	50	3180	12	—	—	100	—	—	—	9.5	10µ 6V
7½ i.p.s. 19 cm/sec	CCIR/DIN IEC94 (GB) BSI (1970)	70	∞	13	0.5	22	—	160	—	—	∞	s/c
	NAB, IEC (USA)	50	3180	12	0.5	22	—	100	—	—	9.5	10µ 6V
	IEC (FRANCE)	50	∞	12	0.5	22	—	100	—	—	∞	s/c
3¾ i.p.s. 9.5 cm/sec	CCIR	140	∞	15	1.0	22	—	—	390	—	∞	s/c
	BSI (1970) } IEC94 (GB) }	90	3180	14	1.0	22	—	—	220	—	9.5	10µ 6V
	IEC94 (EUR)	140	3180	15	1.0	22	—	—	390	—	9.5	10µ 6V
		or 90	∞	14	1.0	22	—	—	220	—	∞	s/c
1⅞ i.p.s. 4.75 cm/sec	CCIR	280	∞	20	1.5	22	—	—	—	820	∞	s/c
	BSI (1970) }	120	1590	15	1.5	22	—	—	—	330	19	10µ 6V
	IEC94 }	or 120	∞	15	1.5	22	—	—	—	330	∞	s/c

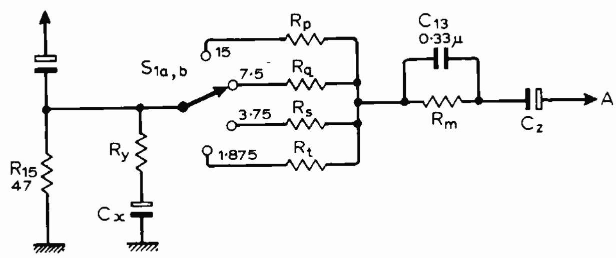
* IEC94 inc. GB, USA, FRANCE.
† BS 1568 (1970). NOTE: Measurements on this unit used the CCIR replay time constants, and were made before the publication in September of BS 1568 (1970).

current' was obtained by generating a very large signal voltage, and then swamping the head impedance with a large series resistance. Although simple to implement with valves this technique is inefficient and inelegant, although there are no problems with bias rejection.

Others have made use of the high intrinsic collector impedance of a transistor, notable examples being P. W. Blick[5], J. B. Watson[6], and G. Wareham[7].

Certainly the best method of ensuring accurate 'constant-current' drive is to include the head in the feedback loop of a high gain amplifier. However, this gives rise to considerable problems of bias rejection, and for this reason this technique was not employed in the basic recording unit. It will however be described in Part 3.

The circuit developed for this recorder is simple but effective. Tr_1 is a common-emitter amplifier with local feedback in the emitter and this stage is biased by the current source Tr_2; this gives a high output impedance, and the load seen by Tr_1 is essentially the recording head. Fig. 7 shows the equivalent circuit of the output



Equalization circuit referred to in Table 2.

stage for small signals at mid-band. The trans-conductance is given by $I_o/V_{in}=1/R_{12}$. Tr_3 is an emitter-follower stage arranged to set the d.c. conditions in the amplifier. The d.c. stability is excellent, and substituting for Tr_1, transistors with h_{FE} between 30 and 475, causes a variation of only 200 mV on the standing d.c. level at the collector of Tr_1. Beware of measuring this with a meter of less than 10 MΩ resistance. The measured output impedance at 1 kHz is 420 kΩ, falling to 390 kΩ at 20 kHz. Maximum output is 5.6 V r.m.s. and clipping occurs symmetrically at an output of 18 V pk-pk.

The frequency response measured with a 2.2 kΩ load was flat between 30 Hz and 100 kHz with −3 dB at 10 Hz and 220 kHz. At rated output the distortion in the current waveform in the head at 1 kHz was 0.01%.

It is strongly recommended that capacitors C_1, C_3 and C_9 be paper or polyester. In particular any leakage in C_9 would cause a permanent polarization to build up in the recording head, degrading the performance. To avoid large currents flowing in the head during switch-on the d.c. level at the output rises slowly and the h.f. bias is arranged to decay slowly after switch-off to demagnetize the head.

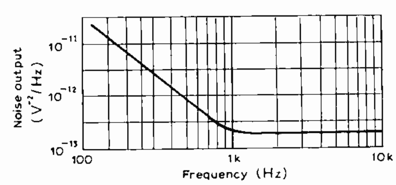


Fig. 9. Output noise spectrum of replay amplifier.

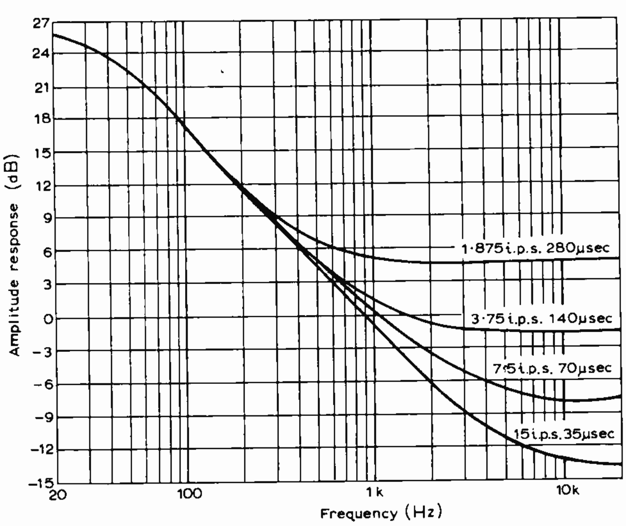
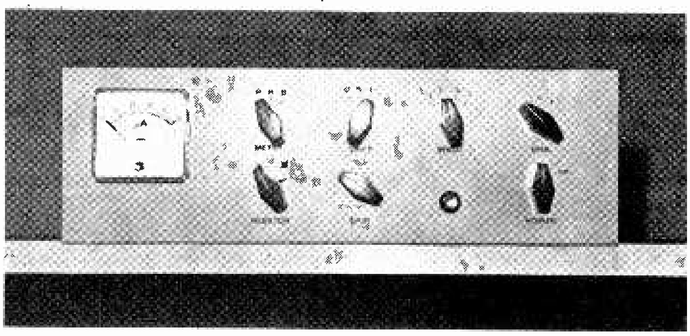


Fig. 10. Replay frequency response.

Replay

Fig. 8 shows the circuit of the replay amplifier. It is arranged as an equalization stage and a 20 dB gain stage to raise the output level to 250 mV r.m.s. The input from the UK 202B replay head is 2mV r.m.s. for a 1 kHz tone recorded at 32 mMx/mm at 7½ i.p.s.

Careful power supply design has enabled a hum level of −80 dB to be achieved with a very low crosstalk. The amplifier crosstalk measured was −74 dB at 1 kHz, and −65 dB at 10 kHz, for rated output; distortion is less than 0.01% and is predominantly 2nd harmonic; the overload capacity is 17 dB at 1 kHz with 7½ i.p.s. equalization. To obtain the best signal to noise ratio in this amplifier the CA 3048 amplifier is used; it has a tighter noise specification than the CA 3052 and is slightly more expensive. The measured noise was 66 dB below 0 dB level with 7½ i.p.s. C.C.I.R. replay equalization in a 20 kHz band and Fig. 9 shows the spectral density of the noise output of the replay stage.



R_{15} sets the open loop gain of the i.c. amplifier to 55 dB and the replay characteristic is determined by the equalizing network. This is shown in detail in Table 2, along with the values for the various standards. Fig. 10 shows the frequency response of the amplifier for the C.C.I.R. replay time constants. C_x and R_y can be added to lift the response at high frequencies. This is discussed fully in Part 2. As the power supply voltage at the i.c. terminal 12 rises slowly at switch-on, the charging current for C_{11} through the head is less than 1 μ A, and if C_{11} is a paper or polyester capacitor there should be no problem with polarization of the head. However, routine demagnetization will always be essential for high-quality work. The possibility of head magnetization is the only disadvantage with integrated or bipolar devices. An f.e.t. input would certainly eliminate the problem, but the circuit shown is far more convenient and this current has been reduced to an acceptable level. Those interested in the reduction of head polarization should refer to an article by P. F. Ridler[8].

In Part 2 next month the design will be concluded and constructional details given.

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Home Video Again

Since we last reported on video recording and playback for home use (p.340 July issue) further announcements have been made. Ampex have declared that their Instavision recorders and players will be available in Europe by the end of 1971 and a little sooner in the U.S.A. Rank Bush Murphy demonstrated their EVR Teleplayer—see p.562—and Sony have given a preview of their NTSC VCR cassette system.

The Ampex equipment is claimed to be the smallest cartridge-loading video recorder and player. Using ½-in wide chromium dioxide tape the cartridges are compatible with conventional reel-type recorders employing the 'type 1 standard' of the Japanese E.I.A. being adopted by many manufacturers of ½-in recorders. Cartridges have recording time of 30min or 60min in an extended play mode. Cost will range from £320 for a monochrome player to £400 for a colour recorder and player. A camera with zoom lens will be available for home recording. Compatible with 525, and 625-line television standards, the resolution is 300 lines monochrome and 240 lines colour. Signal-to-noise ratio is 42dB. Equipment will be made by Toshiba.

Sony demonstrated their home video recording system recently in London, although it is not clear why, as theirs is an NTSC-only system aimed at the U.S. and Japanese markets. Called a Videocassette system, it uses cassettes with two reels similar to those being made by Philips for use with the PAL colour television system. Sony expect to market their equipment in Japan in the autumn of 1971. Using chromium dioxide tape the 60-min cassettes are expected to have a life of 100-200 playings.

playback only systems

trade name	maker	type	price	estimated availability
EVR Teleplayer	CBS/RBM†	film	£360	spring 1971
Selectavision	RCA	embossed plastic film	£175	late 1972
Teldec	Decca/AEG-Telefunken	plastic disc	£60-120	1972

†Motorola in U.S.A., Bosch in Germany.

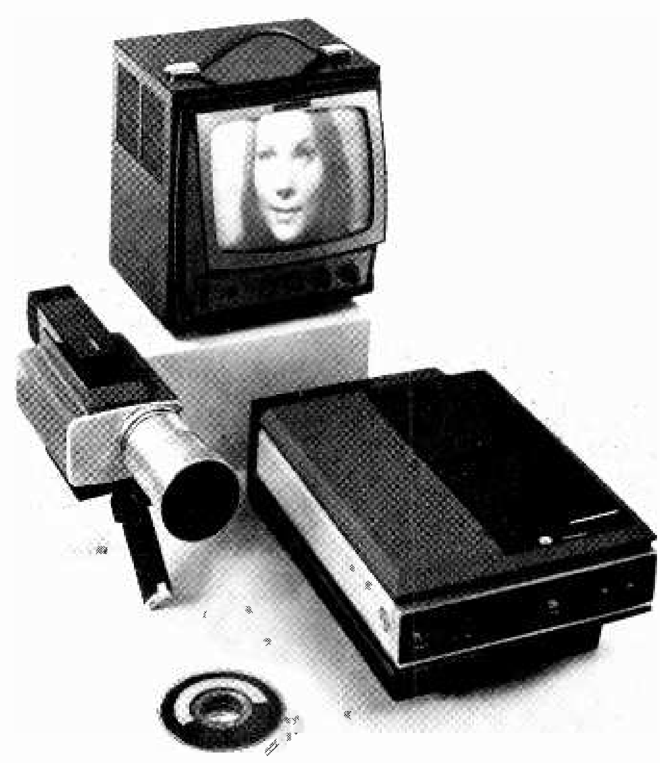
record and playback systems

trade name	maker	type	price	estimated availability
VCR*	Sony	tape cassettes	£200	autumn 1971
VCR**	Philips	tape cassettes	£250	late 1971
CTV/Cartrivision	Avco	tape cartridge	£160-200	early 1971
Instavision	Ampex/Toshiba	tape cartridge	£320-400	1971
Vidicord	Vidicord Holdings	8-mm film	£230-370	now

*NTSC system only. **PAL system only

Very soon the public will be confused about the variety of home picture recording and playback methods and equipment that will be available—assuming all the systems finally appear on the market. One rational element in the situation is the agreement amongst European makers AEG-Telefunken, Blaupunkt, Grundig, Loewe-Opta, and Philips to standardize on the Philips video cassettes for the European colour television system. The similar Sony cassettes will probably be used as a standard for NTSC-system cassettes. The accompanying tables show the present state of the systems. A table comparing technical features was published in an article discussing the Teldec disc system.‡

‡Gilbert, J.C.G. "The video disc", *Wireless World,* August 1970, pp.377/8.



Ampex/Toshiba Instavision cartridge system which includes camera for home recording.

News of the Month

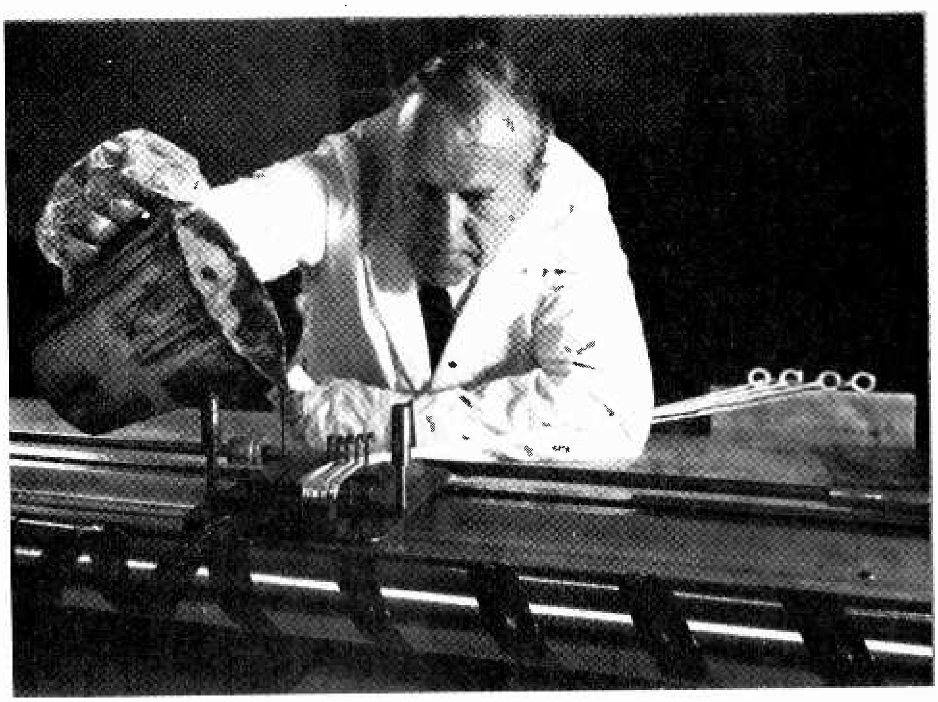
Communications in the 80s

Recently the press were invited to the Post Office Research Station, at Martlesham in Suffolk, to have a look at the work which is being done there on circular waveguides. Although the station is still very much in its infancy, most of the buildings being still under construction, the various groups have installed their equipment in temporary accommodation so that work can continue.

At Martlesham there is a 1km run of circular waveguide on which initial experiments are being done. This will be supplemented by a 30km run from Martlesham to Mendlesham where it will connect into the national microwave grid.

The waveguide is 50mm (about 2 inches) in diameter and consists of a copper tube, wound from 40 s.w.g. enamelled copper wire, covered with a 'lossy' dielectric and encased in a steel tube. The microwave energy is transmitted along the guide in what is called the TE_{01} mode which roughly means that the energy travels around circumference of the tube. Initial work is being carried out between 30 and 50GHz with transmission rates of 500M bits per second. Later these figures will be raised to 90GHz with up to a 2G bits per second and later to 110GHz. In terms of information carrying capacity this means about a third of a million two-way telephone calls or 200 two-way television channels or the equivalent in computer data. It was stated that if the system is employed on the British trunk routes a cost saving of one third to one quarter over normal methods per channel would result. However really this is rather a 'pie in the sky' figure because it assumes that the whole capacity of the guide is used all of the time and there are not many routes on which this could be achieved for quite a long time to come.

A technician at Martlesham making an experimental 3m long section of 50mm wave guide. A mandril has been wound with a coil of 40 s.w.g. enamelled copper wire. The machine is winding glass wool, which is steeped in epoxy resin with a powdered iron content, over the copper.



There are a lot of problems to be overcome before the waveguide can be employed—which will probably be towards the end of this decade. One of these is due to temperature changes causing the guide to buckle or snake, because of internal expansion and contractions, changing its characteristics.

While at Martlesham the opportunity was taken to have a quick look round the cable research department where work is going on on 60MHz cable systems, amongst other things. One cable contains eighteen coaxial ways, or tubes, each with a 60MHz bandwidth; such a cable will provide 97,200 telephone circuits between London and Birmingham in 1973. Exploratory measurements will be made on cables at up to 1 or 2GHz and we saw the partly completed prototype of a gain, loss and group delay measuring set with an accuracy of a thousandth of a dB at a few tens of MHz falling to a dB or so at 1GHz. The instrument employs high performance coaxial changeover switches using mercury wetted relays which can switch 1GHz signals. These switches are the result of a great deal of design development effort carried out when the group were at Dollis Hill.

Circular waveguides and coaxial cables are not in competition with one another because, when one comes to think about it, they are really complementary.

It is probable, in our estimation, that the circular waveguides will be used to carry inter-city communications and the waveguide runs will be along railway lines and motorways where maximum advantage can be taken of the long straight runs and gentle curves. At the outskirts of the cities wideband coaxial systems will take over to distribute the data to its various destinations as it would be uneconomic to employ circular waveguides in cities. Not only would sharp bends in the waveguide be necessary, not a good thing, but how many of the destinations would be able to take full advantage of the bandwidth of a circular waveguide? Smaller towns and villages would also be fed by coaxial systems.

Nothing has been said about optical waveguides which are also the subject of work at Martlesham. These are a step further on and will probably not be used on the scale we are talking about here in this decade, so that's another story.

New dielectric

Mervyn Geoffrey Harwood, a research scientist at the Mullard Central Materials Laboratory, Mitcham, has developed, with the support of the Ministry of Technology, a doped form of titanium oxide that has a wide range of properties depending on subsequent treatment. For example, one process produces a semiconductor material with a high temperature coefficient and a permittivity of about one million; another forms a dielectric with a permittivity of about 100 but having much lower losses and greater stability than other materials with a comparable permittivity; and careful treatment of the material can give it any resistivity value in the range 10^{-5} to $10^{12}\Omega$ cm.

The new material can be used to make capacitors that are more stable, have lower losses and, consequently, a longer life than present capacitors containing a titanium oxide dielectric. The improved stability will enable this type of capacitor to be produced with closer tolerances. Furthermore, it could be deposited on silicon chips to provide integrated circuits with built-in, high-value capacitances. The material is also particularly suitable for use in the manufacture of ballast resistors.

Titanium oxide, known to capacitor manufacturers as rutile, is widely used in small capacitors because of its high permittivity. The marked anistropy of single crystals makes it difficult to achieve consistent results and manufacture capacitances with close tolerances.

Pure rutile also has the disadvantage of not being very stable. Investigations have shown that single crystals at a temperature of 150°C and under a direct potential gradient of 100V/mm in one direction (001) rapidly break down after one minute. Stability in other directions (100) and (110) although better is not good.

Harwood has overcome these drawbacks by introducing small amounts of niobium and other elements into the lattice of the titanium crystal. Niobium in concentrations of 150 parts per million greatly increases the stability of the material, and a concentration of 250 parts per million has the added advantage of producing a marked reduction in the a.c. losses.

Under tests, the resistivity of the new material remained constant at $10^{12}\Omega$ cm for many months while subject to a voltage stress of 1kV/mm. Capacitors made with it in a ceramic form have a corresponding increase in capacitance stability.

Skynet-2 contract

Higher powered satellites for operation in the defence satellite system Skynet are to be developed by G.E.C.-Marconi Electronics Ltd with Philco-Ford, Palo Alto, California, who built the first Skynet satellites, as the principal sub-contractors.

Continuous semiconductor lasers

Two research organizations, S.T.L. in the U.K. and Bell Labs in America, have made simultaneous announcements of semiconductor lasers capable of continuous operation at room temperature. These devices are extremely small and are intended mainly for use with optical waveguides in wideband transmission systems.

Both devices are double heterostructure diodes constructed from four layers of gallium arsenide alternating with gallium aluminium arsenide. The American laser has a threshold current of 2700A/cm² and an output of 20mW while that at S.T.L. has a threshold current of 1000A/cm² and an output of 10mW.

Education in c.a.d.

Redac Software Ltd is now offering three electronics design programmes suitable for initial education in computer-aided design. These programmes are for general circuit analysis (REDAP 1), d.c. analysis (REDAP 15), and non-linear transient analysis (REDAP 16) of electronic circuits.

The cost of this educational package is £500, claimed to be a fraction of the current market price of even one programme. The package consists of Algol source-code programmes, together with 20 copies of the relevant REDAC user's manual, REDAC is making this offer to assist in electronics education and to allow universities, colleges, and other educational establishments to provide their students with the opportunity to use computer-aided-design as early in their careers as possible.

Science Research Council report

The Science Research Council's report* for the year 1969-70 expresses concern at the uncertainty in the Government's budgeting policy. 'What is really needed', says professor Sir Brian Flowers—chairman of S.R.C. 'is a guaranteed growth rate for incoming funds for ten years ahead.' This would enable the S.R.C. to plan ahead with more certainty. However, the chairman thought that probably a more realistic approach would be to link S.R.C's growth rate to the science based industries it was serving rather than to the gross national product.

Capital spending on S.R.C. projects is now only 5.5% of income compared with over 16% in 1965-66; a fall of £2M from £6M.

Failure to spend money now on research would be felt, not now, but in ten years' time, said professor Flowers.

Professor Flowers thought that the last Government's decision not to participate in the design and construction of a European 300GeV proton synchrotron should be reversed. Other projects with the veil of uncertainty hanging over them mentioned by professor Flowers are a £12M high flux beam reactor, the £5M Jodrell Bank radiotelescope and the U.K.5 research satellite.

An announcement was made that South Africa and the U.K. are going to amalgamate their astronomy research facilities in South Africa at a new observatory at Karoo, near Sutherland.

*H.M.S.O. 8s 6d

N.A.S.A. go metric

The American National Aeronautics and Space Administration have issued a directive which says that all technical scientific publications will, from November 14th, use the metric system (Systeme Internationale or S.I. units). This will probably mean that the remainder of American industry will follow suit in due course making the S.I. system truly international.

By Jupiter! What a dish

A massive 210ft diameter parabolic aerial supported on a concrete pedestal and a tracery of steel will soon appear on the skyline at Madrid in Spain. It will be the third in America's National Aeronautics and Space Administration's deep space tracking network designed to make it possible to monitor space probes twenty-four hours a day to the outer limits of the solar system. The first 210ft dish, and the only one of the trio in operation, was built in 1966 in Goldstone, California.

At the second site, at Tidbinbilla in Australia, the 60ft deep foundation has been filled with concrete and the base is nearly completed. The Madrid aerial will not need such a deep foundation because there is a bed of rock below the surface.

The network will be operational by 1973 in time for the flight of the spacecraft Pioneer-F which will pass near to the planet Jupiter.

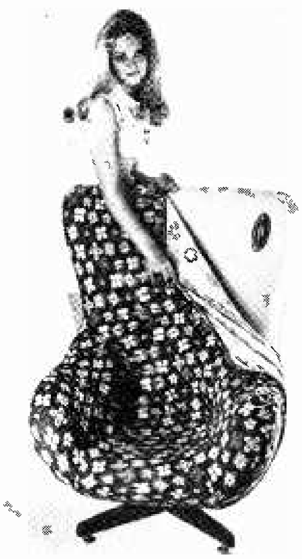
Satellite contract

The Space Systems Group of the British Aircraft Corporation has received a $1M contract from Hughes Aircraft Company for the manufacture of sub-systems for the Intelsat-4 satellites F5 to F8. BAC are at present preparing similar equipment for the F2 and 4 models.

Dated data

The range of techniques available to publicity seekers is quite varied. There are some, perhaps short of something to write about, who will go through a catalogue and write about something they think, one supposes, will hoodwink editors. No doubt this works a lot of the time. One of the worst cases we have seen recently was the announcement of a range of avalanche rectifier diodes from General Instrument. A press release from the company's publicity agents claims this is a new range. Our records show that devices electrically identical with those described in the press release were available in 1965!

London
Audio Fair Exhibitors



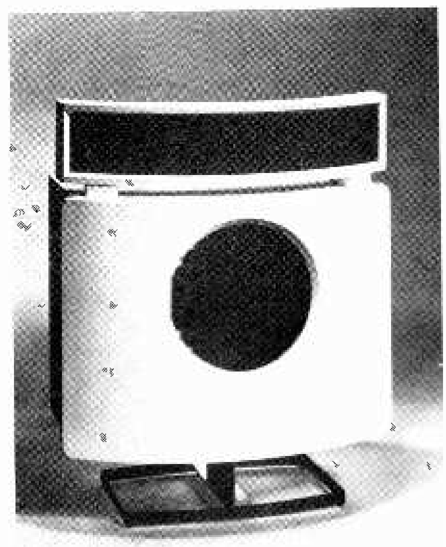
The Elisabethan Audio Chair—sonically somewhere in between headphones and bookshelf speakers.

The Audio & Music Fair at Olympia will be open to the public between 10 a.m. and 9 p.m. from Tuesday 20th to Saturday 24th October. The admission price is 5s. A list of exhibitors is given below.

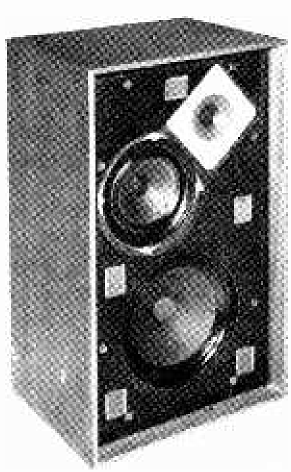
Details of the demonstrations and presentations were given in last month's issue. Any visitor to our stand may obtain a ticket for the day's *Wireless World* lecture demonstration. Each ticket will admit one person, and 350 will be available for each session. The common theme of these lecture demonstrations is 'what is fidelity in sound reproduction?'

The lecturers will be: Jack Dinsdale (Tuesday), Peter Baxandall (Wednesday), Arthur Bailey (Thursday), John Linsley Hood (Friday), and Ted Jordan (Saturday). These designers have made, and are still making, significant contributions in the development of audio equipment in this country.

Acoustical Manufacturing Co.
AEG (GB)
Akai Electric Co.
Alba (Radio & Television)
Armstrong Audio
Arrow Tabs
Audix B. B.
Bang & Olufsen
BASF (UK)
B.B.C.
Bell & Howell
Billboard Publications
Bosch
B & W Electronics
British Radio Corporation
BSR
Decca Record Co.
Denham & Morley
Diamond Stylus
Dynatron Radio
EMI Electronics
Farnell-Tandberg
Fed. Brit. Tape Recording
Feldon Recording Co.
Ferrograph Co.
Garrard Engineering
General Gramophone Publications
Goldring Manufacturing Co.
Goodmans Loudspeakers
Grundig (GB)
Hacker Radio
Hansom Books
Hammond. C. E., & Co.
Haymarket Press
Heath (Gloucester)
Highgate Acoustics
Howland West
I.P.C.
ITT Consumer Products
KEF Electronics
Kellar
Leak. H. J., & Co.
Lee Products
Link House Publications
Markovits, I.
Metrosound Sales
Minnesota Mining & Mfg. Co.
Mordaunt-Short
Morris, B. H.
Mullard
Multicore Solders
National Radio
National Westminster Bank
Philips Electrical
Philips Records
Power Judd & Co.
Practical Electronics
Precision Tapes
Protecta Systems
Pye Records
Radio London
Rank Wharfedale
Reslosound
Rogers Developments
Rola Celestion
Sanyo-Marubeni (UK)
Sharp Electronics
Shuro (UK)
Shure Electronics
Silber, J. J.
Sinclair Radionics
S.M.E.
Soho Record Co.
Sonab
Sony UK Division
Sugden A. R. & Co.
Tannoy Products
Tape Music Distributors
Transcriptors
United Dominions Trust
Vernitron
Whiteley Electrical Radio
Wireless World

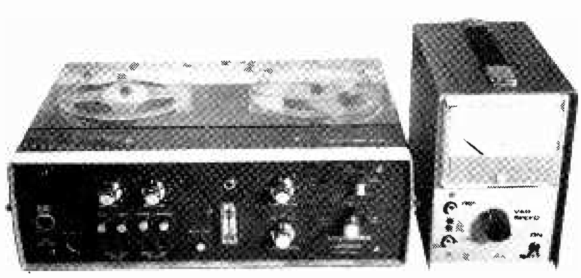


Satin white continental version of the DM70 speaker from Bower and Wilkins—employing moving-coil and electrostatic drivers.



The MSO77 'bookshelf' speaker from Mordaunt Short with a specified frequency range of 40 Hz-20 kHz.

Farnell-Tandberg's Sound Film System provides for those 'wanting to produce sound films with perfect synchronization'.



The Design and Use of Moving-coil Loudspeaker Units

A survey of facts and current theories

by E. J. Jordan

What is the aim of a loudspeaker? "To reproduce the electrical input signal as accurately as possible"! Try again. "To reproduce the original sound as realistically as possible"! The first is an objective definition, the second is subjective and much more appropriate for the following reason. No loudspeaker is perfect and distortion of the following kinds will always occur to some degree—frequency, transient, harmonic intermodulation, and phase.

Now it is often possible for the loudspeaker engineer to trade an increase in one kind of distortion for a reduction in another. How does he determine a balance? To add to the confusion the ear is much more sensitive to some kinds of distortion than others, and sensitivity varies with the individual, so we are back to the second subjective definition. But again this has its drawbacks. Some loudspeakers can achieve a breathtaking reality but only with certain inputs and in particular environments. They have what I would call *prima donna* temperaments. On the other hand, many modern loudspeakers rarely allow the listener to escape from the fact that the sound is "canned" but most of the time they are more than just acceptable and rarely intolerable. (Most of the monitor loudspeakers I have heard fit this category.) These two extremes are quoted to further illustrate the problem of defining the aim of a loudspeaker and until this is done, we cannot begin to discuss the design.—"The aim of a loudspeaker is to make money"! Now we're getting there. One may regret that loudspeaker manufacturers are not altruistic missionaries, but getting things into their right perspective we can now state "The aim of a loudspeaker is to provide a standard of quality judged by the widest possible market as providing the highest degree of realism, when fed from the signal sources available, consistent with economic viability." This means that the greatest number of people get the best value for money—so there is a measure of altruism after all.

To meet the above criteria a loudspeaker must always have its distortions in *balance.* The more expensive a loudspeaker the lower should be the various types of distortion—*but still in balance.* A loudspeaker costing the earth and sporting a very wide bandwidth will be most unacceptable if there is not for example an appropriate reduction

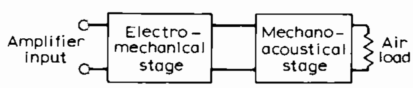


Fig. 1. The loudspeaker as a two-stage energy converter.

in transient and intermodulation distortion.

How then can we design to meet criteria that are so subjective? The road to loudspeaker design starts off with precise mathematical analysis: further along we have to rely on well established theory which itself reduces speculation, and finally we have the engineers "feel" for the subject—pure artistry!

Although we may have the most advanced equipment to help us on the way, in the end we must make the final analysis with the help only of a pair of experienced ears coupled to an open mind.

Objective analysis

The loudspeaker may be regarded as a two-stage energy converter. It converts electrical energy to mechanical energy, and this to acoustical energy as depicted in Fig. 1.

The overall conversion must be effected with the maximum efficiency and minimum distortion. (Distortion is used here in the general sense).

One prerequisite would appear to be to match the load impedance to that of the generator. In practice this can only be achieved over a restricted frequency range but is nevertheless very relevant.

Opening up the boxes in Fig. 1 we have the circuits in Figs 2(a) and (b). Circuit (a) is how the system appears from the point of view of the air load on the cone and (b) shows it as seen by the amplifier. In both cases mechanical and acoustical components are represented by electrical symbols.

Radiation impedance

For the purpose of this article the loudspeaker is assumed to be on an infinite baffle. The air load appears in Fig. 2(a) as a mechanical impedance on the cone surfaces and is represented by the radiation resistance R_{MA} and the radiation mass L_{MA} in series. Unlike true electrical components, however, both these components vary strangely with frequency. This is shown in Fig. 3 and full expressions for these are developed in Appendix 1. It is also shown that the sound distribution pattern changes, becoming more directional at high frequencies.

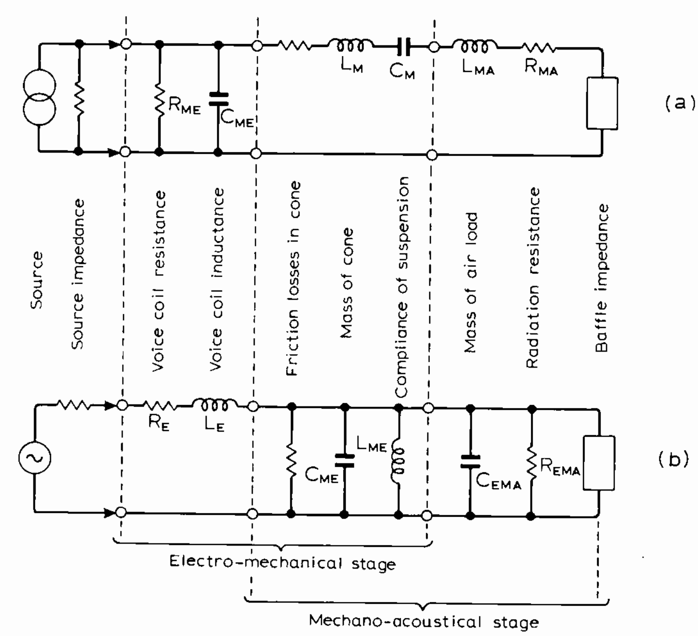


Fig. 2. The effective speaker circuit as seen (a) by the air and (b) by the amplifier.

In the case of moving-coil systems the radiation mass may be neglected since it appears in series with and is very much less than the mechanical mass of the cone L_{MA}.

The radiation resistance R_{MA} is the component in which we actually develop the sound power P_{MA}. This is given by the mechanical equivalent of Ohm's law

$$P_{MA} = v^2 R_{MA}$$

where v is the velocity of motion. From Appendix 1 we see that the value of R_{MA} is determined by the dimensions of the cone, the frequency, and a constant due to the air. The frequency at which the knee in the curve occurs is determined by the cone diameter. Fig. 4 shows normalized curves for 12-in., 8-in. and 4-in. diameter cones.

For arithmetic convenience the sloping part of the curve and the horizontal part are treated separately and have their own approximate equations. From the appendix it is seen that over the sloping part R_{MA} is proportional to f^2 and the horizontal part is independent of f.

Mechanical impedance of cone assembly

The components of the impedance are shown in Fig. 2(a) and comprise the cone mass L_M, the suspension compliance C_M and some frictional losses R_M. The most significant resistive component however is usually due to the voice-coil resistance R_E in series

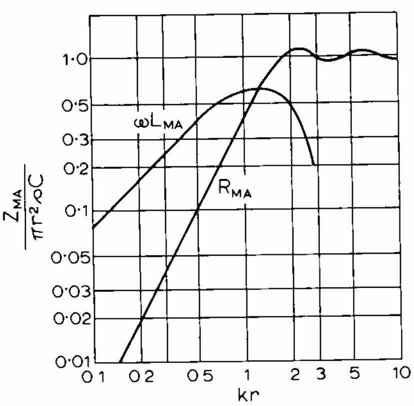


Fig. 3. Mechanical impedance of the air load on a piston surface in an infinite baffle.

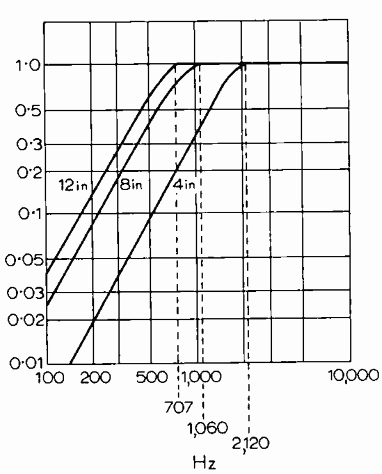


Fig. 4. Normalized R_{MA} curves for cones of 12, 8 and 4 in. diameter.

with its inductance L_E and the amplifier output resistance (which is negligible). From the derivations in Appendix 2 these series electrical components appear as parallel mechanical components R_{ME} and L_{ME} connected via the transducing element in series with the remaining mechanical components. The lower the actual electrical resistance the higher will be the effective mechanical resistance corresponding to it.

Effect of mechanical impedance on radiated power

In general the overall mechanical impedance of the cone is very much higher than that of the air load so the velocity corresponding to the current in Fig. 2(a) will be determined almost entirely by the cone. We will examine the effects of each of the cone components in turn, assuming for the moment the cone is perfectly rigid. Consider first the cone mass L_M. The velocity v is given by

$$v = \frac{F}{2\pi f L_M},$$

where F is the applied force.

Therefore radiated power is

$$P_{MA} = \frac{F^2}{4\pi^2 f^2 L_M{}^2} \cdot R_{MA}$$

Over the sloping part $R_{MA} \propto f^2$

$$\therefore\ P_{MA} \propto \frac{1}{f^2} \cdot f^2$$

i.e. P_{MA} is independent of frequency.

Over the horizontal part R_{MA} is constant with frequency.

$$\therefore\ P_{MA} \propto \frac{1}{f^2} \cdot \text{const}$$

i.e. P_{MA} falls at the rate of 12 dB/octave.

This is shown in Fig. 5(a) and is known as the condition of mass control. Due to directivity effects the axial pressure response may tend to remain constant or even rise but this will be accompanied by a greater rate of fall off axis.

With very high damping factors the resistance R_{ME} may tend to be in control. In this case:

$$P_{MA} = \frac{F^2}{R_{ME}{}^2} \cdot R_{MA}$$

Over the sloping part of R_{MA}

$$P_{MA} \propto \text{const}\,.f^2$$

i.e. P_{MA} rises at 12 dB/octave.

Over the horizontal part of R_{MA}

$$P_{MA} \propto \text{const}\,.\,\text{const}$$

i.e. P_{MA} is independent of frequency.

This is shown in Fig. 5(b) and is known as the condition of constant velocity.

By similar reasoning if the suspension stiffness were in control.

$$P_{MA} = f^2 4\pi^2 f^2 C_M{}^2 \,.\, R_{MA}$$

Over the sloping part of R_{MA}

$$P_{MA} \propto f^2 . f^2$$

i.e. P_{MA} rises at 24 dB/octave.

Over the horizontal part of R_{MA}

$$P_{MA} \propto f^2 \text{ const}$$

i.e. P_{MA} rises at 12 dB/octave.

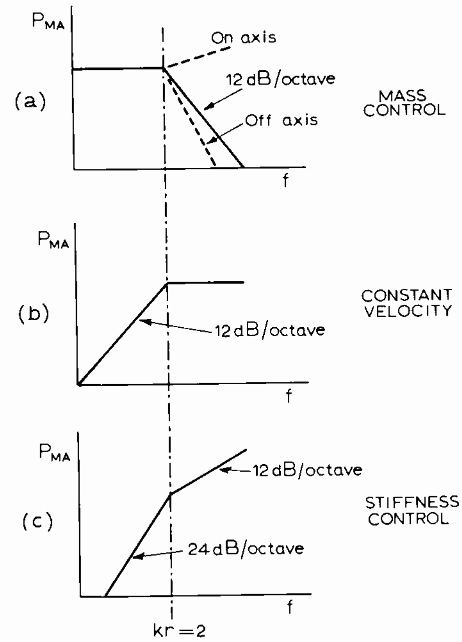


Fig. 5. Effect of mechanical impedance on radiated power assuming a rigid piston in an infinite baffle.

This is the condition of stiffness control and is represented in Fig. 5(c). This is a situation not normally encountered.

Observations (1). From this part of the work it is seen that in order to maintain a constant radiated power over the entire audio frequency range we may:

(a) Have mass control below the knee and constant velocity above it.

(b) Utilize the natural tendency for a practical cone to reduce its effective diameter as frequency rises.

(c) Use crossover techniques to bring into operation progressively smaller loudspeaker units as frequency rises.

In order to achieve (a) the cone would have to be infinitely rigid which is impossible. Method (b) relies on the fact that the cone is not infinitely rigid, and is therefore practicable. (c) is of course practicable. So we have two practicable solutions which we will discuss in detail later.

The transducing element

This is the part of the system which actually converts the electrical energy into mechanical and comprises the magnet and the voice coil. In one sense it behaves like a transformer having a turns ratio of $Bl:l$, where B is the magnetic flux density and l is the length of wire in the magnetic gap. Its other characteristic is that it inverts impedances. For example the mechanical damping resistance R_{ME} is related to the electrical resistance R_E by

$$R_{ME} \propto \frac{B^2 l^2}{R_E}$$

The full derivation is given in Appendix 2 and it will be seen that series inductors on one side of the transducer will appear as parallel capacitors on the other and vice versa. This is illustrated by the difference in the circuits Figs. 2(a) and 2(b) and can be demonstrated by two practical effects.

(1) If the electrical impedance is noted at some low frequency and the cone is then touched, reducing its motion, the electrical impedance will be seen to *decrease* as a result of the *increase* in mechanical impedance.
(2) At resonance the cone velocity reaches maximum, indicating a minimum mechanical impedance characteristic of a *series LCR* circuit. The electrical impedance however will rise to a maximum characteristic of a *parallel LCR* circuit.

Regarded as an impedance-matching component the transducing element at a low frequency will have an optimum value for *Bl*. This should be such as to ensure that the cone maintains the condition of mass control down to the resonance of the system i.e. where the mass reactance of the cone equals the stiffness reactance of the suspension. This implies that for infinite baffle loading the Q of this resonance is unity. Often a Q of 0·5 is preferred since this gives the truly non-oscillatory condition and therefore secures the optimum transient performance. Also the mid and treble range efficiency is doubled. There is a 3 dB loss at the lowest working frequency but this is an acceptable sacrifice. The mechanical circuit Q is given by:

$$Q_M = \frac{2\pi f L_M}{R_M}$$

If R is mainly due to:

$$\frac{B^2 l^2}{10^9 R_E}$$

$$Q_M = \frac{2\pi f L_M R_E}{B^2 l^2} \cdot 10^9$$

$$Bl = \sqrt{\frac{2\pi f L_M R_E}{Q_M} \cdot 10^9}$$

Units are given in Appendix 1.

The design of the coil and magnet system should be determined by the above expression. The value chosen for $Q_M l$ will in fact be determined by the type of loading used but the aim will be the same, i.e. to maintain an overall system Q of between 0·5 and unity.

Observations (2). There is no advantage whatever to be had from a value of *Bl* greater than that above. Although mid- and high-frequency efficiency will be further increased this will be at the expense of the low frequency efficiency. The resulting "tilt" in the response may give a subjective impression of a better high-frequency transient response. In fact the transient performance at these frequencies is determined by quite different factors and is virtually unaffected by the value of *Bl*. In the case of all vented enclosure systems either increasing or decreasing *Bl* away from its optimum value will actually worsen the l.f. transient performance. This will be made clear in the next article.

In our Q calculations we used R_E to represent the electrical resistance of the voice coil and have ignored the output resistance of the amplifier which appears in series with it. The reason is that this is normally many times smaller than R_E. Some amplifier manufacturers make this resistance variable but if this *is* much less than R_E its precise value is of no consequence. If it is not much less than R_E then it is a very poor amplifier.

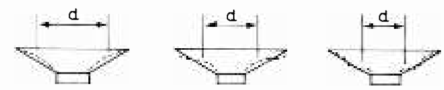


Fig. 6. Concentric flexure resulting in a reduction in effective cone diameter as frequency rises.

Loudspeaker cones

The foregoing analysis is restricted to the sloping part of the R_{MA} curve where it may be reasonably assumed that the cone will work as a substantially rigid piston. At higher frequencies however this is not so and the cone moves with different amplitudes and phase over different parts of its surface. It is this fact which enables a single cone loudspeaker to operate over a wide frequency range instead of falling at 12 dB/octave at above the R_{MA} knee as shown for the theoretical rigid piston in Fig. 5(a). Fig. 6 shows how a cone flexes concentrically at various high frequencies where the side of the cone becomes comparable to, or longer than, a wavelength. If we can assume that the incident wave is attenuated as it travels up the cone it will be seen that the effective cone diameter d reduces as frequency is raised.

Above the knee $R_{MA} \propto A \propto d^2$

Cone mass $L_M \propto A \propto d^2$

Radiated power $P_{MA} = v^2 R_{MA} \propto \frac{1}{d^4} \cdot d^2$

Therefore the reducing effective diameter tends to increase the radiated power as frequency rises thereby offsetting the condition in Fig. 5(a) and at the same time it broadens the polar response, this being a function of d (Appendix 1). It is readily possible by careful cone design to use this feature.

Another type of cone flexure is radial or bell-mode, shown in Fig. 7. This flexure can result in a very irregular frequency response

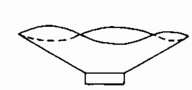


Fig. 7. Radial flexure or bell modes.

and transient ringing. This is particularly prevalent in straight sided cones but much less significant in sharply curved cones and can be virtually eliminated.

Observations (3). An interesting result occurs if we apply the above simple arithmetic proportionality argument to the situation below the R_{MA} knee.

Below the knee $R_{MA} \propto A^2 \propto d^4$

Cone mass $L_M \propto A \propto d^2$

Radiated power $P_{MA} = v^2 R_{MA} \propto \frac{1}{d^4} \cdot d^4$

This indicates that for a given cone material and a given applied force, the radiated power at low frequencies is independent of the cone diameter. However, there are two other considerations. If we use a smaller diameter cone we can for the same material reduce its thickness proportionally. Therefore:

$$\text{Cone Mass } L_M \propto d^3$$

Further we saw that to maintain the correct Q value

$$Bl \text{ (and therefore the force)} \propto \sqrt{L_M} \propto d^{1 \cdot 5}$$

$$\therefore \text{ radiated power } P_{MA} \propto \frac{d^{1 \cdot 5}}{d^6} \cdot d^4 \propto \frac{1}{\sqrt{d}}$$

which indicates that the *smaller* the cone the *more efficient* it is at low frequencies.

The problem here is that to maintain the same radiated power one would expect that the cone displacement would increase in inverse proportion to the cone area. A few people imagining cone displacements of 2–3 in have cried "doppler distortion".

Now doppler distortion in this context, along with the Loch Ness monster, flying saucers and the Yeti, has provided a small band of devotees with an interest in life whilst the vast majority of people have been unaware of it. I am far too open minded to say these things do not exist. I can only say that after devoting a quarter of a century to the design and development of loudspeakers I have yet to encounter any significant distortion due to doppler effect. In any case with the far more efficient loading techniques practicable with small cones displacement need not normally exceed ±0·125 in so the problem does not arise.

The single-cone loudspeaker

In order to achieve an extended coverage of the audio frequency range the cone needs to have a flared profile of hyperbolic form with the correct rate of flare. The effective reduction of area with increasing frequency can be arranged to compensate not only for the condition in Fig. 5(a) but also for the rising inductive reactance of the voice coil. The high-frequency limit of extension is approached when the reducing effective mass of the cone becomes comparable with the mass of the voice coil. There tends to be an efficiency maximum when these two are equal. In the case of the straight-sided cone the reduction of area is too rapid with the result that the output rises until again the effective cone mass equals the voice coil mass. The output then falls. This gives the peak usually around 5000 Hz, characteristic of these cones.

Polar distribution

This is very important. A level on-axis frequency response is quite useless if the off-axis response is falling. If the ear is to experience an adequate high-frequency performance this must be maintained off axis. Having said this however, we can add that for normal domestic applications a response that is maintained through a polar angle of about 60° is perfectly adequate. With the loudspeakers placed in their usual corner positions it would be unusual to find oneself listening outside this angle.

In this respect I would regard as excellent any loudspeaker that maintained a level treble response to 15 kHz or beyond at an angle of 30° off axis. I would also regard this as proving to be of much greater overall significance than the axial response since it gives a far better indication of h.f. power bandwidth.

Since the upper limit of the h.f. response is set by the voice-coil mass this must be kept as low as possible, consistent with reasonable efficiency. This compromise is usually resolved by the use of a very large magnet having a deep gap in which is immersed a short coil.

The cone diameter should be chosen so that the knee of the R_{MA} curve coincides with the effective area reduction.

The cone material poses some interesting problems. In general it needs to have a high stiffness-to-weight ratio and ideally a fairly high degree of internal friction. However, there is considerable likelihood that the normal mass, stiffness and internal friction properties of a material are vastly different when seen by a wave travelling in the material. Not only may these properties vary in a complex manner with frequency but also with amplitude. These problems started to interest me with the development of the titanium cone which provides much higher subjective definition than a corresponding aluminium cone. At the time of writing my article for the November 1966 issue of *Wireless World*† I was unable to find an adequate explanation for this in terms of the normally measured parameters.

The likely explanation, which has since emerged, is that after the incidence of any waveform the cone material must restore immediately to its original static position. The very soft material from which the aluminium cone was made had almost no elasticity so the cone was not fully restoring. This is a hysteresis effect and is particularly significant in materials where the internal friction is high compared with the material stiffness. Most mechanical damping materials exhibit a high degree of hysteresis.

Hysteretic distortion is a particularly insidious form of distortion upsetting frequency and transient response, and producing harmonic and intermodulation distortion. Usually the objective measurement of any one of these does not give any significant indication of hysteretic distortion but its combined effect on all these factors can make a complete mess of the subjective performance. Very often when faced with a resonant diaphragm it is tempting to apply some "gungy" damping material. This may certainly kill the ringing to the satisfaction of objective pulse tests. However, the resulting hysteretic distortion usually makes the subjective performance very much worse. Generally speaking hysteretic distortion is lower in metals than in papers, plastics or rubbers. These comments are applicable to all electromechanical transducers.

The cone surround is in every respect as important as the cone itself, in the effects it can have on sound quality. It has to

1. provide a highly flexible support for the cone edge;
2. provide an acoustically opaque seal to the enclosure;
3. completely absorb the incident concentric waves travelling up the cone at high frequencies; and
4. be completely non resonant.

A suitable surround material will have high density, high internal friction and be extremely soft and flexible. One of the best materials is highly plasticized p.v.c. sheeting but this is not a stable material. Various acrylic coatings on to polyurethane foam are being used with moderate success but application is difficult in production since a precise degree of impregnation is required.

There has just become available a new coating material which has precisely the right properties and is remarkably good for this application. Coated on to almost any speaker the improvement in treble smoothness is quite noticeable. The coating is very stable over very wide temperature ranges and completely waterproof. Further the quantity and method of application is not critical. A patent may be taken out on this application.

Observations (4). The single-cone high-quality loudspeaker has a great deal of objective argument in favour of it. Subjectively the approach can provide a sound quality that is outstanding, clean and well defined. Such loudspeakers can sometimes sound unkind on certain inputs and they have been criticized particularly by the American market as having inadequate power bandwidth. Further, the manufacturing processes are critical and unless close attention is paid to detail large variations between units and unreliability can result. I have often had the comment made to me, "Ted, the single cone loudspeakers are so very nearly right if only . . . etc."

According by request I have produced the design of a single cone loudspeaker which whilst broadly similar to previous units embraces a number of significant improvements. The high-frequency power response has been made smoother and more extended by redesign of cone and coil. The voice coil is both lighter and more efficient.

The radiated power at very low frequencies has also been very considerably increased by the use of a new type of loading. The power bandwidth is exceptionally wide. The overall performance has been balanced to provide a high standard of quality from first class inputs and an acceptable performance from indifferent inputs. The manufacturing processes have also been simplified with, it is hoped, an increase in repeatability and reliability. This loudspeaker is being manufactured by Audio Sound Techniques, of Leicester.

Cross-over systems

The alternative approach to securing a wide power bandwidth is to use separate loudspeaker units to cover discrete parts of the frequency range. A great deal of the loudspeaker design considerations already discussed apply also to the units used in crossover systems. It would seem to be a fundamental truism to say that it is a retrograde step to use two or more loudspeakers with their associated crossover matrices if one unit could do the job. Therefore, we must examine the areas in which this approach is justified.

The most significant advantage to be secured by crossover systems is that due to the fact that the bass unit cone can be large and massive, the low-frequency power-handling capacity may be extremely high. This is to some extent offset by the reduced efficiency which we have seen is characteristic of large heavy cones, but in many markets, particularly in the States where very high powered amplifiers are often used, the ability of a loudspeaker to handle these power levels without damage or noticeable distortion is of paramount importance.

The design of bass driver units follows exactly the same principles that we have already discussed. Their frequency range is normally limited to frequencies well below the knee of the R_{MA} curve, so that they should operate in the mass-control condition with the *Bl* factor determined as before. Since the cones are not required to flex they are constructed of either extremely thick hard paper or very often are formed solid from expanded polystyrene. This is sometimes coated with an aluminium skin to increase the rigidity but while it may do so as far as static forces are concerned it makes little difference to the rigidity as seen by oscillatory and transient forces. The adhesive used to stick the aluminium, however, may serve as a useful damping medium to the polystyrene which is highly resonant.

Mid-range units are usually more conventional cones since these are often required to straddle the knee of the R_{MA} curve and therefore need to flex in the way we have described.

For the high frequencies-plastic-domed tweeters are popular. Again the dimensions and frequency range of these is such as to straddle the R_{MA} knee, and while such tweeters may be perfectly satisfactory on the slope of the R_{MA} curve they may experience difficulty with the range above the knee where flexure is required. If a cone or diaphragm is to flex, it must have the form of a transmission line where the force is applied at one end and the correct termination is applied at the other. In the case of a cone, the coil applies force in the centre and the surround provides the termination at the edge. The dome tweeter cannot meet these conditions, so any damping must be as a result of the internal friction of the material and since, in the case of plastics this is likely to be hysteretic, we may have a potentially unsatisfactory situation.

Both ionic and push-pull electrostatic tweeters are used in currently available crossover systems and these provide excellent high-frequency performances.

Crossover matrix design must be carried out experimentally. The use of formulae expressing the various values of inductance and capacitance in terms of crossover frequency and nominal impedance is unsatisfactory since the amplifier impedance is nearly zero and the impedance of moving-coil units is complex (Fig. 2b).

†E. J. Jordan, "Titanium Cone Loudspeaker," *Wireless World*, Nov. 1966.

The use of iron and ferrite cored inductors is undesirable. Any such core exhibits a high degree of hysteresis. The voltage developed across a ferrous cored inductor will only follow the applied voltage if this is derived from a zero impedance source. In the case of output transformers in valve amplifiers this condition can be met but with crossover systems it is not; the inductors will eventually have other impedances in series with them. The resulting hysteretic distortion can result in a complete loss of sound definition. Once again objective testing may not reveal the problem. A further point to watch is that at any significant power level a ferrous cone may be driven readily into saturation.

Observations (5). The development of a really good crossover system is not easy. In addition to the problems discussed above there is the difficulty of phase differences due to the physical spacing between units. Further, at the crossover frequency the voltage across one unit will be in phase advance the other in phase retard according to the matrix and also there is inevitably a step in the radiated power and/or polar response at the crossover frequency. These factors do not help the production of firm transient wavefronts.

I am also of the opinion that the majority of manufacturers of crossover type systems do not make full use of the potential advantages of the technique. The relative dimensions of the constituent units and the choice of crossover frequencies ought to be closely related. Instead they often appear to be chosen at random.

In spite of the many intrinsic problems good crossover systems can be designed and the problems can be overcome. A design could be provided, for example, which would provide mass controlled piston operation throughout its entire frequency range.

Conclusions

We have reached a stage in the art where the basic distortion forms can be objectively measured and dealt with. Given an engineer with some feeling for his work, loudspeakers can be produced which very adequately satisfy objective measurement and provide a very pleasant sound. One may be tempted to say that this is the end of the matter. From a purely commercial point of view it probably is and loudspeaker manufacturers may well wish to leave it at that. However, sooner or later someone is going to rock the boat. (Me for example).

Peter Walker caused a bit of a panic in the fifties with the full-range electrostatic loudspeaker. Every loudspeaker manufacturer frantically tried to catch him. However it was soon discovered that as a commercial proposition this approach was not on for the big boys. It was also discovered that you could not hit it with 35 W of sinewave at 30 Hz—which is a disadvantage in some markets. It is outside the scope of this article to discuss the design technology of the full-range electrostatic loudspeaker in any detail but it is very relevant at this stage to make some mention of its performance. The two particular features of the design are first that the diaphragms are driven equally all over their surfaces—thus tending to provide piston operation throughout the entire frequency range—and secondly, the diaphragms are driven under push-pull constant charge conditions.

Objectively the frequency response is smooth but not apparently better than that of many conventional systems. Non-linearity distortion is acceptably low throughout most of the range but below 100 Hz is higher than normally expected from better class units. As we have already indicated the power bandwidth leaves something to be desired particularly in the extreme bass. The transient response is excellent and the reproduction of square waves is superior to that of any other unit I have measured.

Subjectively the full-range e.s.l. can provide a standard of naturalness and realism not matched by dynamic systems. The high degree of definition and absence of colouration is quite outstanding. A point of particular interest is that these comments about the full range e.s.l. are pretty well universally shared which indicate that if a loudspeaker is good enough, people will agree about it.

The use of a moving-coil bass system and an electrostatic middle and top is the obvious thought to overcome the problem of bass power bandwidth but while this approach can provide a smooth pleasant performance, the definition of detail so apparent in the full-range e.s.l. is, in my experience severely reduced. It is worth noting that whilst the full-range e.s.l. uses a crossover system this is quite different from the type of matrix employed in conventional systems. The only effective reactive component is the leakage inductance of the signal transformer. Since the primary of this transformer is connected directly to the amplifier output and the transformer core is of extremely high-quality hysteretic distortion is minimized.

It seems to me now that the aim of future development should be to achieve the definition standard set by the full-range e.s.l. coupled to the wide-power bandwidth which we have come to associate with American loudspeakers. I, personally feel that this situation is most likely to be resolved for the time being by further development of the single-cone approach coupled to improved loading techniques. I believe I can also see the next major step in loudspeaker development—but that is a story for a later date.

APPENDIX 1

Radiation impedance

Radiation impedance is given by the Bessell series.

$$Z_{MA} = \rho c\pi r^2\left\{\left[\frac{(2kr)^2}{2.4} - \frac{(2kr)^4}{2.4^2.6} + \frac{(2kr)^6}{2.4^2.6^2.8}\cdots\text{etc.}\right] + j\frac{4}{\pi}\left[\frac{2kr}{3} - \frac{(2kr)^3}{3^2.5} + \frac{(2kr)^5}{3^2.5^2.7}\cdots\text{etc.}\right]\right\}$$

where

$$k = \frac{2\pi f}{c} \quad\text{and}\quad c = 3{\cdot}44\times10^4\ \text{cm/sec}$$

From this the following approximate equations can be derived. Below the knee of the curve where $kr \ll 2$

$$R_{MA} \approx \frac{\rho c k^2}{2\pi}(\pi r^2)^2$$

$$X_{MA} \approx \frac{8}{3}\rho c k r^3\ \text{g}$$

where

$$\rho = 1{\cdot}21\times10^{-3}\ \text{g/cc}$$

Above the "knee" of the curve where $kr \gg 2$

$$R_{MA} \approx \rho c\pi r^2\ \text{mech. ohms (g/cm/sec)}$$

$$X_{MA} \approx \frac{2\rho c r}{k}\ \text{g}$$

All the foregoing expressions are for *mechanical* impedance Z_{MA} due to the air load. If the expressions are divided by $(\pi r^2)^2$, $(=A^2)$ we obtain the acoustical impedance Z_A

Directivity

The ratio of pressure p_θ at an angle θ' degrees off axis to the pressure p_0 at the same radial distance on axis is given by

$$\frac{p_\theta}{p_0} = 1 - \frac{kr\sin\theta}{8}.$$

APPENDIX 2

Relationship between mechanical and electrical impedances.

$$e_b = \frac{Blv}{10^8}\ \text{volts}$$

$$v = \frac{\text{Force}}{Z_M} = \frac{Bli}{10Z_M}\ \text{cm/sec}$$

$$\therefore e_b = \frac{B^2l^2i}{10^9 Z_M}$$

Electrical impedance Z_{EM} due to mechanical impedance Z_M is given by

$$Z_{EM} = \frac{e_b}{i} = \frac{B^2l^2}{10^9 Z_M} = \frac{1}{R_M + j\left(\omega L_M - \frac{1}{\omega C_M}\right)}\cdot\frac{B^2l^2}{10^9}$$

From this the following relationships can be derived.

$$R_{EM} = \frac{1}{R_M}\cdot\frac{B^2l^2}{10^9}\ \text{ohms}$$

$$\omega C_{EM} = \omega L_M\cdot\frac{10^9}{B^2l^2}\ \text{mhos}$$

$$\omega L_M = \omega C_M\cdot\frac{B^2l^2}{10^9}\ \text{ohms.}$$

Also

$$Z_{ME} = \frac{1}{Z_E}\cdot\frac{B^2l^2}{10^9}\ \text{mech. ohms (g/cm/sec)}$$

$$R_{ME} = \frac{1}{R_E}\cdot\frac{B^2l^2}{10^9}\ \text{mech. ohms (g/cm/sec)}$$

$$\omega C_{ME} = \omega L_E\cdot\frac{10^9}{B^2l^2}\ \text{mech. mhos (cm/dyne)}$$

$$\omega L_{ME} = \omega C_E\cdot\frac{B^2l^2}{10^9}\ \text{mech. ohms (g/cm/sec).}$$

Tone Control Circuit

Versatile circuit with independent cut and boost controls

by P. B. Hutchinson, B.Sc.

This article describes an extremely versatile yet simple tone control circuit which combines the functions of all tone control circuits known to the author in present use, with the exception of sharp cut-off filters.

The idea of the type of tone control network described has been in the author's mind for some time, and it was publication of the design for a 'Tone balance control' by R. Ambler in the March 1970 issue of *Wireless World,* which made the author decide to try it.

The normal kind of tone control circuit, for example the Baxandall design, has greatest effect at the extremities of the audio spectrum (Fig.1). But often it is desirable to provide correction in mid-band without the severe correction at extreme frequencies. For example, it may be desirable to increase the crispness of speech but without making the sibilants and other high-frequency sounds seem unnaturally boosted. To do this it is necessary to provide treble boost to frequencies in the range say 1kHz to 4kHz, and to then hold the gain constant above 4kHz. An approximation to this can be achieved by using a control such as the one described by R. Ambler. This control is designed to supplement the normal type of tone control network, and to a large extent the characteristics of the two networks overlap.

Another way is to include additional tone controls such as 'middle' and 'presence', similar to treble and bass controls except they operate on different parts of the frequency spectrum.

What is really needed is some sort of tone control in which a level amount of treble or bass boost (or cut) can be applied above or below a certain frequency, and with this frequency and the level of boost (or cut) variable. The circuit to be described achieves this together with certain other useful facilities. Circuit design is greatly simplified by using high-gain linear i.c. amplifier.

Principle

The circuit has four potentiometers (though a simplified version can be made using only two), best named treble boost, treble cut, bass boost, and bass cut, although their functions are slightly different from normal. They each control the 3-dB frequency of a 6dB/octave curve, the direction of the slope being in accordance with the name of the control.

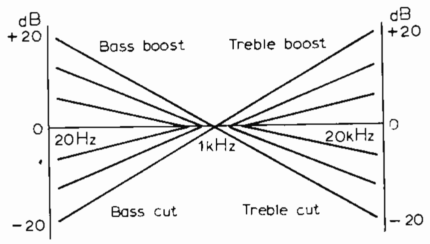


Fig.1. Conventional kind of tone control circuit has greatest effect at spectrum extremities.

As increasing treble boost is applied, with all other controls set flat, the 6dB/octave treble boost curve is brought progressively down the frequency spectrum as shown in Fig.2. In this way one could just boost above say 5kHz, with theoretically 12dB boost at 20kHz, or above say 500Hz with theoretically 36dB boost at 20kHz. The increase in boost with frequency for any given setting is overcome by bringing in a −6dB/octave treble cut. Where the two curves act together, the result is a flat response. This flat portion will be shifted up or down relative to mid-band frequencies by an amount corresponding to the difference between the 3-dB frequencies of the two curves.

In this way, the desired treble boost or cut characteristic can be built up by using the treble boost and cut controls together. A typical resultant curve is shown in Fig.2. The bass controls act in the same way, but at the other end of the audio spectrum.

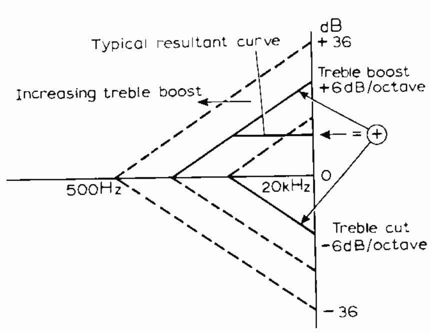


Fig.2. Increasing treble boost with frequency is counteracted by a cut giving a resultant curve as shown.

A particularly important use of this type of bass control is in applying bass boost to compensate for deficiencies in loudspeaker performance at low frequencies. In this case it is required to boost only the frequencies below which the loudspeaker response begins to fall off.

There are three basic sections in the circuit—a variable frequency-selective network in the forward signal path, one in a feedback loop, and an operational amplifier.

Selective networks

In the frequency-selective network shown in Fig.3, C_1, R_1 and RV_1 form a simple

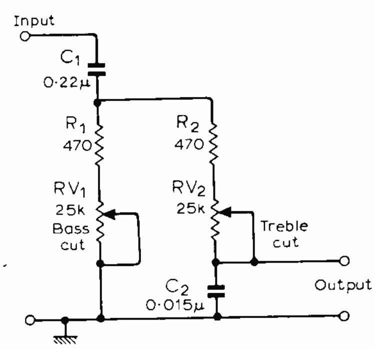


Fig.3. Frequency-selective network used for high- and low-frequency attenuation and, by inserting in a negative feedback loop, for high- and low-frequency accentuation—see Fig.4.

first-order bass cut circuit with a −6dB/octave slope. The 3-dB frequency is given by $1/CR$, where C is the value of C_1 and R is the value of R_1 in series with RV_1. The highest 3-dB frequency is therefore 1.54kHz. and the lowest is 28Hz. The network comprising C_2, R_2, and RV_2, forms a simple first-order treble cut circuit with a −6dB/octave slope. In this case the highest 3-dB frequency is 22.6kHz and the lowest is 415Hz. The network is arranged so that the mid-band response remains constant irrespective of the potentiometer settings, which independently vary the roll-off frequencies of the treble and bass cut slopes.

The control ranges have been made deliberately large and overlapping so that extreme settings of the tone control network could be investigated, although it is realised that such extreme settings (e.g. bass boost operating below 1.5kHz with +36dB boost at 20Hz) will not be needed for most applications. An advantage of having the ranges of the treble and bass controls overlapping is that the slopes can be combined in the overlapping regions to give a resultant slope of 12dB/octave. This can be used to give a 'tonal balance' type of response with greatly sharpened corners.

Treble and bass cut characteristics are obtained by putting the network directly in series with the signal path. The boost characteristics are obtained by putting an identical network in the negative feedback loop of the operational amplifier, which simply inverts the characteristics of the network (Fig.4). By using identical frequency-selective networks for both the boost and the cut slopes it is ensured that the two sets of slopes are approximately matched. This is important to achieve good levelling off when the two slopes are combined.

According to the settings of the potentiometers, the input impedance of the frequency-selective network can vary between 470Ω in parallel with 470Ω and 25.5kΩ in parallel with 25.5kΩ. It is therefore necessary to feed the network from a low-impedance source of less than say 200Ω. Also, the output impedance of the network can vary between 470Ω and 25.5kΩ and it is therefore necessary to feed the network into a high-impedance load of greater than say 50kΩ.

These are therefore two conditions which have to be met by the amplifier specification. The amplifier will also need to have a gain of at least 36dB.

The demands made on the amplifier are therefore fairly stringent and, for this reason, an integrated-circuit operational amplifier is well suited to the application. The author used an SN72709, one of the well-known 709 series. The specification is more than adequate and these amplifiers are available very cheaply. This is the only active circuitry required for the basic tone control network, although for most applications it will be necessary to add an emitter-follower driver stage to provide the low-impedance source for the network.

Complete circuit

A complete circuit diagram of the tone control network, including the emitter follower, as shown in Fig.5.

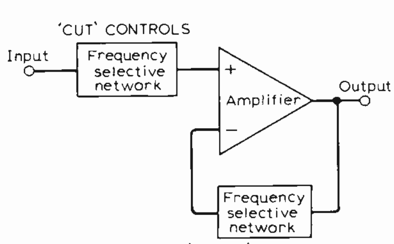
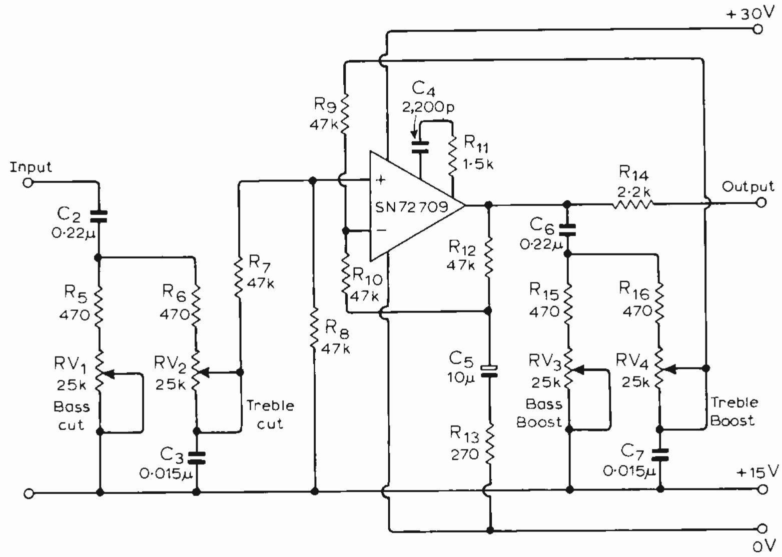


Fig.4. Block diagram of tone control. Both networks use the circuit of Fig.3.



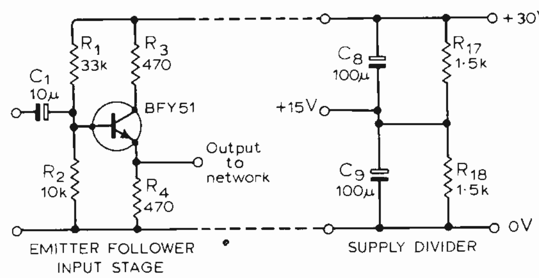


Fig.5. Complete tone control circuit. Component tolerance of ±5% is recommended. Listening tests have shown that linear-law potentiometers gave smoothest control. Amplitude response of this circuit is shown in Fig.6.

The operational amplifier requires supplies at ±15V, but for a.c.-coupled audio work, the need for a negative supply can be overcome by having a supply at +30V with the input and output of the amplifier held at +15V. Compensation of the amplifier is straightforward, and is achieved by C_4 and R_{11}. Pin connections for the amplifier have not been given because they depend on the type of encapsulation.

Resistors R_{10} and R_{12} provide d.c. feedback to maintain the output of the amplifier at +15V. Capacitor C_5 decouples audio frequencies from this d.c. feedback loop, but R_{13} provides a limit to this decoupling so that the a.c. closed-loop gain is limited to +36dB. This was found necessary to avoid resonances at the extreme ends of the audio spectrum under conditions of maximum boost. The resonances are caused by interaction between the boost characteristics and the d.c. feedback loop at the bass end, and the high-frequency compensation at the treble end.

Resistors R_7 and R_8 give an attenuation factor of two on the positive input to the amplifier to compensate for the attenuation factor of two on the negative input to the amplifier produced by R_9 and R_{10}.

Construction

The circuit was constructed on 0.1-matrix Veroboard using a flat package integrated circuit. The complete circuit excluding potentiometers can easily be built into a space 7.5 × 5cm. There is no evidence to show that layout is critical.

Measured performance

Measured amplitude-frequency response of the tone control circuit is shown in Fig. 6. Fig.6(a) shows the response at extreme settings for each control, and also the resultant response with all the slopes brought in to the middle of the audio range. The small peaks at the extreme ends of the audio spectrum, due to the resonances described earlier, could probably be reduced by adjustment of R_{13}. Resultant response with all the slopes taken to the extreme ends of the audio range is flat to within ± 0.5dB.

Fig.6(b) shows some typical combined

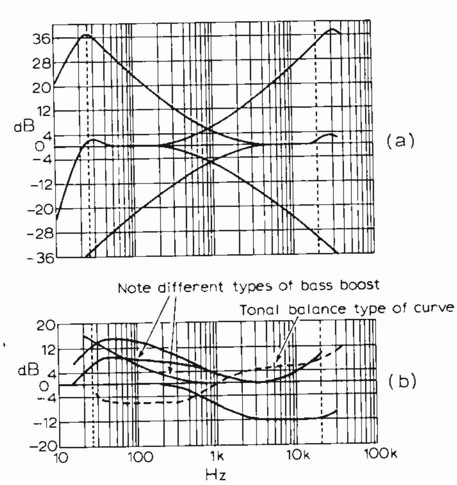


Fig.6.(a) Amplitude-frequency response of circuit in Fig.5 showing response for each control at maximum. Middle curve is with all controls at maximum. (b) Typical tone control response curves showing two kinds of bass boost.

characteristics of the network. Note in particular the two types of boost. Both the bass boost curves shown have approximately + 14dB boost at 30Hz, and both treble boost curves have approximately +6dB boost at 15kHz. Note also the "tonal balance" characteristic and the flatness in the two halves of the audio spectrum.

Subjective tests

For experimental purposes, the tone control network was connected between the tape recording output and the tape monitor input socket of an amplifier. The before/after tape monitor switch on the amplifier enabled the tone control circuit to be switched in and out so that the effects of the circuit could be compared against the direct unaltered sound.

Results were extremely encouraging and gave a feeling of building up the exact sound wanted from scratch, as it were, rather than simply just patching up the original. On a recording which contained some complex percussion work, the effect of the normal treble control was just to increase rather unnaturally the "hiss" of the cymbals. With the tone control circuit described the main body of the cymbal sound could be brought out together with the sound of a cow bell.

It is worth pointing out that any standard tonal correction curve such as the R.I.A.A. magnetic pickup characteristic can be built up using the network.

Extreme settings of the controls were indeed very severe and would not need to be used for normal use. For those who enjoy experimenting with sound, however, the extreme settings may be useful.

Setting up

At first, the idea of having to set up four tone controls instead of the usual two may seem formidable, but in practice it is very easy, and for those interested in obtaining the exact sound they want the extra trouble is more than justified by the versatility of the system.

Accurate calibration of the controls is not necessary, and a guide to setting the controls to give a particular desired effect is as follows.

A "tonal correction" curve is obtained by setting both boost and cut slope into the middle of the audio spectrum, and then shifting one or the other out until the required effect is achieved. A 6dB/octave curve is obtained by setting both slopes to the appropriate end of the spectrum and then shifting the appropriate one in towards the middle until the required effect is achieved.

Simplified version

For certain applications some of the controls can be left out. One system in particular which might be useful would be to leave out the cut controls and to set the maximum gain of the amplifier to say +10dB by increasing R_{13}. The tone controls would then operate as shown schematically in Fig. 7. This gives in effect variable frequency control of treble and bass boost rather than variable slope control.

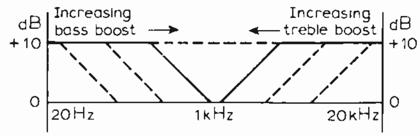


Fig. 7. Response of simplified version with cut controls omitted and gain adjusted to 10dB.

November Meetings

Tickets are required for some meetings: readers are advised, therefore, to communicate with society concerned.

LONDON

2nd. I.E.E.—"A calculable standard of capacitance" by G. H. Rayner at 17.30 at Savoy Pl., W.C.2.

3rd. I.E.E.—"C.R.T. displays for road traffic control—West London experience" by K. W. Huddart at 17.30 at Savoy Pl., W.C.2.

4th. I.E.E./I.E.R.E.—Colloquium on "Performance monitoring techniques" at 14.30 at Savoy Pl., W.C.2.

4th. I.E.R.E.—"Microwave generation devices" by K. Wilson at 18.00 at 9 Bedford Sq., W.C.1.

5th. I.E.E. /Inst. Meas. & Control.—Discussion on "Dynamics and identification of biological systems" at 14.30 at the Royal Free Hospital, Grays Inn Rd, W.C.1.

5th. I.E.E.—"The ionosphere and radio engineering" Appleton Lecture by G. Millington at 17.30 at Savoy Pl., W.C.2.

6th. R.Inst.—"The Open University" by Dr. Walter Perry at 21.00 at 21 Albemarle St., W.1.

9th. I.E.R.E./I.E.E.—"Semiconductor gamma camera system" by E. Moss and W. Gore at 18.00 at 9 Bedford Sq., W.C.1.

11th. I.E.E.—Discussion on "Microwave holography" at 17.30 at Savoy Pl., W.C.2.

12th. I.E.R.E.—Discussion on "What management expects from electronic engineers and what the young graduate expects from management" at 18.00 at 9 Bedford Sq., W.C.1.

17th. C.E.I.—Graham Clark Lecture "Engineers in a changing world" by Sir Henry Jones at 18.00 at the Inst. of Civil Engrs, Gt. George St., S.W.1.

18th. I.E.E.—"Sonar and underwater communications" by Prof. D. G. Tucker at 17.30 at Savoy Pl., W.C.2.

18th. I.E.R.E.—"The application of ultrasonic holography in non-destructive testing" by E. E. Aldridge at 18.30 at 9 Bedford Sq., W.C.1.

19th. I.E.E.—"Helicopter aerials" by W. Kelly and A. Burberry" at 17.30 at Savoy Pl., W.C.2.

19th. I.E.R.E.—"High fidelity loudspeakers and their evaluation" by Dr. A. R. Bailey at 18.30 at 9 Bedford Sq., W.C.2.

19th. R.T.S.—Discussion on "The first year of 3-channel colour broadcasting" at 19.00 at the I.T.A. 70 Brompton Rd, S.W.3.

23rd. I.E.R.E.—"Microwave ultrasonic devices" by R. F. Humphryes at 18.30 at 9 Bedford Sq., W.C.1.

25th. I.E.E.—Discussion on "Digital transducers" at 17.30 at Savoy Pl., W.C.2.

26th. I.E.E.—"Digital synthesisers—a case history of an equipment design using special-to-type i.cs" by D. J. Martin and A. F. Evers at 17.30 at Savoy Pl., W.C.2.

26th. R.T.S.—Discussion on "PAL tolerances" at 19.00 at the I.T.A., 70 Brompton Rd, S.W.3.

30th. I.E.E.—Discussion on "Thick film technology" at 17.30 at Savoy Pl., W.C.2.

ABINGDON

11th. I.E.E.—"The electronic performance testing of motor vehicles" by D. C. Freeman at 19.00 at the Culham Laboratories, Culham.

BIRMINGHAM

4th. R.T.S.—"The impact of automation on television transmission" by H. Steele at 19.00 at ATV Studio Centre, Bridge St., 1.

BRIGHTON

25th. I.E.E.T.E.—"Electronics in crime detection" by A. T. Torlesse at 19.30 at the Royal Albion Hotel.

CAMBRIDGE

26th. I.E.R.E./I.E.E.—"New horizons in meteorological instrumentation" by Dr. H. T. Ball at 18.30 at the University Eng'g Labs, Trumpington St.

CARDIFF

26th. S.E.R.T.—"Television studio operation and maintenance" by H. Lewis at 19.30 at the Harlech Studios.

CHATHAM

26th. I.E.R.E.—"Dynamic characteristics of silicon controlled rectifiers" by R. G. Dancy at 19.00 at the Medway College of Technology.

COLCHESTER

12th. I.E.E.—"Electronic aids in medicine" by J. L. Gedge at 18.30 at the University of Essex, Wivenhoe Pk.

DORKING

4th. I.E.E.—"Thoughts on the future of world communications" by Prof. E. C. Cherry at 19.30 at the Martineau Hall.

25th. I.E.E.—"Continuing education for electronic engineers" by Dr. K. G. Stephens at 19.30 at the Star and Garter Hotel.

LIVERPOOL

9th. I.E.E.T.E.—Discussion on "Metrication and the engineer" at 19.30 at the Royal Institution, Colquitt St.

MANCHESTER

19th. S.E.R.T.—"Decca single standard colour receiver" by T. Bamford at 19.30 in Room J17, U.M.I.S.T., Sackville St.

NEWCASTLE-ON-TYNE

4th. S.E.R.T.—"Electronically controlled fuel injection" by J. T. Davies at 19.15 at the Charles Trevelyan, Technical College, Maple Terrace.

PLYMOUTH

11th. R.T.S.—"Colour tilting" by M. Cox at 19.30 at the Polytechnic.

READING

12th. I.E.R.E.—"Data communications" by E. B. Stuttard at 19.30 at the University, Whiteknights Pk.

TUNBRIDGE WELLS

26th. S.E.R.T.—"Sound reproduction" by D. Chave at 19.30 at the Masonic Hall, St. Johns Road.

WESCON Show 1970

New devices and techniques seen at Los Angeles

*by Aubrey Harris**, M.I.E.E.

The 1970 WESCON (Western Electronic Show and Convention) opened at Los Angeles amidst an atmosphere of gloom. This was only partly due to the ever-present smog in the city; a more significant reason was that more than a mild recession is taking place in the electronics and associated industries. Just as the show was starting, it was announced by the Electronic Industries Association that in the first six months of this year the sales of colour television sets in the U.S. were 27.2 per cent lower than in the same period of last year. Black-and-white TV set sales were 10.2 per cent down, radio sales 6.9 per cent, and gramophone equipment almost 25 per cent lower. One brighter spot: sales of magnetic tape recorders were 26.7 per cent higher.

When Dr. John Granger, this year's president of the I.E.E.E., addressed the conference he gave no hopeful prognosis. Although the recession, which is now affecting all industry, may lift towards the end of 1970, the electronics industry, he said, will not start its recovery for two to three years. There seemed to be an anti-technology bias shared by all segments of society with a new emphasis on environmental considerations.

The attendance figures emphatically showed a decline: 36,700 this year compared to about 45,000 in 1969.

Despite all this, there was the usual variety of technical papers; a review of some of them follows.

The cost of semiconductor memories is being reduced and it is forecast that by 1972 they will be cheaper, in large quantities, than their equivalent magnetic core memories. Of the various types the metal-oxide-semiconductor (m.o.s.) will be the most economical. Some of the reasons for this are that the m.o.s. memory has a high density, high yield percentage and uses low power. Offsetting these advantages somewhat is the lower speed of the m.o.s., limiting the range of application. A factor contributing to the speed limitation is the 'overlap' capacitance of the gate electrode. Photo-lithography has been tried in order to alleviate this problem but lower yields resulted. Another technique is the use of self-alignment, where the gate electrode acts as a mask for one edge of the source and drain electrodes. The two last-mentioned are then produced by diffusion using a silicon gate as a mask, or by ion implantation with a metal gate as a mask.

L. F. Roman and A. C. Tickle (Zeion, Inc.) gave details of this technique. The process is to ionize dopant atoms and accelerate them by an electric field to velocities sufficient to permit penetration directly into the material to be doped. The implanted areas have a resistivity an order of magnitude higher than the p-diffusions in regular m.o.s. processing; the source and drain regions are kept as short as possible and connect to the normal p-diffusions.

Another advantage of ion implantation is in the production of resistors in l.s.i. In an i.c. monolithic resistors cause problems in design; this is due to the low resistivity of the sheet material. Where a high ohmic value of resistance is required the area occupied by it is often larger than the transistors. In ion implanted m.o.s. circuits, high value resistors can take the place of the inefficient m.o.s. transistor loads. These last-mentioned are often non-linear and either they require separate bias for the gates or they absorb a substantial fraction of the supply voltage to turn them on.

Integrated circuits for consumer electronics

Solutions to some of the problem areas in integrated circuit application to consumer products have been found in the past few years, and much larger volume usage of i.cs is forecast between now and 1975. The areas where most progress will be made are considered to be in home entertainment equipment and motor vehicle control devices.

In a review of the status of i.cs in colour television receivers Norman Doyle (Fairchild) estimated that the unit cost of digital and linear integrated circuits would be down to 60 to 80 cents (5 to 7 shillings) by 1975. However, in the highly competitive field of consumer manufactured goods, it is not price alone which determines acceptance. Certainly the cost of the i.c. must be lower than the circuitry it is replacing but also the performance must be at least as efficient as the replaced system.

At present about 40% of colour television chassis are using at least one integrated circuit. System partitioning (separation of the receiver into logical areas for individual i.cs) has defined six or seven sub-systems: chrominance demodulator, chrominance processing, signal processing, video i.f., sound i.f., detector and output, a.f.t. and sync-video detector. It is predicted that the typical colour TV receiver in 1975 will contain six i.cs, three hybrid circuits, plus valve line output and high voltage sections.

Some details of an i.c. sub-system for video i.f. and detector were given by Gerald Lunn (Motorola). The video i.f. amplifier in a TV receiver is a wide-band high-gain a.g.c. controlled amplifier. This is followed by a high level detector, working at up to 3 volts peak-to-peak, which must operate with good linearity at up to 100% depth of modulation. Valve and transistor i.f. strips at present in use suffer from several disadvantages: tuned circuit design is critical because they are used for maximising power gain as well as bandshaping; input and output parameters vary with gain control; there are cross-modulation and inter-modulation problems due to high input levels at low gain; the simple diode envelope detector causes distortion and intermodulation at colour subcarrier frequencies.

The integrated circuit i.f. uses one i.c.

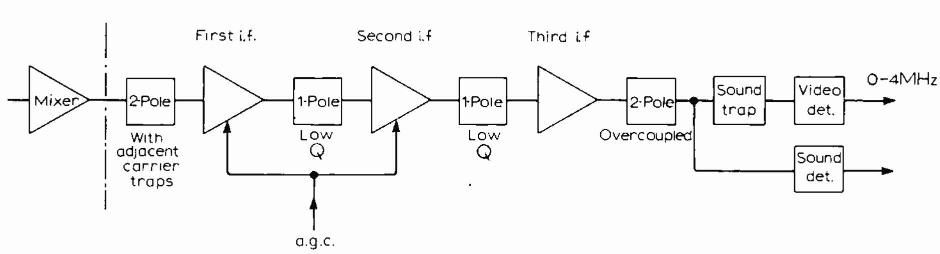


Fig.1. Block diagram of typical transistor i.f. circuitry.

* University of California, Santa Cruz

having 50 dB gain with 60 dB a.g.c. range and an amplifier-detector i.c. A single selectivity filter block is used between the mixer and the i.f. amplifier; this combination effectively avoids the problems of the i.f. strips at present in use.

Comparison of Fig. 1, a discrete circuit i.f., and Fig. 2, an integrated circuit i.f., shows the simplication obtained, and Table I lists the improved operational characteristics.

The MC 1352 integrated circuit has sufficient gain to replace two stages of the discrete-component i.f. without any interstage matching. It is possible to design an input block filter having almost all selectivity required for the strip because of the high and constant input impedance of the input amplifier. The coupling between the i.f. amplifier and the i.f./detector may be either a broadband tuned device or may add to the selectivity of the strip. Various techniques are being tried to find an economic solution for the production of the block filter, from conventional wire-wound coils with disc capacitors, coils and capacitors printed on substrates, to ceramic filters.

Probably the two separate i.cs used for the system described will eventually be built on a single chip. No solution has yet been found to the problem of obtaining a satisfactory layout of the strip combined with good mechanical construction, owing to the high i.f. gain.

It seems likely that this integrated circuit i.f. strip concept will come into common use, having as it does many advantages in predictability of response, tuning, colour sub-carrier distortion, intermodulation and cross-modulation characteristics and detector linearity.

TABLE I

		Integrated circuit	Discrete circuit
		MC 1352	
I.F. amp	Input impedance	1.4 kΩ 10 pF	200–20 ohms 80–40 pF
	Output impedance	11 kΩ–11.4 kΩ 2.0–2.4 pF	20 kΩ–200 ohms 3-1.3 pF
	A.G.C. range	65 dB	60 dB (two stages)
		MC 1330	
I.F. and detector	Input impedance	3.5 kΩ 4 pF	80 ohms 40 pF
	Output impedance	< 200 ohms	3 kΩ
	Maximum linear output	> 7 volts p-p	4-7 volts p-p
	Bandwidth (1 dB)	8 MHz	3 MHz

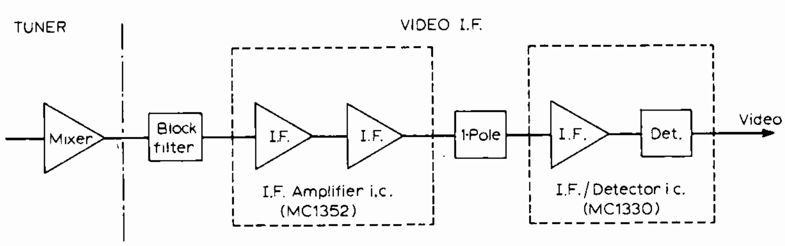


Fig.2. Video i.f. using integrated circuits.

Millimetre Waves

There has been increased activity in the development of devices and systems for millimetre wavelengths (30 to 300 GHz). Some of the reasons for this are that the crowding of the spectrum at lower frequencies is getting worse, greater bandwidths are required in communications channels, and there are needs for narrower beam widths.

The disadvantages of millimetre waves—atmospheric transmission losses, low transmitter power, low receiver sensitivity and reliability—are gradually being overcome and considerable progress has been made in the aerial and solid-state fields. One unusual application of these short wavelengths is ground mapping from aircraft. The maps so produced have almost the resolution of optical photographs, with the added advantage of increased object discrimination. This discrimination is possible because of actual temperature differences (between buildings and open areas) and is also due to apparent temperature differences caused by the varying emissivity of, for example, calm and agitated water.

A feasibility study of a digital transmission system using millimetre waves was described by E. T. Harkless (Bell Telephone Labs). This system is expected to have a capacity approaching a quarter of a million two-way telephone channels, using one circular, 2-inch diameter, electric-mode waveguide. The error-rate objective is 10^{-7} over 4000 miles. A two-level pulse code, time division multiplex system will be used to phase-modulate the 40-110 GHz signal, at a rate of 282 × 10^6 bits per second. There are to be 58 two-way operating channels, each 550 MHz wide, yielding a total of 233,856 telephone channels or 2436 Picturephone (video telephone) signals. With a transmission loss of about 3 dB per mile and 100 milliwatts of transmitter power the received signal level is not expected to be worse than −53 dBm.

A significant design problem was that of splitting at the repeaters the circular waveguide port down to 120 rectangular ports each handling its own 550 MHz channel. An arrangement has been devised utilizing band splitting and channel dropping filters (Fig. 3). The band splitting filters are microwave circuits consisting of two high pass filters and two hybrid junctions; these junctions are formed of dielectric sheet, so that 50% of the power reaching it is reflected and 50% transmitted. Enlarged sections of

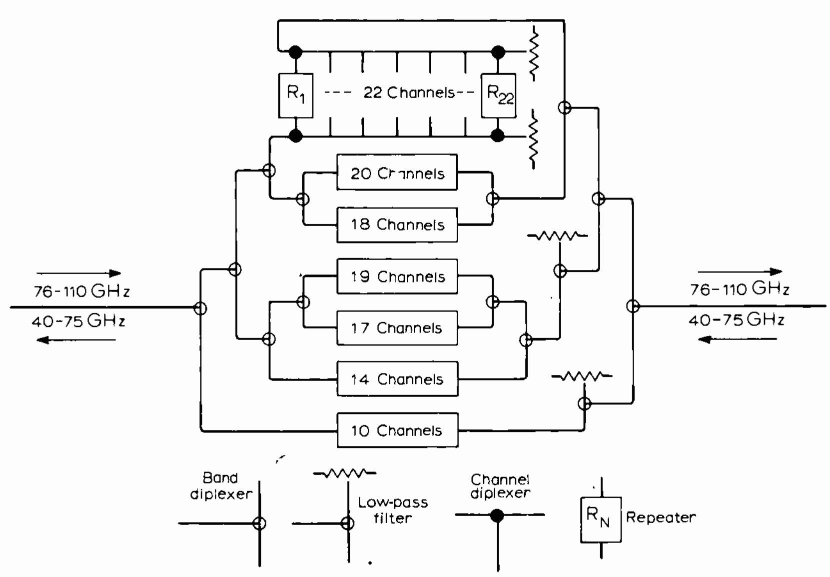


Fig.3. Arrangement for splitting the 40-110GHz spectrum into 120 channels by band and channel filters.

circular waveguide are used as resonant cavities for the channel dropping filters.

Optoelectronics

The word optoelectronics has been coined to embrace the interdisciplinary technology of optics and electronics. Included is a great range of applications: solid-state TV pick-up tubes, punched card and tape readers, smoke and flame failure detectors, solid state displays and isolators, to name just a few.

Some innovations with light-emitting diodes were described by W. M. Otsuka and R. A. Hunt, Sr. (Monsanto). Light-emitting diodes (l.e.ds) have all the assets of solid state devices and have many advantages over filament and gas-filled display devices, namely, compactness, reliability, shock-resistance, low power requirements. A monolithic alpha-numeric display device measuring only 0.240 in. by 0.168 in. was described. It has mounting and interface compatibility with i.cs. It consists of seven light-emitting elements in the format of the familiar segmented display tube (Fig. 4). The light emitting areas are formed with standard planar technology by zinc diffusion into a single piece of n-type gallium arsenide phosphide. Each of the seven elements is made up of five light-emitting diodes interconnected in parallel by evaporating aluminum on the surface of the chip. The last-mentioned is attached to a lead frame pad which provides a common cathode connection. The segment anodes are bonded to frame leads to provide the segment address. The whole thing is then cast in clear epoxy.

The device can display all numerals from 0 to 9 as well as non-ambiguous letters and a decimal point. There are many applications where the display would prove useful: digital clocks/watches/meters, pocket calculators, TV channel indicators, desk top computer readouts.

Each of the segments of the display device can be considered as a l.e.d with a voltage drop of 1.7 volts at 5.0 mA. This gives a brightness of 680 cd/m^2. The anode of each of the l.e.ds is brought out to a separate lead on the package. These can be connected to any suitable i.c. driver or to a specially designed decoder/driver.

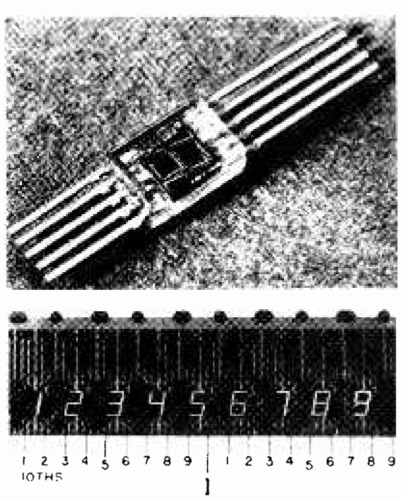


Fig.4. Monsanto GaAs light emitting diode seven-segment readout. Its size is only 0.24in x 0.168in.

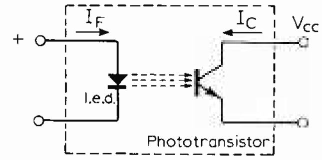


Fig.5. Photon coupled silicon phototransistor/l.e.d.

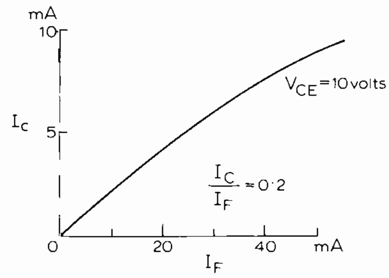


Fig.6. Transfer characteristic of phototransistor/l.e.d.

Another application of the l.e.d. is for opto-isolators. There are many situations where electrical isolation is required between two parts of a circuit. Two conventional devices, the relay and the filament-lamp/photocell, are limited in speed of response and are not compatible with i.c. interfacing. Also, reliability is often low because of contact bounce, mechanical wear and corrosion of the relay contacts. The solid state opto-isolator has superior characteristics as regards input/output isolation, transfer linearity, and speed of operation, and is easily integrated with transistor and i.c. circuits.

Typically, a GaAs l.e.d. control element is mounted in close proximity and photon-coupled to a silicon solid state detector, such as a p.i.n. photodiode, phototransistor, photo-s.c.r. or photo-f.e.t. Photon coupling takes place only in one direction, from l.e.d. to the detector: there can be no feedback from detector to the l.e.d. part of the circuit (Fig. 5). Forward current through the l.e.d. produces photon output proportional to the input current. The variation of photons falling on the detector gives a corresponding output current in the detector (Fig. 6). Isolation resistance between the input and output exceeds 10^{11} ohms, voltage isolation is of the order of 2.5 kV and capacitive coupling is less than 3 pF. The output/input current ratio is 0.2; rise and fall times are in the region of 2 microseconds.

New hardware at the Show

Tektronix have expanded the usefulness of their 7000-series oscilloscopes, introduced a year ago, with the announcement of two new plug-in units. The 7000-series becomes an 'integrated test system' with the 7D13 Digital Multimeter and the 7D14 Digital Counter (Fig. 7).† This means it is possible for the user to measure frequency, temperature, resistance, voltage and current and simultaneously watch waveform displays. The plug-in units are the same size as the other plug-ins for the 7000-series and will operate in any of the four positions.

The readings measured by the units are displayed on an alphanumeric scale factor readout on the c.r.t. The multimeter has four ranges of direct voltage (1.999 V, 19.99 V, 199.9 V, and 1000V full scale) and four ranges of direct current (up to 1.999A full scale). Polarity is automatically indicated. Temperature measurements can be made from −55°C to 150°C in one range and resistance in five ranges (199.9 ohms lowest range to 1.999 megohms on the highest range).

A typical application for this new assembly would be monitoring the internal temperature of a piece of equipment under test while displaying the output waveform. Another use would be measurement of the change in pulse amplitude (or width) and simultaneous display of bias voltage on a transistor while adjustments are made to the bias potential.

The digital counter plug-in can measure frequency from zero to 500 MHz, without prescaling, displaying an 8-digit readout on the c.r.t. screen. Direct counting has an advantage over prescaling, in that with the last-mentioned, if, for example, a prescale division factor of ten is used the resolution of the counted signal would also be divided by ten. The input impedance of the counter is either 50 ohms or 1 megohm and its sensitivity is 100 mV pk-to-pk; accuracy is ± 0.5 p.p.m. ± 1 count. Display time can be varied from 0.1 to 5 seconds or fixed at infinite. The unit also has an externally gated mode; by using the oscilloscope in the delaying time-

† Now available in the U.K. from Tektronix UK Ltd. —Ed.

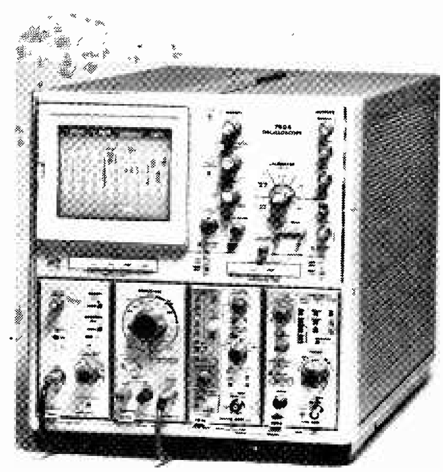


Fig. 7. Tektronix 7504 oscilloscope with the 7D13 digital multimeter and the 7D14 digital counter as well as a vertical amplifier and timebase.

base mode, the delayed sweep can be made to drive the external gate of the counter. In this mode a signal can be displayed on the screen with the intensified portion of the waveform being counted.

When the counter unit is used in conjunction with the multimeter it is possible, for example, to display the output waveform of an oscillator, while watching the readout on the screen of frequency count vs ambient or internal temperature.

A novel measuring device shown by Burr-Brown Research Corporation was their 4128 r.m.s module. This enables true value r.m.s readings of voltage to be made irrespective of waveshape. Its integrated circuits and other components are encapsulated in a 3 in. × 2.1 in. × 0.4 in. module. The device is capable of an accuracy of 0.5 per cent of reading; with external trimming this figure can be improved to 0.1 per cent. The voltage to be measured can be at any frequency from zero up to 10 kHz—the shape of the waveform is not critical. The measurands may be s.c.r. outputs, pulse trains, noise, distorted sinewaves.

Exact details of the operation are proprietary information but the block diagram (Fig.8) shows the general principles. The output voltage $E_0 = K(E_1)$ r.m.s. where $|E_1| < 10$ volts peak. The scale factor, K, is normally either unity or ten but can also be set externally to larger values. The scale factor and the crest factor are directly related. When there is a large crest factor, K should also be large for highest accuracy. The filter time constant $RC/2$ must have a value of at least 100 times the period of the lowest input frequency, if the device is to average the squared input accurately. Brief specification: peak input voltage ± 10 V, input impedance 5kΩ, output ± 10 V ± 5 mA, power requirements ± 14 V to ± 16 V at 30 mA.

General Radio Company showed the Type 1656 impedance bridge, an improved version of the 1650. The 1656 has a basic accuracy of 0.1 per cent when measuring capacitance, inductance, resistance or conductance with resolution down to 0.1 pF, 0.1μ H, 0.1 milliohm and 0.1 nanohm, respectively. The familiary *CGRL* dial has been replaced by four lever-type digital switches (Fig.9). This type of adjustment reduces reading error as well as allowing rapid determination of balance.

Until recently, a digital filter necessitated a sizeable computer, special programming and input/output devices. Two companies showed digital filters in rack/bench cases no more than 7 inches high. The filters are in fact special purpose computers programmed to accept analogue signals and to digitize them with an a-d converter. The quantized signals are operated on in the computer and converted back to analogue signals. M.o.s. shift registers and t.t.l. logic are used for the filtering circuitry.

Fig.9. General Radio 1656 impedance bridge showing the digital CGRL controls.

The Rockland Corporation's 4100 has recursive (poles and zeros) and non-recursive (zeros) characteristics, where the ECI 999 operates non-recursive only. This latter type provides with extreme accurancy phase/frequency characteristics which are some 100 times better than are available with analogue filters. Recursive digital filters can produce very sharp frequency cut-off almost to the theoretical "brick wall" function.

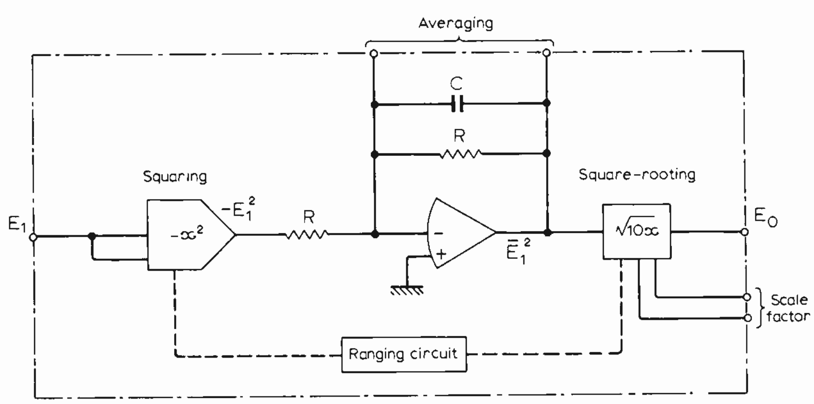


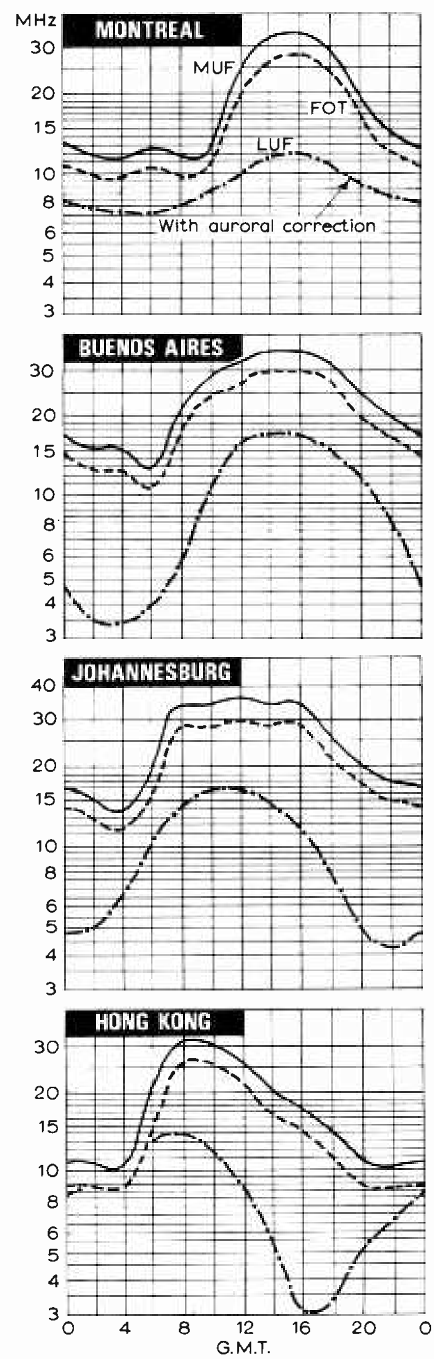
Fig.8. Block diagram of Burr-Brown r.m.s. meter module.

H.F. Predictions—November

Predicted solar activity for November is the same as that observed 12 months ago. The relatively large number of disturbed days observed recently should decrease. High daytime MUFs continue on transequatorial routes and are becoming apparent on northern hemisphere routes so frequencies above 25MHz remain of some utility.

The northern auroral zone passes through Alaska, Hudson Bay, Iceland and northern Norway. Paths crossing this zone are subject to periods of high, sometimes infinite, absorption.

All LUFs shown are for reception at good sites in the U.K. of commercial telegraphy from medium-power transmitters with directive aerials. LUFs for domestic reception of high-power broadcasts would be very similar.



Elements of Linear Microcircuits

2. Makers: Numbering codes: Obtaining information: Pitfalls

*by T. D. Towers**, M.B.E.

If you are going to use linear microcircuits effectively in your designs, you should know what are available on the market, where to get them and what precautions to take in procuring them.

Supply sources for linear microcircuits

Linear i.cs come on to the U.K. market from all over the world; the main manufacturing sources are: U.S.A., U.K., Western Europe, and Far East (Japan, Hong Kong, Korea and Taiwan).

U.K. products can be obtained direct from the manufacturers or from electronics distributors. Microcircuits of overseas manufacture reach the British user mostly through subsidiaries of the prime manufacturers, although more and more agents and distributors are handling imported linear devices direct from the overseas sources.

To help you in your search, I give in Table 1 a list of the major U.K. manufacturers of off-the-shelf linear microcircuits.

To complete the picture, Table 2 sets out the major overseas manufacturers (apart from those already appearing in the U.K. list).

It is impracticable to give details of the many distributors handling linear microcircuits, but most good distributors now hold stocks of what are rapidly becoming standard items. The sort of thing you will find is reflected in the catalogue of one U.K. national distributor currently offering a standard μA709 op. amp., a μA710 d.c. comparator, a μA711 dual d.c. comparator, a 3-W audio power amplifier and a 2 to 13V, 100mA d.c. power supply regulator module.

Microcircuit numbering codes

If you are new to the microcircuit game, you will find yourself confused and often frustrated by the huge variety of type numbers given to commercial units. Cynics have said that the numbers put on devices by manufacturers are designed to confuse. There might be some truth in this if we are to judge by the now-legendary '709', which you could come across under about a hundred different type numbers. You will find it easier to make your way in the world of microcircuits if you know and can recognize the different numbering systems you will come across.

There are three main systems current in the U.K.: 'House-code', 'Pro-electron' and 'Military'.

House-code numbers

Linear microcircuit manufacturers generally use their own in-house coding systems. For their commercially available off-the-shelf units they tend to adopt a coding which is identifiable with the company. For example, Newmarket Transistors, the company with which I am associated professionally, uses the three letters NMC (standing for Newmarket Micro Circuit) followed by a three-digit numerical reference for its standard range. But, in addition, most manufacturers also use a separate 'private' in-house coding for the special microcircuits they do not make generally commercially available. You may occasionally come across such private numbers in technical articles and may find it difficult to identify the manufacturer from the code alone. Table 3 gives a list of the more common commercial house-codings which can be readily identified.

Obviously the user would like a common number for interchangeable microcircuits, whatever the source, and the Pro-electron system to be described below is a useful move in this direction.

Pro-electron numbering

Pro-electron is an international organization in Belgium with which manufacturers register their microcircuits (and incidentally many other semiconductors and valves) according to a carefully designed coding system.

So far as linear microcircuits are concerned, the standard type designation code comprises three letters followed by three numerals, e.g. TAA263. This block of six elements breaks down into three sections, T . . . AA26 . . . 3, and each of the three sections has a special significance.

The initial letter T is always used for purely linear microcircuits but there is provision in the system for the initial letter U to be used for combined linear-digital circuits. Thus the code for a linear microcircuit always starts with T or U.

The middle two letters and two numerals comprise a serial registration number. In this, the letters start from AA and will continue through BA, CA up to ZA. The two digits in the middle section run from 10 through to 99.

The last figure, i.e. the third one in the full number, gives an indication of the operative temperature range for which the circuit can be used, and has the following meaning: 0 = no temperature range indicated, 1 = 0 to +70°C, 2 = −55 to +125°C, 3 = −10 to +85°C, 4 = +15 to +55°C, 5 = −25 to +70°C, and 6 = −40 to +85°C. If a circuit specification is for a wider temperature range, but does not qualify for a higher classification, the figure indicating the narrower temperature range is used.

Although the Pro-electron coding for a linear microcircuit is normally three letters followed by three numerals, a version letter can be added to a type number to indicate a different version of the same type; for instance encapsulated in another package with other interconnections or showing minor differences in ratings or electrical characteristics.

Referring back to the TAA263 mentioned earlier as an example of the Pro-electron coding. Although registered with Pro-electron initially by Philips, any other manufacturer who can produce it to meet the registered specification can use the same number 26, and it is likely that there will be more than one supplier for many of the registered Pro-electron types. At present, however, the position is that most of the Pro-electron-registered linear microcircuits are obtainable only from the manufacturer who initially registered them. As a result, some of the Pro-electron codings have become associated in the minds of users with the originating company.

Military numbering systems

In the United Kingdom, just as valves and transistors for use in government equipments were registered under CV numbers, so microcircuits have been

*Newmarket Transistors Ltd.

covered by a CN numbering system. For example, the well-known differential voltage comparator, μA710, is designated CN431T (multi-lead TO-5 version) and CN432F (flat-pack version).

A system is also being developed under which industrial microcircuits will be allotted numbers under the BS9000 scheme.

Cost of linear microcircuits

Until 1969 linear microcircuits were very expensive but in the middle of 1970 a very heavy price slide took place and we experienced a very interesting situation where quite complex microcircuits were down hard on the heels of the price of single transistors. High-quality linear microcircuits can now be purchased at one-off prices from 7s 6d. A welcome situation has thus been reached where the amateur and home experimenter can "try his 'prentice hand" without being unduly out-of-pocket. And all indications are that the price decline is likely to continue, as more and more supplies come on the market.

Caveat emptor

There are several pitfalls in the path of the buyer of linear microcircuits. The first snare is interchangeability. You can buy a μA709 operational amplifier from two different manufacturers, each meeting a common data sheet specification, and find that one works well in your circuit and the other does not. This may not be because anything is wrong with either of them, but because they differ materially in parameters not specified in the data sheet. All you can do is to try samples of the different makes and design your circuitry to give equal performance with both. The fact that two 709s from different manufacturers cannot be interchanged with certainty is not surprising when you consider that there is an assembly of 15 transistors and 15 resistors diffused into a tiny chip of silicon in this device.

However closely you study the specification of a microcircuit, you will not find some characteristics that can have a more than marginal influence on its operation in circuit. This is not because the manufacturer wishes to conceal them from you. It is because they are not measured on a production basis, and are held to be secondary characteristics that do not materially affect the operation of the device in the application for which it is designed.

Remember that it is almost impossible to produce a true low-frequency transistor in the sense of the old germanium alloy transistors when you fabricate by planar techniques. Cut-off frequencies below 100MHz are most unusual in planar types. This means that you are dealing with a compact circuit with potentialities of high gain at very high frequencies. Because of these "unspoken" specifications, you can run into enormous difficulties with high-frequency instability in low-frequency circuits.

Another point to be wary of is the question of 'pin compatability'. What this means is . . . look carefully at the lead-out pin-numbering of your microcircuit in relation to the internal circuitry to ensure that an alternative you are trying is an exact drop-in replacement.

If you buy microcircuits direct from a reputable manufacturer, you can be fairly sure they will meet specification. However, the semiconductor industry is such that units can come on the market via other outlets which may have the proper code number marked on them but may not meet the full data sheet specification. If you use such orphans, you must have the facility for testing them against specification. Since it can be quite difficult to test a linear i.c. satisfactorily, some guidance will be given in later articles how to set about this.

If you are seriously contemplating using linear microcircuits, there is a lot to be said for getting some practical handling experience. Make up a working circuit using a linear microcircuit. The old adage about

Table 1
U.K. manufacturers of off-the-shelf linear microcircuits

A.B. Electronics Co., *Apemworks, St. Albans Road, Watford, Herts.*
Erie Electronics Ltd., *South Denes, Gt. Yarmouth.*
Ferranti Ltd., *Gem Mill, Chadderton, Oldham, Lancs.*
Marconi-Elliott-Microelectronics Ltd., *Witham, Essex.*
Mullard Ltd., *Mullard House, Torrington Place, London W.C.1.*
Newmarket Transistors Ltd., *Exning Road, Newmarket, Suffolk.*
Plessey Microelectronics Ltd., *Cheney Manor, Swindon, Wilts.*
S. G. S. (U.K.) Ltd., *Planar House, Walton Street, Aylesbury, Bucks.*
Texas Instruments Ltd., *Manton Lane, Bedford.*

Table 2
Overseas manufacturers whose off-the-shelf linear microcircuits are available in the U.K.

Amelco Semiconductors, *1300 Terra Bella Avenue, Mountain View, California, U.S.A.*
Beckman Instruments Inc., Helipot Div., *2500 Harbour Blvd., Fullerton, California, U.S.A.*
Fairchild Semiconductors, *313 Fairchild Drive, Mountain View, California, U.S.A.*
General Electric Company, *Northern Concourse Building, Northern Lights, Syracuse, New York, U.S.A.*
General Instrument Corp., *600 West John St., Hicksville, New York, U.S.A.*
ITT Semiconductors, *3301 Electronics Way, West Palm Beach, Florida, U.S.A.*
Mitsubishi Electric Corp., *1 Shuga-Ike, Ojika, Itami-Shi, Hygo-Ken, Japan.*
Motorala Semiconductor Products, Inc., *5005 E. McDowell Rd., Phoenix, Arizona, U.S.A.*
National Semiconductor Corp., *2975 San Ysidro Way, Santa Clara, California, U.S.A.*
Philips Gloelampenfabrieken, *Building BFP, Eindhoven, Netherlands.*
RCA, Electronic Components, *Somerville, New Jersey, U.S.A.*
Raytheon Company, *350 Ellis Street, Mountain View, California, U.S.A.*
Sanken Electric Co., *1-22-8 Nishi, Ikebukuro, Toshima-Ku, Tokyo, Japan.*
Siemens Aktiengesellschaft, *Balanstrasse 73, 8000 Munich 8, West Germany.*
Signetics Corp., *811 East Argues Avenue, Sunnyvale, California, U.S.A.*
Siliconix Inc., *1140 W. Evelyn Avenue, Sunnyvale, California, U.S.A.*
Sescosem, *101 Boulevard Murat, Paris, 16e, France.*
Telefunken A.G., *Postfach 1042, 7100 Heilbron/Neckar, West Germany.*
Tokyo Shibaura Electric Co., *1 Komuka Toshiba Cho, Kawasaki, Japan.*
Transitron Electronic Corp., *168-182 Albion St., Wakefield, Massachusetts, U.S.A.*

Table 3
House code prefixes

CA	= R.C.A.	PC	= General Instrument
L	= S.G.S.	RC	= Raytheon
LH	= National Semiconductors	RM	= Raytheon
LM	= National Semiconductors	S	= Signetics
M	= Mitsubishi	SE	= Signetics
MC	= Motorola	SFC	= Sescosem
MIC	= I.T.T.	SI	= Sanken
N	= Signetics	SL	= Plessey
NC	= General Instrument	SN	= Texas Instruments
NE	= Signetics	TDC	= Transitron
NH	= National Semiconductors	TOA	= Transitron
NMC	= Newmarket Transistors	TVR	= Transitron
PA	= General Electric (U.S.A.)	μA	= Fairchild

an ounce of practice is almost truer with microcircuits than with anything else in electronics.

Further reading

Manufacturer's application notes, data sheets and catalogues:
'Linear Integrated Circuit D.A.T.A. Book', Computing and software Inc., 32 Lincoln Ave, Grange, New Jersey 07050, U.S.A.
'Microelectronics Year Book', Shaw Publishing Co., London.
'The Applications of Linear Microcircuits', Fairchild Semi-conductors.
'Linear Integrated Circuit Applications Handbook', Marconi Elliott Microelectronics.
'The Application of Linear Microcircuits', S.G.S.
'Linear Applications', Signetics.
'Linear Integrated Circuit Fundamentals', R.C.A.
I. Eimbinder, 'Linear Integrated Circuits: Theory and Applications', Wiley.
I. Eimbinder, 'Designing with Linear Microcircuits', Wiley.
A. J. McEvoy and L. McNamara, 'Practical Integrated Circuits', Butterworth.
The following articles using linear integrated circuits have appeared in *Wireless World:*
P. J. Forrest, 'I.Cs in Communication Equipment', Jan. 67, p.23.
A. J. McEvoy, 'Integrated Circuit Stereo Mixer and Pre-amplifiers', July 67, p.314.
G. J. Newnham, 'FM Tuner Using Integrated Circuits', June 69, p.250.
F. C. Evans, 'Frequency Divider with Variable Tuning', July 69, p.324.
G. B. C. Harrap, 'Driver Amplifier for Pen Recorder', Aug. 69, p.379.
G. J. Newnham, 'R.F. Amplifier for F.M. Tuner', Nov.69, p.525.
J. M. A. Wade, 'I.C. Driver for Power Amplifier', Nov. 69, p.530.
A. Basak, 'Constant Amplitude Modulator', Nov. 69, p.530.
D. Bollen, 'A Thermistor Hygrometer', Dec. 69, p.557.
R. Hirst, 'The Future of Linear I.Cs, Jan. 70, p.6.
A. E. Crump, 'Instrumentation Amplifier', Feb. 70, p.70.
M. V. Dromgoole, 'Op. Amp. A. C. Millivoltmeter', Feb. 70, p.75.
J. Bryant, 'Linear Integrated Circuits', Feb. 70, p.75.
L. Nelson Jones, 'Integrated Circuit Stereo Pre-Amplifier', July 70, p.312.
P. Williams, 'Sinusoidal Oscillator for High Temperature', July 70, p.332.
G. B. Clayton 'Operational Amplifiers'.
1. 'Device Characteristics', Feb. 69, p.54.
2. 'Compensation Techniques', Mar. 69, p.130.
3. 'Applications', Apr. 69, p.154.
4. 'Applications', May 69, p.213.
5. 'Applications', June 69, p.270.
6. 'Integrators and Differentiators', July 69, p.332.
7. 'Voltage Comparators and Multivibrators', Aug. 69, p.384.
8. 'Selection of Practical Amplifiers', Sept. 69, p.429.
9. 'Practical Circuits', Oct. 69, p.482.
10. 'A Triangular Square-wave Generator', Dec. 69, p.586.

Announcements

A graduate course in **electronic design** is to be held at Hendon College of Technology, The Burroughs, London N.W.4, commencing 4th November and terminating in early May 1971. Fee £30.

The **1972 I.E.A. Exhibition** (Instruments, Electronics and Automation) will be held at Olympia. London, from 8th-12th May. The IEA Committee has decided not to open the exhibition on Saturday.

Motorola Semiconductors announce that they have set up an advanced facility for the custom design and production of m.o.s. l.s.i. arrays at their Phoenix, U.S.A. plant.

Plessey Dynamics Group has formed an association with AOA Apparatebau Gauting GmbH, of Germany, for the **joint promotion** of a selected range of both companies' aviation products.

Pye TVT Ltd has signed an agreement with Telecommunications Radioelectrique et Telephoniques, of Paris, **to manufacture and sell under licence** the range of T.R.T. radio and television transmitting equipment in the U.K. and certain overseas countries.

K.G.M. Vidiaids of Clock Tower Road, Isleworth, Middx, have signed an agreement to market in the U.K. the range of **video data processing modules** manufactured by Colorado Video Incorporated, of Boulder, Colorado, U.S.A.

The entire range of **magnetic pickup cartridges** made by the Empire Scientific Corporation of America is now available from Rank Aldis—Audio Products, P.O. Box 70, Great West Road, Brentford, Middx.

LST Electronic Components Ltd, 7 Coptfold Road, Brentwood, Essex, have been appointed sole U.K. distributors for the International Rectifier "Semiconductor Centre" range of products.

Guest International Ltd, of Thornton Heath, Surrey, are to become U.K. representatives of **Jaco Electronics Inc.**, of New York, specialist distributors of capacitors.

V-F Instruments Ltd, Gloucester Trading Estate, Hucclecote, Glos, GL3 4AA, have been appointed **U.K. representatives for Datawest Corporation**, of Scottsdale, Arizona, U.S.A. The range of products available includes high- and low-level multiplex systems and computer interfaces.

Du Pont de Nemours International S.A., of Geneva, has appointed Richard Klinger Ltd, of Sidcup, Kent, as **U.K. distributors** of "Teflon" fluorocarbon film.

An order from the Ministry of Defence (Army), worth over £500,000, has been received by Marconi's Radio Communications Division. This contract is for the installation of a two-way **tropospheric scatter system** for telephone communication with London and the British Army in Germany.

Rank Precision Industries Ltd have been awarded a contract by Sumitomo Shoji Kaisha Ltd of Japan, for the supply of their two-way field store **television standards converter** and synchronizer to be installed in the earth station at Warwork, New Zealand.

Two destroyers recently ordered by the Argentine Navy are to be fitted with **target tracking radars** manufactured by Marconi Radar Systems, of Leicester. It is the first export order received for this radar and will be fitted at a cost of over £3M.

A contract, valued in excess of £3M, has been signed between Decca Radar Ltd and the British Aircraft Corporation. Decca are to manufacture and supply the surveillance radar and command link equipment for use in the **Rapier air defence missile systems** provided by B.A.C. to the Government of Iran.

Cossor's **secondary surveillance radar** equipment has been selected for Denmark's civil air traffic control.

Cable and Wireless Ltd announce that the main contract for a £2.5M **satellite earth station** to be built in Barbados has been awarded to The Marconi Company Ltd, of Chelmsford, Essex (see also p.561).

The U.K. division of the G.T. Schjeldahl Company, of Minnesota, U.S.A., has become a limited company. The division was established in 1967 to manufacture laminates and flexible printed circuits. **G. T. Schjeldahl Ltd** are situated at Eastern Road, Bracknell, Berks.

Martin Audiokits, the constructional units for building amplifiers and f.m. tuners, are again in production. Full servicing facilities are available from Martin Audiokits, 154 High Street, Brentford, Middx. (Tel: 01-560 1161.)

Hitachi, of Japan, have set up a U.K. Sales organization, Hitachi Sales (U.K.) Ltd, at Park House, Coronation Road, Park Royal, London N.W.10, to market their range of radio and television receivers and audio equipment.

Russona Ltd, manufacturers of special education equipment for handicapped children, have occupied new offices at "The Firs", Rother Street, Stratford-upon-Avon, Warwickshire. The company have appointed GEC/Elliott Automation Ltd, of P.O. Box 110, Crows Nest, New South Wales 2065, to handle sales and servicing of the "Russaid" v.h.f. radio teaching aid throughout Australia.

The Instant Starter Engineering Co. Ltd. have bought the Instrument Division of Coutant Electronics Ltd and formed a new subsidiary company **Exel Electronics Ltd,** with offices at Trafford Road, Reading.

Two companies in the Pye of Cambridge Group have **changed their name.** The Telephone Manufacturing Company becomes Pye TMC Ltd and Ether Ltd, Pye Ether Ltd.

Corrections

YIG Radiometer (October p.501). In Fig. 4, the range switch should have only two positions; in the high setting the switch is open-circuit, and in the low setting connects the 4.7kΩ resistor in parallel with the upper 47kΩ resistor. In Fig. 8, a connecting link should be shown between pin 3 of IC_3 and the switch contract on S_{3c} which is connected to S_{3b} pole via a 4.7kΩ resistor. Thus the 56kΩ resistor is placed in parallel with the 1MΩ feedback resistor of IC_3 when S_3 is switched to the cycle position.

The DSV4 digital voltmeter from International Electronics mentioned in **New Products** last month (p.517) was incorrectly priced at £25. The correct price is £190. The £25 quoted is the cost of an optional b.c.d. interface unit which provides four decades of binary coded decimal information, together with sign and overload indication coding.

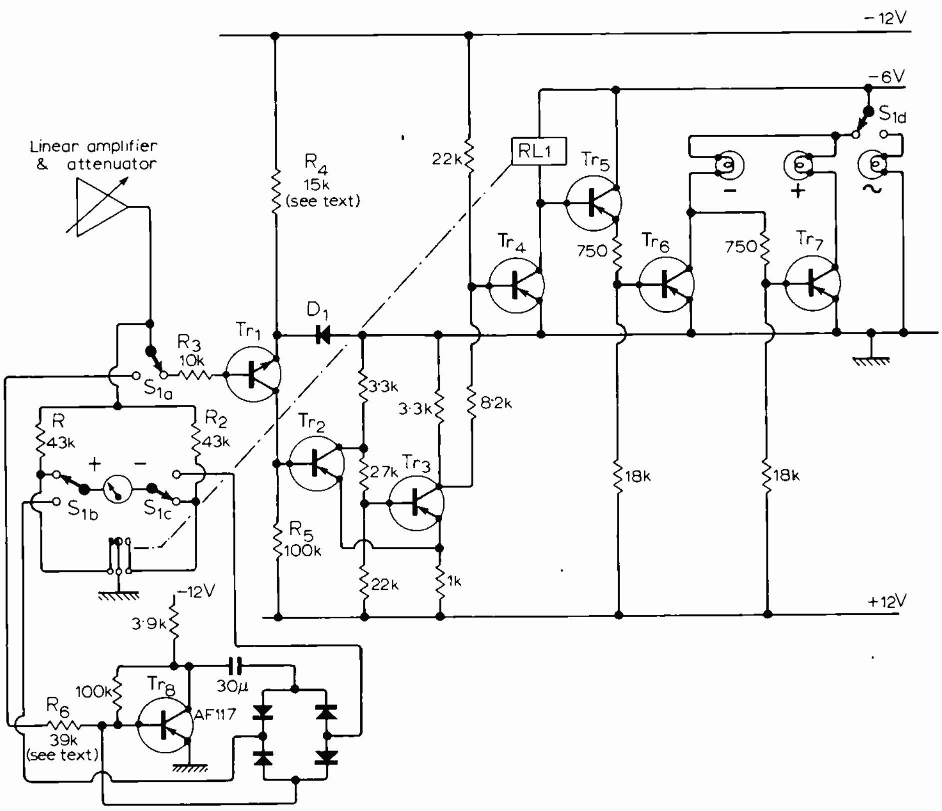
F.M. Tuners Survey (September, p.468). The price of the Korting T500 a.m./f.m. stereo tuner was wrongly given as £79 15s 0d. The correct price is, in fact, £48 15s 0d.

Circuit Ideas

Auto-change for d.c. meter

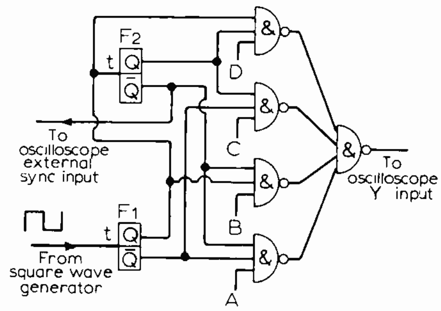
An instrument was required to measure d.c. and a.c. voltages; and for the d.c. an automatic change-over from positive to negative without the use of a centre-zero meter. The circuit shown uses economy type germanium transistors, except in the case of Tr_1 where a silicon transistor was used for better thermal stability. The 10kΩ/V meter polarity is changed over by switching either positive or negative of the meter to earth. The resistors R_1 and R_2 are a matched pair of 1% h.s. R_3 (10kΩ) was chosen to ensure that the linear amplifier output was not loaded to more than 0.5mA on full swing. The amplifier Tr_1 (2N706) was backed off from earth by D_1 and R_4. The value of R_4 was selected so that the switching point of the circuit was around zero volts input. D_1 can be almost any silicon diode giving the same forward voltage as the base-emitter junction of Tr_1. For greater stability D_1 could have been replaced by another 2N706 connected in a 'long-tail pair' configuration. Tr_2 and Tr_3 operate as a Schmitt trigger driving the switch Tr_4. The relay used has a 24V coil but by careful adjustment of the contacts and return spring, it works very reliably on 6V. Tr_5 is an emitter follower driving the inverters Tr_6 and Tr_7 which have as collector loads 6-V 10-mA lamps for positive and negative indication. The voltage swing required at the linear amplifier output to give a change in indication is approximately 2mV and the drift caused by Tr_1 circuitry is less than 5mV (1% of f.s.d.) checked at periods over the meter's three months use. In this application, it was considered quite sensitive and stable enough. The a.c. circuit is the F. P. Mason-G. W. Short design (see *Wireless World*, Dec. '69 and March '70) which gives very good results in this application. R_6 was adjusted to give the appropriate full-scale r.m.s. reading to correspond with the d.c. thus making the linear amplifier attenuator simpler. The −6V is an unstabilized supply.

D. GOODMAN,
Tel Aviv,
Israel.



Digital outputs displayed on a 'scope

When working with digital circuits it is often necessary to monitor the states of several outputs simultaneously. This unit samples each of the outputs in turn and displays them on an oscilloscope. The four states of a two-bit binary counter are gated out using NAND gates. The outputs of the circuit under test (A, B, C, D) are also fed to the NAND gates. The counter is driven from a pulse generator at a rate suitable for



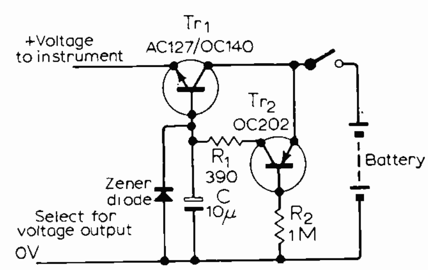
both the circuit under test and the oscilloscope. The oscilloscope's timebase is triggered by one of the flip flops.

The counter/gating system selects each output in turn and, provided the sweep and trigger controls of the oscilloscope are correctly adjusted, the states of the four outputs will be displayed on the c.r.t. side by side. The same technique can of course be used to monitor more than four outputs.

N. F. WILSON,
London S.E.26.

Low-drain battery regulator

The circuit provides good regulation with low battery drain, and is employed in two instruments to drop the battery voltage to a required lower level. Tr_1 is a germanium transistor with a low V_{CEsat} giving good performance with 'low' battery, and a low V_{EB} drop allowing better regulation. Tr_2 is a silicon transistor having low leakage and



high gain. C reduces any noise generated in Tr_2 and the zener diode, and reduces any surge at switch-on. R_1 provides zener current control and a degree of short-circuit protection when the battery voltage is almost completely saturated. For an input change of 10-18V the circuit gave an output variation of <0.2V using an OAZ206 zener diode, and the current drain alters by less than 5mA.

P. LACEY,
Crediton,
Devon.

Letters to the Editor

The Editor does not necessarily endorse opinions expressed by his correspondents

Mobile radio & amateur bands

I wish on behalf of the British Amateur Television Club to answer the letter in the September issue from Capt. R. A. Villiers of the Electronic Engineering Association concerning frequency spectrum allocation.

It is now some 20 years since Britain lead the world in making television transmission facilities available to amateurs. In these years amateurs, including those specializing in television, have broken new ground at u.h.f. They have exploited what many professional engineers previously considered an unusable part of the spectrum, much as amateurs did 50 years previously at h.f.

Today, television forms an active and growing part of the amateur communications scene, offering not only a most rewarding field for private research and development, but an invaluable training ground for young engineers entering the industry.

With the advent of colour and many new techniques the amateur stands on the threshold of valuable and exciting fields of investigation. We do not know what the future will bring, but we do know that in addition to those frequencies necessary for industry, it is essential that there must always be adequate frequencies available for private experimentation and self-training, and a reasonable access to this part of our natural environment by the individual.

I. M. WATERS, G6KKD/T,
Ely,
Cambs.

The i.c. industry

Your September editorial which warns of the danger to our i.c. industry through the import of American i.cs at almost give-away prices, and your suggestion that import controls are required, raises in my mind a number of points.

Can we afford to keep out by price American technology? Would import controls raise prices enough to cause U.K. users to seek less sophisticated devices to incorporate in their products and wouldn't the increased cost of incorporated U.S. integrated circuits raise the cost of the product and lower its export potential?

American companies have been and still are setting up distribution and manufacturing networks in the U.K. and on the Continent and a strong point provided by such an organization is the immediate availability of a spare in the user's area. Can this be matched by the U.K. industry?

Our industry must not be destroyed, so some Government help is required. Import controls are an immediate answer but perhaps a long-term one of "If you can't beat them buy them" might be the solution. If the Government would allow U.K.-owned companies to keep some profit free of tax provided they used it to buy their way into U.S. companies we might stem the tide and gain benefit from the investment. Common Market or not, the Americans are already inside the stable and care not if the door is left open or closed.

R. V. KILLICK,
West Drayton,
Middx.

Sine-wave power oscillator

In reply to Mr. Roddam's criticisms in the October issue of the circuit on p. 402 of the August 1970 issue, I agree that a circuit should be comprehensible, designable and as simple as possible, It was with this in mind that the circuit appeared as it did. After discussion with several colleagues, it was agreed that the circuit shown was the easiest to understand (the other two arrangements appear in the Patent Specifications).

As to designability, several different versions have been constructed and have functioned satisfactorily. Care in selection of components for the tuned circuit must be exercised if the maximum efficiency of around 90% is to be obtained, as the circulating current is considerable.

The question of whether L_1 and L_2 are in series or parallel is answered by the fact that both a.c. ends are virtually joined together when the transistor is conducting and the d.c. ends are joined via the low impedance path of the supply. Therefore the inductors L_1 and L_2 must be in parallel to a.c. but in series to d.c.

As regards frequency, a change in value of L_1 or L_2 will cause the output frequency to change, therefore the frequency is determined by both.

Regarding the comment about lightness, there is very little difference in weight to a conventional oscillator, having the same output power and frequency.

In fairness it must be stated that, the circuit shown in the August issue did not include the method of connection to the 13-W fluorescent tube used. Also, the article was not intended to be used for the construction of a complete unit but to illustrate a new form of oscillator on which a fair amount of research and development work has been carried out.

The inductor L_1 was an LA2 pot core with a core volume of 3.73 cm^3 which is just about the limit for the 13-W version. A further increase in output is possible using the LA7 with a core volume of 7.62 cm^3. The inductor L_2 was designed to keep the cut-off voltage low.

The comment about saturation is worthy of further discussion. If a transistor with its collector and emitter connected to a low impedance supply that can be adjusted over a range of zero to 1 volt, and the base is connected to the slider of a variable potentiometer, across the same supply, the collector current can be varied from zero to quite large values by varying the base current, the amount of variation being determined by the collector-emitter voltage. The voltage should be kept within the limits between zero base current and the knee in the base current characteristic.

In the oscillator, the collector-emitter voltage varies fractionally during the conduction period due to the current through the transistor and increases as the base current increases, the current gain being that of the type of transistor used.

H. L. ARMER,
Feltham,
Middx.

Intolerable tolerance code

May I through the courtesy of your columns register a protest at the new ludicrous resistor code for tolerance. Had you asked a nine-year-old school boy to invent a code he would have had the intelligence to have avoided K and M at all costs (not really difficult as there are 26 letters in the alphabet.) Thus 6.8kΩ 10% becomes 6k8K and 4.7MΩ 20% 4M7M!! Who is responsible for this travesty of commonsense?

I hope someone will enlighten me as to who the geniuses (or is it genii?) are! In the meantime am I a lone voice? I would have thought there must be a few other indignant electronics engineers besides myself.

A. SPROXTON,
Home Radio Ltd.,
Mitcham,
Surrey.

Electronic Building Bricks

6. Storing information

by James Franklin

The most familiar information stores are, of course, documents—books, films, punched cards, gramophone records—in which patterns are permanently impressed on some physical medium. Some storage media can be used over and over again—the blackboard, magnetic tape. With each medium the information is stored in a characteristic form or "code".

In electronics although permanent stores are sometimes used the biggest requirement is for temporary storage of information—perhaps for only fractions of a second. In a radio receiver, for example, a storage function analogous to persistence of vision is used to extract the sound signal from the radio signal. In a computer, an electrical codification of a number is temporarily held in a "register" while, say, another number is added to it. How we use electrons for storage depends on the manner in which the information is already represented electrically. One method has been shown in Part 2, Fig.3(a). A variable, such as air pressure, may be represented by a quantity of material held in a container. This material could be a quantity of electrons, and there are in fact devices which will store electrons. *The idea is further illustrated by the analogue Fig.1, in which quantity is measured in volume units.

Now if the outflow valve were closed the container would simply fill up and overflow, and thereafter cease to function as a store. This situation, for a constant inflow rate (i.e. constant electric current), is illustrated by graph (1) in Fig.2(a). If, however, the stored contents were allowed to pass out through the outflow valve at a constant rate the overflow would be avoided. If the outflow rate were exactly equal to the inflow rate the quantity stored would remain constant, as shown by graph (2) in Fig.2(a). If the inflow rate varied with time the quantity stored would vary with time as shown by graph (3) in Fig.2(b). Thus we see the principle of a store in which the quantity of electrons held (charge) is proportional to the electron inflow rate (current).

*One is the capacitor, in association with other components.

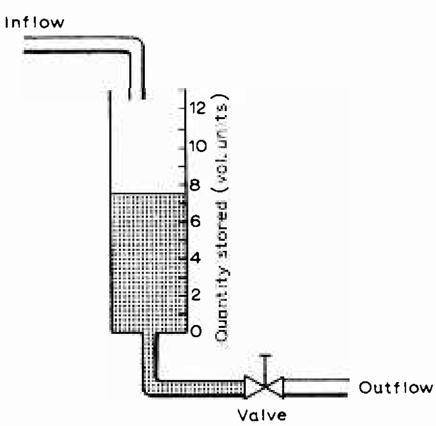


Fig.1. Analogue of a device which stores information by holding electrical charge (quantity of electrons).

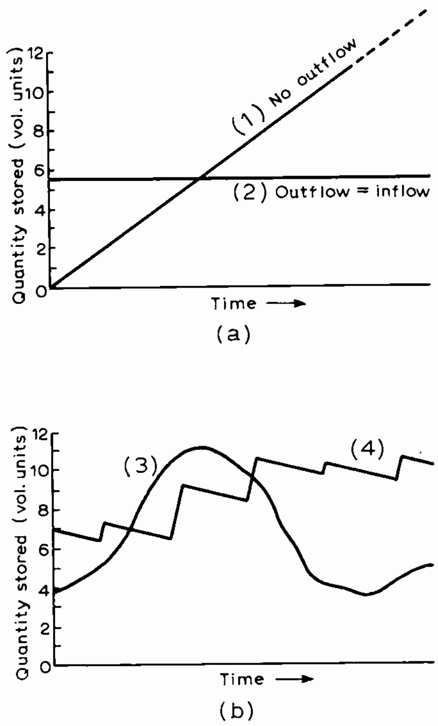


Fig.2. Graphs of quantity stored for Fig.1: (a) with constant inflow; (b) with varying inflow, continuous and pulsating.

In some electronic systems the charge inflow is not continuous but in pulses. Here the store works in a similar fashion—the contents being allowed to leak away between inflow pulses—and the resulting graph of quantity stored has a stepped shape as shown by (4) in Fig.2(b).

Fig.3 is a functional block representing a store of this general type. The electrical charge stored is continuously indicated by the value of an electrical variable.

What about information that is encoded as numbers, events, letters, symbols, pictures—in short patterns in space or time? The principle of storage here is to use electrical *states*. What do we mean by this? In a car's mileage counter, for each digit there is a numbered wheel which can take up any one of ten mechanical states, indicated in a window by the numerals 0, 1, 2, ...9. An electronic version of this would be a row of ten electronic switches† labelled "0" to "9": one of them is "on"—equivalent to a numeral appearing in the window—and the rest are "off". This principle can be used for an electronic counter (Part 2)—and in a sense such a counter can be regarded as a store in which the information held is a total of events counted.

The "on" and "off" states of an electronic switch, however, provide a very flexible system of storing information which can handle much more than just decimal numbers. All that is necessary, for any type of information, is to adopt or invent a suitable code. Two examples are shown in Fig.4. The Morse code can be further encoded into: dash = "on", dot = "off" and at (a) we see how this can be utilized to make a row of electronic switches store the letter "B" or numeral "6". The international telegraph code (used for teleprinters) can be handled in a similar way, and, of course, so can the binary code (since it represents numbers by two symbols, 0 and 1). Thus in Fig. 4(b) the row of electronic switches has an on/off pattern which can mean "J" in the telegraph code, if you are using that, or 11010 (=26) in the binary code, if you are using that.

†Switches which can be either "on" (conducting) or "off" (non-conducting) but are operated by electrical signals, not by hand.

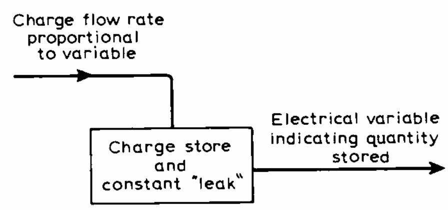


Fig.3. Functional block for a store using electrical charge.

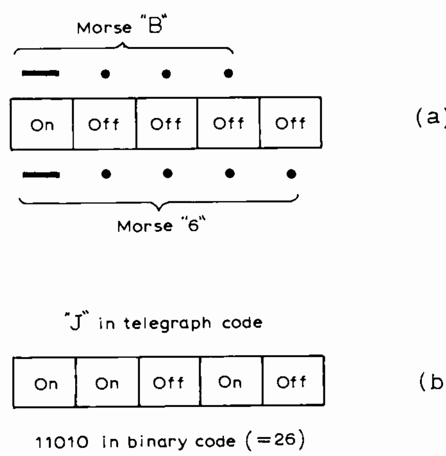


Fig.4. Using on/off patterns in rows of electronic switches for storing (a) Morse characters; (b) telegraph and binary code characters.

Automation in Broadcasting

New techniques revealed at the London broadcasting convention

The reason for needing automation in broadcasting is much the same as for needing it in industry. Broadcasting organisations, whether they be public service or commercial, want to increase the productivity of labour and capital investment in their manufacturing plants for sounds and images. Productivity is an output/input ratio, a measure of efficiency. In this case it means getting more output (e.g. programmes, broadcasting hours, signal complexity) from a given input (number of workers, quantity of broadcasting equipment) so that costs may be held reasonably stable. As everyone knows broadcasting is expanding, not only in terms of hardware—more transmitters, studios, equipment generally—but also in terms of the bits-per-second and complexity of the signal information put out: compare, for example, the PAL colour television signal of today with the a.m. sound signal with which broadcasting started in the 1920's. If this expansion is brought about simply by multiplying the equipment and workers using existing techniques, the cost of operation will become higher than the public service and commercial broadcasting organizations are willing to bear—not to mention us, the consumers, who pay for it all in the end. But by using new techniques—in particular automation—there is a good chance that the increased output may be obtained without an excessive rise in costs.

At least that is what the broadcasters are hoping for, to judge from many of the papers, discussions and equipment demonstrations at the recent International Broadcasting Convention in London. Here is how James Redmond, the B.B.C's director of engineering, put it in an introductory address: "We are, of course, looking for ways to cut our costs. Engineers, technicians and operators are becoming more scarce and more expensive—and sometimes more militant! We need equipment and facilities which are stable and reliable: which can be left unattended for long periods—and by that I mean a year or more—which can be aligned automatically, and which can be operated by the maker of the programme himself, whether he be a radio producer, a newsman, or even, ultimately, a television producer. In asking for these features I think you would agree that we are not asking for the moon".

It was clear from the contributions that followed that he was not asking for the moon, and that automation techniques and hardware are coming in fast. But what do we mean by automation in this context? It is a whole body of techniques, largely electronic, ranging from closed-loop servos on individual pieces of equipment, through automatic monitoring and control systems, to extensive data processing schemes using digital computers encompassing even the planning and organizational activities of broadcasting. In the following pages a few examples of these techniques are chosen from what was seen and heard at the I.B.C. starting with the individual automatic controls and ending with the comprehensive automation systems.

Colour television cameras are notorious for requiring lengthy manual alignment and colour balancing routines each day before they can be put into service in the studios. In the latest colour camera produced by Marconi, a small, light, three-tube design called the Mark VIII, these routines, and subsequent adjustments during programme time, are performed automatically by computer-like systems which are started simply by pressing buttons on the camera control unit.

Tokyo control centre of the Japan Broadcasting Corporation's computer system 'TOPICS' which organizes and operates two television and three radio networks. The display unit in the middle gives managers access to all information on programmes in the course of production.

One of the buttons initiates automatic registration and lining up of the red, green and blue pick-up tubes and their video channels. First a diascope test slide in the optical system of the camera is brought into operation by a motor-driven shutter which incorporates a mirror. The image of the test slide is reflected by the mirror into the light splitting optical system and so into the three camera tubes. A special-purpose computer then adjusts the gains of the red and blue channels so that their signals correspond with that from the green tube. Next a focus "rocking" voltage is applied to each tube, and the tube alignment currents are adjusted in sequence to produce the minimum displacement at the middle of the picture. The computer then examines the picture at a number of points, to detect any displacement of the red and the blue signals relative to the green. Adjustments are made to the width, height, rotation, skew, horizontal and vertical centring, and horizontal linearity to eliminate any discrepancies in the geometry of the three pictures.

All adjustments are made by means of small motor-driven potentiometers. Each of these units is fitted with a thumb-wheel to allow manual adjustments to be made for test purposes, or in an emergency. These motor-driven controls constitute mechanical information stores which cannot drift or be changed accidentally during operation.

Marconi say the complete sequence of automatic operations takes approximately three minutes in the worst case of misalignment, but will probably be well under a minute in normal day-to-day operation.

A further push-button initiates an automatic colour balancing sequence. The camera is pointed at a white object, occupying about 10 per cent of the picture area in roughly the middle of the picture. The iris is automatically set to give a peak green signal of 0.6 volt, and the red and blue channels are then adjusted to match this level. This operation takes 10 seconds, and if required can be carried out during a transmission when the camera is temporarily not 'on air'.

An automatic process called dynamic centring provides a continuous check on the registration of the three tubes while the camera is in operation. The signals from the three colour channels are examined continuously for transitions in the picture waveform. The positions of these transitions are compared electronically, to ensure that they are accurately in registration on all three channels. If an error is detected, and confirmed by at least one other transition position error, at least 3 per cent of picture height away from the first, a correction is applied to the appropriate tube deflection circuit.

An automatic testing routine, replacing the normal maintenance testing procedure, is started by a further push-button. First, a pattern of white rectangles is displayed on the channel picture monitor. Each rectangle relates to either the supply voltages or video signals from a specific part of the camera channel. If any of these parameters fall outside specified limits, the appropriate area of the display will be blanked out. This automatic test routine takes a few seconds, and enables the operator to assess the state of the complete channel.

Detailed information on a technique for achieving automatic registration of colour camera tubes was given by C. B. B. Wood of the B.B.C. Research Department. The basic principle is that a difference signal—for example the signal from the green tube subtracted from that of another tube—contains a minimum amount of detail when the picture is correctly registered. Picture detail for this purpose can be defined as the integral of the modulus of the derivative of the signal, and as such is a measure of the high-frequency content.

Fig. 1 (a) shows a difference signal $(A-B)$ obtained from two channels producing respectively signals A and B in a colour camera. The detail in this reaches a minimum at the point of correct registration. From this single response, however, it is not possible to determine in which direction the misregistration lies. In the B.B.C. method two separate difference signals are produced and the difference between the detail content of each is then used to produce an output. One difference signal is derived by delaying signal B by a suitable period, τ and then subtracting it from signal A while the other is derived after delaying signal A and subtracting the undelayed signal B. The detail responses due to these two difference signals $(A-B_\tau)$ $(A_\tau - B)$ are also shown in Fig. 1 (a). A direction-sensitive signal is then produced by subtracting one of these responses from the other, as shown in (b). It can be seen that the output is zero at the point of correct registration.

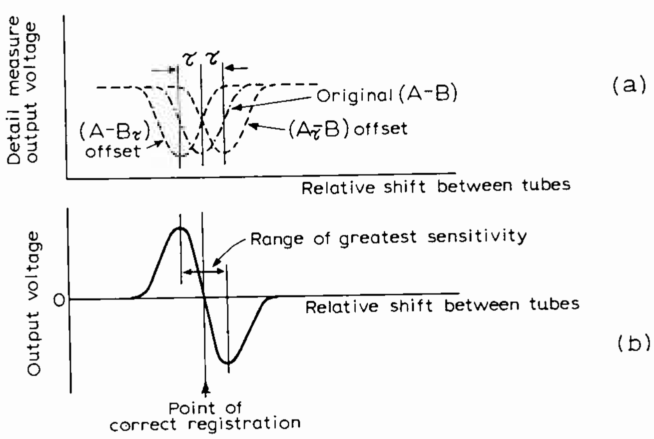


Fig. 1. Principle of system for automatic registration of colour television cameras: (a) two similar responses offset from the original response by delaying signals A and B; (b) output resulting from subtraction of two offset responses in (a).

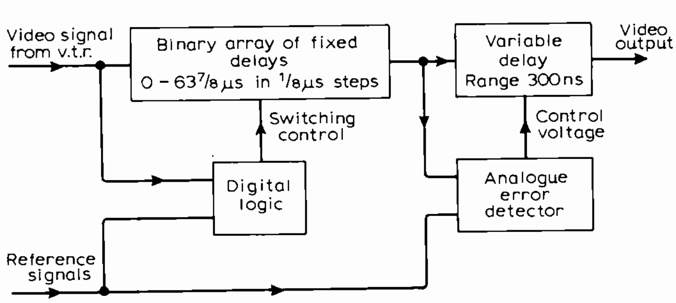


Fig. 2. Basic principle of timebase corrector for video tape recorder.

This principle is used to provide an electronic error detector. The output of the error detector is applied to two threshold detectors in the form of Schmitt triggers. One detector is set to change state when the output exceeds a predetermined positive threshold potential and the other is set to change state when the output exceeds a predetermined negative threshold potential. Thus when the error output exceeds one of the thresholds, the appropriate detector changes state and causes a correction process to start. This continues until the error output is reduced below the threshold.

Mr. Wood stated that one threshold detector could be used to cause a motorized potentiometer (as used in the Marconi camera) to turn in one direction and the other to cause it to turn in the opposite direction, and thereby adjust the shift in such a direction as to reduce the error which initiated the correction process. When there was no error information the correction potentiometer would remain at its last set position.

V.T.R. timebase correction

Another video signal source in which automatic control techniques are increasingly being used is the video tape recorder, and a process of particular importance here is the stabilization of the timebase. Professional v.t.rs have, for a number of years, relied on the use of electronically variable delay devices to remove the timing perturbations in the video output signal that arise from mechanical fluctuations in the recording and playback processes. These devices are necessary because of the need for a high degree of timing uniformity, particularly with colour, and because of the requirement that the output signal be synchronized with other video signal sources. Typical timebase correctors permit timing variations in the recorder of up to 1µs peak-to-peak, or about 2-3ns peak-to-peak for colour. By increasing the range of error correction, however, it is possible to achieve distinct operating advantages—for example, short starting-up time and quick recovery from timing disturbances such as splices—and C. Ginsburg of Ampex described a method by which the correction is increased to the period of a whole television line. This is used in the latest Ampex v.t.r., the type AVR1.

The technique utilizes switched, fixed delay lines, the delay times of which are arranged in binary order, the delay of each line being exactly twice that of the preceding one. If these are connected in cascade, utilizing any desired number of lines from the collection, then the total delay obtainable can be anything from zero (no delays in the path) to a maximum equalling the sum of all delays, going up in increments equal to the size of the smallest delay.

The Ampex corrector (Fig.2) has nine such delays, from $\frac{1}{8}\mu s$ to $32\mu s$, thus giving a range from zero to $63\frac{7}{8}\mu s$ in $\frac{1}{8}\mu s$ steps Electronic switching is provided to change the sequence of lines utilized as required. An incoming signal, after passing through this system, is therefore stabilized to within a time "spread" of $\frac{1}{8}\mu s$, assuming perfectly accurate delays. This residual timing error is further reduced by a continuously variable delay system similar to those utilized in existing colour timebase correctors.

Control of the switching of the fixed lines is by a system of digital logic, the function of which is to convert information about time separation between the signal and some reference sync pulses into multiple digital signals which will operate the delay-line electronic switches in the signal path. Basically, the logic system measures the time by which a sample of the leading edge of a line sync pulse leads the next following reference sync pulse, and converts this into suitable signals to control the switches. In the signal path, the video waveform is delayed by an amount that will cause a sync edge in the signal to emerge a fixed, known time after the specific reference sync pulse against which its time lead was measured. Making this fixed time equal to the sync pulse interval results in the emerging video being synchronous with reference sync.

The tremendous proliferation of u.h.f. transmitters necessary to give adequate television coverage in the U.K. would result in extremely high costs if all these stations had to be manned. All the B.B.C's u.h.f. television transmitters have, however, been designed for unattended operation. This requires automatic monitoring and fault correction techniques. The B.B.C's approach to the requirement is that monitoring should be performed at each station rather than remotely, and that only necessary information should be sent to the nearest manned station.

Transmitter monitoring system

Fig. 3 is a simplified block diagram of an automatic quality monitoring and control system for a u.h.f. transmitter, as described by I. J. Shelley and D. J. Smart of the B.B.C. Designs Department. The general principle is to have a single monitoring equipment, consisting of a group of measuring units, switched sequentially to a number of test points. Under normal conditions the monitor input switch would be at position 1. If the monitor detects an 'urgent' fault the system automatically switches to position 2 and checks the incoming main video feed. It will then switch to position 3, check the reserve video feed, and finally return to position 1, where it will ascertain if the fault is still present. If so, appropriate action will be taken, either by changing the input feed or by changing to the standby transmitter or both (sequentially). Also, details of the action taken and the reason for it can be sent out by a data transmission system to a manned station.

In order to allow for some inevitable signal impairment caused by the transmitter it is necessary to narrow the limits when the monitor is switched to positions 2 or 3. Normally it is sufficient to use the 'urgent' alarm limits when monitoring the transmitter output and change to 'caution' alarm limits when monitoring the input video feeds, but the system is sufficiently flexible to enable additional limit units to be used if necessary. Faults can be reported back by two signalling methods: modulation of a 23kHz sub-carrier radiated by the television sound transmitter; and digitally coded pulses inserted into the video waveform on one or more lines during the field blanking interval.

Putting together a day's television programmes requires hundreds of accurately timed signal switching operations on a large number of vision and sound sources—different studios, video tape recorders, film equipment and newsrooms. Doing this switching manually is becoming increasingly difficult—as the viewer can tell from the number of mistakes which appear on his screen—and it is obvious that any help from automation would be a good thing. Automatic switching, under the control of stored instructions, is in fact now possible by means of equipment which was shown by Marconi and described by R. W. Fenton of that company. This equipment, called a presentation switcher (Fig. 4), needs only to have the day's programme schedule fed into its digital store. From then on, it automatically switches up to 30 different programme sources onto transmission at the required times. The switching instructions stored in the system can be inspected at any time on an alpha-numeric c.r.t. monitor screen. If desired a change to the schedule can be entered at any time, and its effect on the schedule is immediately displayed.

Switching instructions are fed in to the store manually by a simple keyboard of push buttons. These instructions comprise the vision source to be selected, the timing of the event to the nearest second, and the type of transition, such as "cut", "mix" or "fade". In the store instructions for up to 15 consecutive future events can be held. When it is fully 'loaded' with instructions, its contents can be transferred to punched paper tape, by pressing a button. The store can then be reloaded with another series of events. Altogether 999 events—more than a full day's requirements—can be stored in this way. The alpha-numeric characters on the display screen are electronically generated, as patterns of bright points on a standard television raster.

For accurate time reference the system relies on an external timing source, such as the station clock. It this fails, it uses video field pulses as a temporary time reference—the change-over being automatic. Although the time normally displayed for each event is its real time of occurrence, the time instruction actually entered by the operator is the duration of the event. The real time is immediately computed from this and shown on the alpha-numeric display. If the duration of an event is not known at the time of instruction, the real time computation for succeeding events can be withheld until it is known.

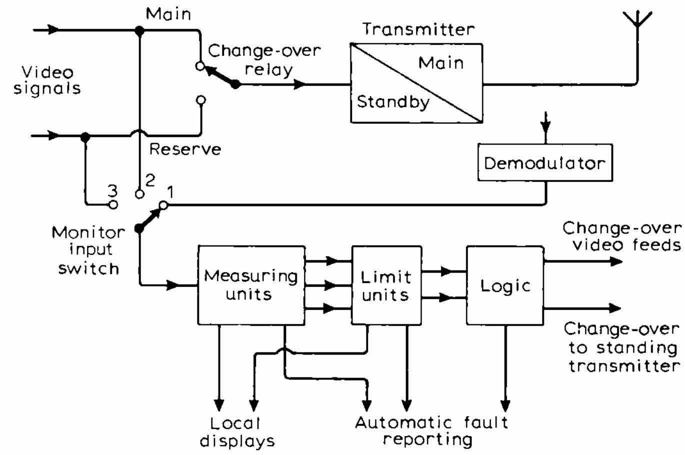


Fig. 3. Simplified block diagram of quality monitoring and control system for B.B.C. u.h.f. transmitters.

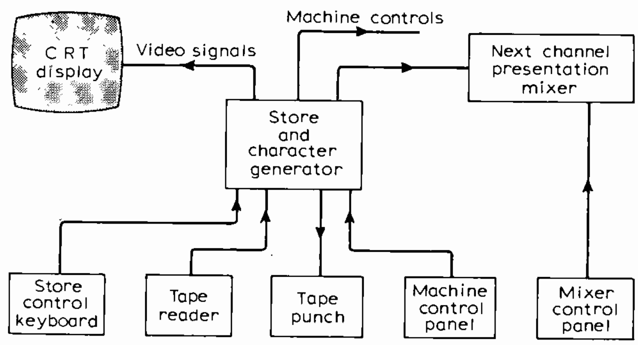


Fig. 4. Automatic programme switching system, controlled by instructions held in a store.

To make adjustments to previously entered instructions, a cursor line on the display is moved to the instruction to be altered, using push buttons on the keyboard. The new instruction is then entered, and appears on the display. An entire event can be erased from the stored instructions. When this is done, the air times of all succeeding events are automatically revised. Conversely, an additional event may be inserted between any two existing ones.

Of course, programme sources such as video tape recorders and telecine machines require particular starting-up times. The system automatically makes allowance for this whenever one of these sources is selected. Up to seven different starting times, to a maximum of 59 seconds, can be provided. Each machine is turned off when its output is not in use.

In addition to automatic operation, the system allows for simple manual control. The operator can preview any vision signal or 'pre-hear' any sound signal before it is transmitted. If an emergency occurs, such as a signal failure, the equipment allows programme corrections to be made very quickly and without disrupting the rest of the programme schedule.

Computer aided broadcasting

What could be regarded as an extension of the Marconi automatic scheduling equipment is a programme control system described by N.W. Green of Thames Television. This has been developed for use in the company's recently built studio centre at Euston, London. It is an 'extension' in the sense that whereas the Marconi equipment is centred on a digital store, the Thames Television system is centred on a complete process-control digital computer—a machine with 12-bit word length, 8000 words of core storage and 32,000 words of disc storage. The need for such an elaborate system (Fig.5) arises basically from the complicated build-up and tightly controlled timing of a commercial company's

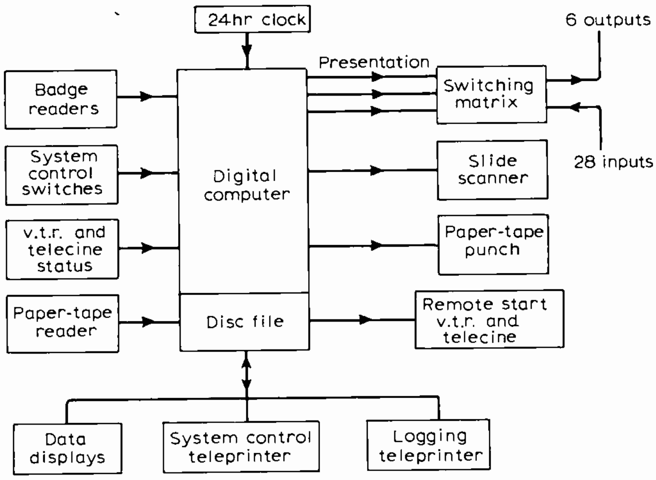


Fig. 5. A process-control digital computer is the heart of this Thames Television system for programme switching and timing.

programmes. The 15 programme contractors in Britain's independent television system produce a variety of programmes, some for local viewing only and some for national viewing; in addition, commercials and programme 'promotions' are locally inserted irrespective of the origination of the programmes. The timing of all this has to be extremely rigid and accurate, and is decided some weeks in advance.

The system in Fig.5 operates in the following manner. At any time before the day of transmission, the programme schedule is typed out on a teleprinter and each item is verified by the computer and punched into paper tape. Information entered concerns the time of starting, duration, originating source, programme title and number, and whether the programme is for local or network transmission. Once the tape has been produced it is kept until the day of transmission, when it is fed into the system. The information is again verified and the appropriate 'roll' cues for telecine and v.t.r. machines are generated, i.e. a 6-second cue for telecine machines and a 15-second cue for v.t.r.

The status of v.t.r. and telecine machines is continually checked and when a reel of programme material is loaded onto a machine its "identity badge" is inserted into the badge reader. The system then reads the badge and searches the programme schedule for the corresponding number. Once this is located the machine number is inserted into the appropriate place on c.r.t. data displays. If the machines are not loaded 5 minutes before transmission time the corresponding line of information on the display starts to flash once every second until the machine is loaded. This flashing will start again if the machine is not put in the remote starting mode 3 minutes before 'roll' time. Any change of status in the machine will immediately be displayed to the transmission controller (a human being!) If the machines start to run and then for any reason stop, the programme automatically selects a stand-by slide.

The data displays indicate, on the top half of the screen, the next seven items to be actuated by the computer, and the bottom half can be used either to display a further 10 items following the already displayed items, or to display sections of the schedule for amendments, etc. The bottom line of the display is used for unsolicited messages from the computer regarding over-running or under-running on items, insertion of extra items creating shortage of time, or deletion of items causing a surplus of unfilled transmission time.

To cater with such problems, some programmes are identified as having fixed starting times because they are to be networked, and others—such as promotions, announcements and some local programmes—are designated as having variable start times. When there is some time to be absorbed, the computer searches between the two fixed items, looks at the variable items, and indicates to the transmission controller whether cuts could be made. Likewise, the reverse happens when there is an excess of time. The data displays show the current items "counting down" a second at a time.

What seems like the ultimate in computer control in broadcasting is the now famous 'TOPICS' system which has been operated by the N.H.K. (Nippon Hoso Kyokai) broadcasting organization in Japan since 1968. This even embraces the audience in its information system (through audience-reaction results) and the IBM man who described it. G. J. Lissandrello, suggested that such a scheme could only be accepted and operate successfully in Japan—perhaps because of the philosophy of life that informs all developments in that country. 'TOPICS' is an acronym for Total On-line broadcasting Programme and Information Control System. installed at the N.H.K. headquarters in Tokyo, it plans and administers the entire production and scheduling operations of two television and three radio networks†. It comprises several digital computers and can be regarded as a central file with two major sections, one concerned with planning and production, the other with the actual 'on the air' broadcasting operations and equipment.

Information in the 'file' includes details on what programmes are in production and what is their stage of completion; their subject matter; when they are scheduled for broadcasting; who is directing them, acting in them, building the sets and supplying the 'props' for them; when and where they will be rehearsed, when they will be recorded and on which machine; whether they are coming in on schedule or whether assistance is needed to bring them in on time; who worked for how long on them and how much he is to be paid.

The N.H.K. broadcasting workers communicate with each other through the system. A director, for example, no longer needs compile a schedule, duplicate it and distribute it. He compiles it and enters it into the central file—in fact with the help of the file, for it contains all the information he needs in the first place. Once in 'TOPICS', the schedule and the assignments for people and equipment are available to all workers. Anyone with a question goes to a computer, presses a few keys, and is immediately presented with information on a c.r.t. display. Paperwork is almost eliminated. Changes in schedules and programme are easily entered into the system. The display screen shows both 'output' and 'input', presenting what is in the system and showing input changes that are made to update it.

Control of machines

In its second major function, the system controls the immediate processes of broadcasting N.H.K's radio and television programmes. Every ten minutes this broadcasting control section receives orders from the organizational-section computer to cover the next period of broadcasting and recording activity. It expands the orders into the longer, more complex routines needed to translate them into action. Given the order to prepare a video tape recorder to receive the output of a specific studio, for example, the system finds a path through an array of switches, thereby connecting studio to recorder. The broadcasting control section then runs the recorder through a warm-up and check-out routine so that it is ready for recording when the performance is scheduled to begin. It then monitors the recording process, rewinds the tape when recording is finished, and shuts down the recorder.

After the performance, the recorded programme is registered in TOPICS' computer files and stored to await broadcasting. At the approach of broadcasting time, the system displays a schedule that warns an operator to put the tape on a specified video tape recorder. Twenty minutes before 'air time' the control system establishes a path in the switching network, checks that the right reel of tape is on the tape recorder, and warms up and tests the machine. Ten seconds before 'air time' the system starts up the recorder, then 300ms before 'air time', it switches the recorder into the broadcasting network and puts out the programme.

The broadcasting control system performs these functions simultaneously for the two television and three radio networks, and at the same time continues to co-ordinate the production of the other programmes in preparation.

Mr. Lissandrello concluded with the remark that TOPICS had given the N.H.K. management "an information system which enables them to improve their operation, decrease their expenses and serve the public in a much more efficient and timely way".

* Buddhism has been a strong influence in Japan, and a characteristic feature of this philosophy/religion is the lack of importance of the individual and the "one-ness" of all living creatures.

† A lecture on 'TOPICS' will be given at a Royal Television Society meeting on 3rd December by Eric Rout of the B.B.C. Research Department (7.00 p.m., I.T.A., 70 Brompton Road, London, S.W.3.)

Active filters

15. Simulated inductance

by F. E. J. Girling and E. F. Good**

An active *CR* equivalent of an inductance may be designed from consideration of the required external property: the current is proportional to the integral of the voltage; or from the premise that if a high-*Q* tuned circuit has the tuning capacitor removed the network remaining must present the impedance of a high-*Q* inductor.

Since in general the special reason for an active filter is the avoidance of inductance coils, and since also it has been shown that to obtain low sensitivity to errors in component values it is often beneficial to design an active filter to reproduce the internal workings of a passive prototype (and not merely to have the same overall response), it may be wondered why so far in this series active-filter design has not been treated as the problem of devising an active *CR* simulated inductance, to replace on a one-for-one basis the inductance coils of a conventional passive filter. The principal reason is that in many cases the inductance to be replaced has neither end earthed, and that any straightforward active replacement needs a floating power supply or a rather complicated substitute (Ref. 1).

In a high-pass filter, however, inductances appear only in the shunt arms and can therefore have one end earthed. Thus Fig. 1 shows a h-p structure which with suitable

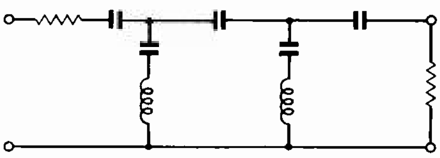


Fig. 1. Structure for 5th-order Darlington h-p filter.

values can give 5th-order Darlington response (the counterpart of the type of l-p response shown in Figs. 1 of Parts 1 and 9) and which seems to call out for active realization by the simulated inductance method, since: (1) the active circuitry will have to perform the functions of only two reactances; (2) it will not in any exacting sense have to operate up to indefinitely high frequencies, since h.f. signals pass directly from input to output through the three series capacitances (which remain); (3) the two capacitors which give the stop-band zeroes also remain. If, however, the two simulated inductances each need several amplifiers, it may turn out that the apparent simplicity and economy of the method is largely illusory. It is also worth keeping in mind that the inductances when connected into a filter form with the capacitances one or more resonant or tuned loops, which are a feature of any filter. It is unlikely, therefore, however novel the construction of the simulated inductances may seem, that the operation of the filter cannot be explained in the familiar terms established in earlier Parts, i.e. loops containing integrators, lags, and so on.

Shunt capacitance will clearly introduce a non-ideal element; but so it does in a passive *LC* filter, and it seems reasonable to suppose that in some cases it may be advisable to adopt a design fed from a low or zero-impedance source, Fig. 2, rather

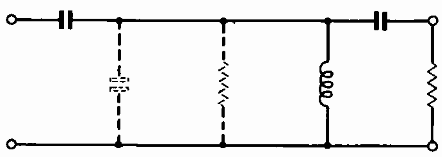


Fig. 2. Stray capacitance and conductance cause less h-f attenuation if the filter has no terminating resistance at the input end.

than an equally terminated design, even though this means losing the low sensitivity to errors given by a power-matched structure. The effect of shunt conductance on the transmission of frequencies well above cutoff will also be minimized.

The external characteristic of inductance is simply that of a two-terminal impedance which, in response to an applied sinusoidal voltage, draws a lagging quadrature current of magnitude inversely proportional to frequency. An active simulated inductance must duplicate this characteristic, and internally be some arrangement of amplifiers with feedback, with, in general, only capacitive reactance.

Integrator with voltage-to-current converter, the reactance valve

Inductance is defined by

$$i = \frac{1}{L}\int v\,dt \qquad (1a)$$

or

$$I = \frac{V}{pL} \qquad (1b)$$

So an integrator is needed, to integrate the applied voltage, and this may be followed by a voltage-to-current converter (or mutual conductance), Fig. 3(a). Since I should be the whole of the input current, the input admittance of the integrator and the output admittance of the V-to-I converter should be negligible. Practical circuits may, therefore, be designed on the lines indicated by the simplified diagrams of Figs 3(b) and (c).

When a capacitor is connected across the terminals, the V-to-I converter becomes an integrator, and the circuits are then two-integrator loops containing one integrator which is sign-inverting and one non-sign-inverting. One must be of the "constant-current" type,† since its capacitor is pre-

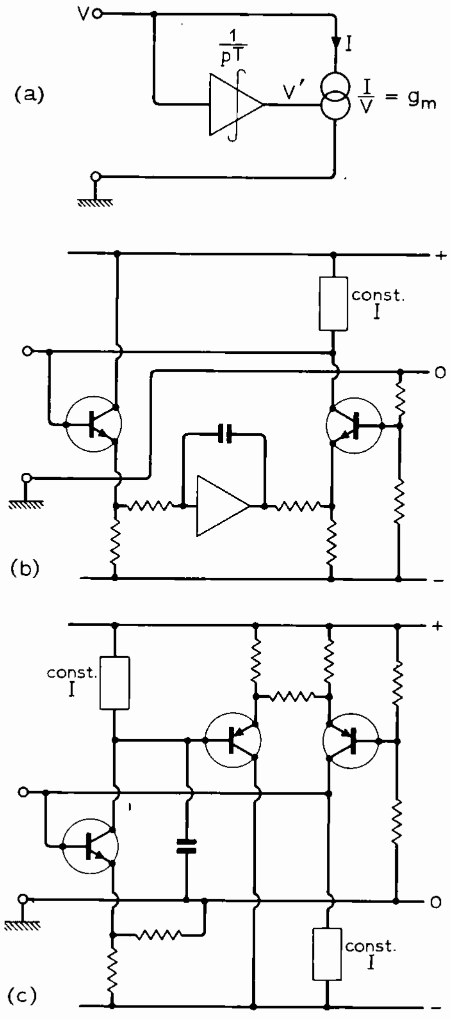


Fig. 3. Inductance-simulating circuits using an integrator and a current source (or mutual conductance).

sented with one terminal already earthed, but the internal integrator may be of any type.

A simple version of this type of circuit is one of the two well known reactance-valve circuits (Part 1, Fig. 12) used for automatic frequency control. The V-to-I converter is a pentode valve using its natural mutual conductance, and the integrator is a passive simple lag (*RC*) working above its corner

* Royal Radar Establishment.

† We use this title for want of a better.

frequency so that the phase shift approaches 90°. Similarly a transistor can present an inductive impedance, Fig. 4, the capacitance arising from charge storage in the base or from an added capacitor. But such inductances are too imprecise for serious filter use.

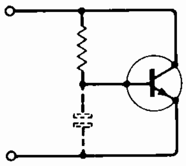


Fig. 4. In conjunction with a base resistance the base storage capacitance causes a lagging (i.e. inductive) component of collector current.

Circuits using voltage amplifiers

Amplifiers with voltage output (op. amps) can be used to make a simulated inductance by producing at the far end of a shunt feedback impedance a suitable voltage. The obvious choice of impedance is a resistance (Fig. 5), and to make $I = V/pL$, $G(p) = V_{out}/V$ must be such that

$$V - V_{out} = IR = VR/pL, \quad (2)$$

i.e.

$$V_{out} = (1 - R/pL)V, \quad (3)$$

which is of the form

$$V_{out}/V = 1 - 1/pT. \quad (4)$$

This calls, in effect, for two parallel paths, one aperiodic and with a gain of exactly one, the other giving integration with a negative sign—so that if V is a step, V_{out} is as shown

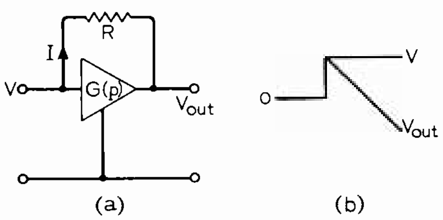


Fig. 5. For $I = V/pL$ the voltage transfer ratio $G(p)$ must have the form $1 - 1/pT$.

in Fig. 5(b) and the difference $V - V_{out}$ is a linear ramp as required.

The aperiodic path may conveniently use unity-gain amplifiers of the nature of emitter followers or op. amps with 100% feedback and if a capacitance is placed as coupling between two of these, the integral part of the required transfer function can be added by building up a charge in the capacitance with the help of a current source. This leads to a circuit as shown in outline in Fig. 6(a), and the alternative shown in Fig. 6(b). The action of each may easily be understood by supposing a step of voltage is applied to the terminals. Both are capable of good performance; but if C is not ≫ than the stray capacitance from A to ground, the instantaneous voltage at the output B will be less than the input voltage, and a fraction $C_s/(C + C_s)$ of the input voltage will appear across R. This causes a resistive (or in-phase) current to flow, with the effect that a conductance equal to the same fraction of

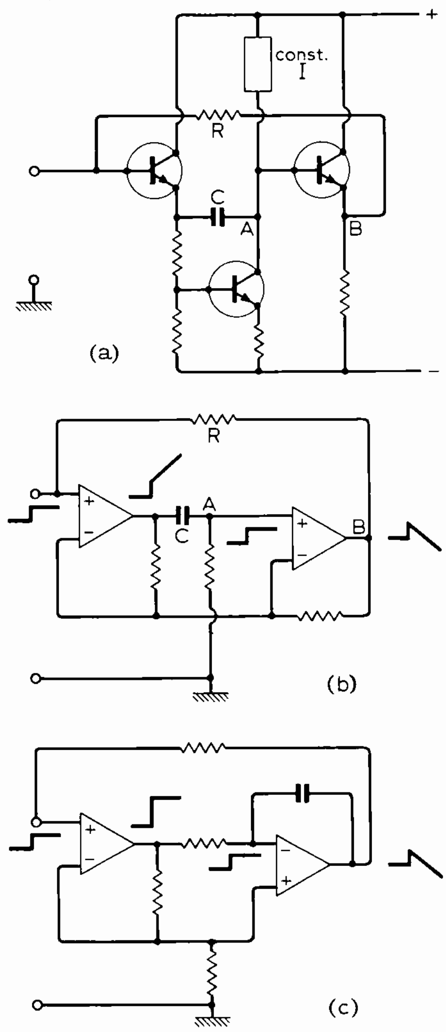


Fig. 6. Circuits for realizing Fig. 5.

$1/R$ appears across the terminals and the simulated inductance is lossy. A gain less than one in the emitter followers has the same effect. Many other inductance-simulating circuits using op. amps can be devised, e.g. Fig. 6(c).

Low-Q circuits

When some conductance across the terminals is acceptable, a circuit such as Fig. 7(a) may be used, giving the impedance shown in Fig. 7(b). If a capacitance is connected across the terminals an integrator-and-lag loop is formed (c.f. the

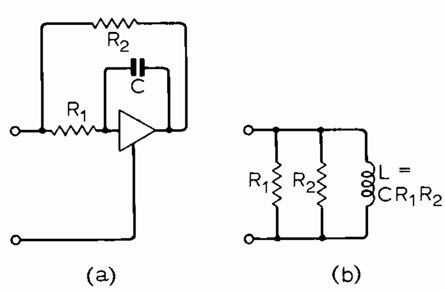


Fig. 7. A low-Q simulated inductance.

circuits of Fig. 3, which form two-integrator loops), and a copy of a 2nd-order h-p filter can be made as shown in Fig. 8. It can be seen that the circuit is of a type which gives tuned-circuit response when the output is taken from the output of the amplifier. Here the output is taken from a high-impedance point, and in a practical application a buffer such as an emitter follower may be needed.

In theory the Q factor can be made arbitrarily high by making R_1 and R_2 much higher than the reactance of C_2, and the reactance of C_1 much higher again. In practice, however, such a move is severely limited: relatively large amplitudes would have to be developed at the output of the amplifier; and even if these can be accommodated, there is a value, Q_{max}, determined by the available loop gain, which cannot be

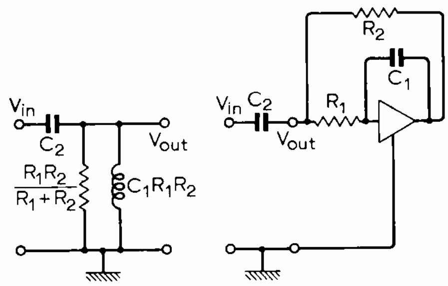


Fig. 8. A low-Q simulated inductance used in a 2nd-order h-p filter.

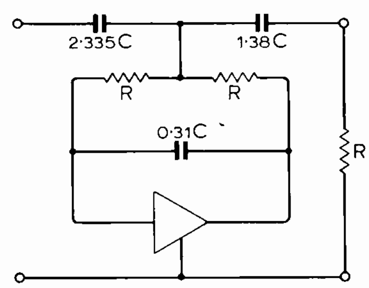


Fig. 9. 3rd-order Butterworth h-p filter.

exceeded (Part 4). The circuit quickly runs out of steam, therefore, in higher-order filters; but Fig. 9 shows a 3rd-order filter in which a lossy "inductor" is acceptable.

Reactance valve with negative-resistance circuit

The weakness of the foregoing circuit is the inherent damping, and it is tempting to consider producing a pure inductive reactance by cancelling the positive conductance by a negative conductance of equal magnitude.

A shunt feedback impedance Z connected across an operational (or negative-gain) amplifier of gain $-A$ gives an input impedance $Z/A+1$), there being a mathematical equivalence as shown in Fig. 10. If the amplifier has positive gain K we may write

$$A + 1 = 1 - K \quad (5)$$

and the diagram of equivalence may be relabelled as in Fig. 10(b). If $K > 1$ and Z is positive, $Z(1-K)$ becomes negative; and if $K = 2$, $Z_{in} = -Z$ (Ref. 2). Thus with an amplifier of voltage gain 2 a positive resistance R is turned into a negative resistance $-R$ and the arrangement may therefore be used to cancel the damping caused by a second positive resistance R.

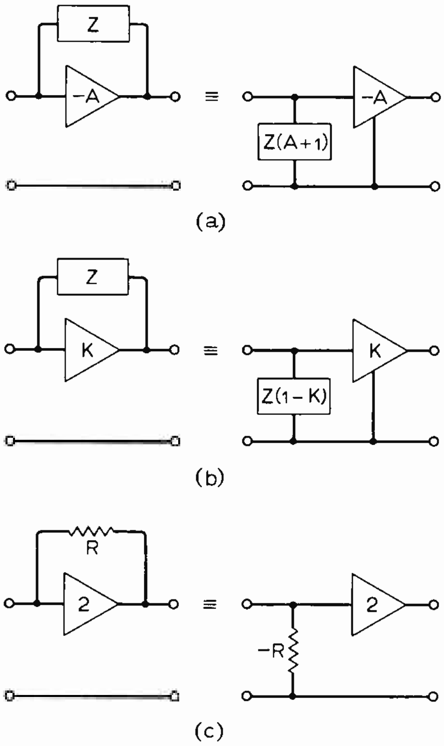


Fig. 10. Equivalent impedances obtained by shunt feedback.

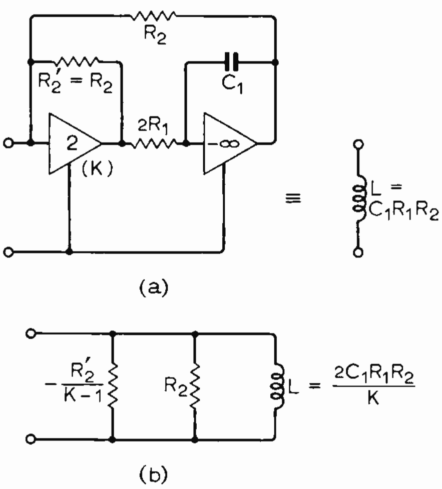


Fig. 11. Cancellation of positive conductance by equal negative conductance.

Such a system is shown in Fig. 11(a), and the effects of using a cancellation method may be calculated with the help of Fig. 11(b), where the gain of the auxiliary amplifier is again assumed to have the general value $+K$.

The auxiliary amplifier is a negative impedance converter, and its use is an application of straight positive feedback (as mentioned in Part 1) which must lead to exaggeration of any errors in certain component values. As, however, accurate cancelation depends only on having two pairs of matched resistances, the pair R_2 and R_2', and the pair which determine the gain of the auxiliary amplifier (Fig. 12), and as accurate and stable resistors are generally easier to come by than equally good capacitors, the method is not open to as serious practical objections as the general use of negative impedance converters, the production of negative capacitance as well as negative resistance.

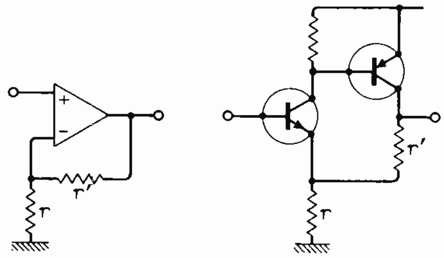


Fig. 12. When internal gain is high, overall gain is determined by the ratio of two resistances.

Errors in the cancellation leave an unwanted conductance, positive or negative, across the simulated inductance; and for accurate performance it is clearly desirable that the unwanted conductance should be small compared with the wanted conductance or damping: in other words the sensitivity to errors increases with the working value of Q factor.

The gyrator

If the internal capacitance is removed from a simulated inductance, e.g. Fig. 3(c), the ideally aperiodic circuit that is left is often considered by itself and called a gyrator. It can be described mathematically by four conductances. The input and output conductances are ideally zero; the forward and backward transconductances (g_{m1}, g_{m2}) are non-zero, finite, and of opposite sign. Its wanted property is that an impedance Z connected across one pair of terminals gives an input impedance R^2/Z at the other pair. For this reason it is sometimes called a positive impedance inverter. The constant $R^2 = -1/g_{m1}g_{m2}$, which is positive, since one of the transconductances is negative.

For the schematic of Fig. 13

$$-g_1V_2 = I_1 \qquad (6)$$

$$I_2 = g_2V_1 \qquad (7)$$

Hence

$$Z_{in} = V_2/I_2 = -I_1/V_1g_1g_2 = 1/Z_1g_1g_2, \qquad (8)$$

since

$$Z_1 = -V_1/I_1.$$

If then

$$Z_1 = 1/pC_1$$
$$Z_{in} = pC_1/g_1g_2. \qquad (9)$$

This may be equated to the impedance of an inductance, pL, showing that

$$L = C_1/g_1g_2. \qquad (10)$$

For precision g_1 and g_2 will in a practical circuit be defined by passive resistances, for example the feedback resistances of current sources, so that $g_1 = 1/R_1$ and $g_2 = 1/R_2$. Eqn (10) then becomes

$$L = C_1R_1R_2. \qquad (11)$$

Implied in this analysis is the assumption of integrators with infinite zero-frequency gain. If leakage resistances R_1' and R_2' across the two pairs of terminals respectively are allowed for, Fig. 13(b), the integrators are seen to have finite zero-frequency gains of magnitudes $R_1'g_1$ and $R_2'g_2$, i.e. R_1'/R_1 and R_2'/R_2. The Q factor of the system is therefore limited as shown in Part 7; and if $R_1'/R_1 = R_2'/R_2 = A$, $Q_{max} = A/2$ and is obtained when $C_1R_1 = C_2R_2$.

Synthesis of a floating inductance

Generally all the inductors in a l-p ladder and half those in a b-p ladder have neither end earthed. To produce a simulated floating inductance which does not need a floating power supply recourse is made to the leapfrog or active ladder system, Parts 12 and 13. The modification needed is the replacing of the outer integrators by ones of constant current types so that the active part of the filter may have the same output and input impedances as the section of the passive model it replaces, as well as the same transfer function.

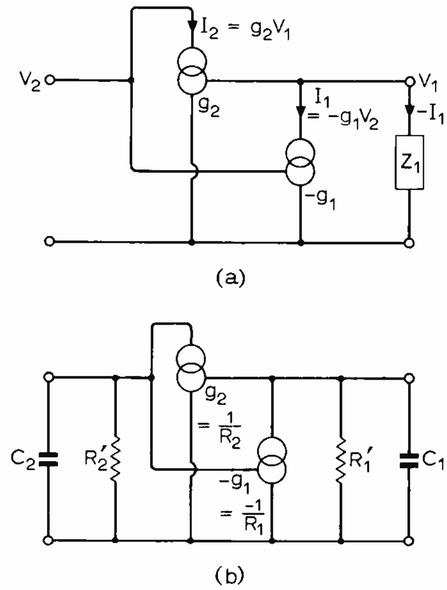


Fig. 13. Theoretical diagrams of a gyrator using two voltage-controlled current generators.

The method is illustrated in Fig. 14, which shows the procedure for a simple 3rd-order l-p filter, and where for convenience all stages are converted to the "constant-current" type. The result can be recognized as two intermeshing gyrators loaded by three capacitors and the two terminating resistors. The inverting stage is shared, and the identity of the two gyrators is seen more clearly in the alternative configuration shown in Fig. 15*, in which there are two separate inverter stages, one in each feedback link. This configuration was described by Holt and Taylor (Ref. 3) as an application of gyrators. A proof that it does produce a simulated floating inductance follows.

For Fig. 16

$$V_2 = V_1 + IpL \qquad (12)$$

$$I = I_1 = I_2. \qquad (13)$$

*Which corresponds to a ladder of the type shown in Fig. 13(c) of Part 12 (July 1970).

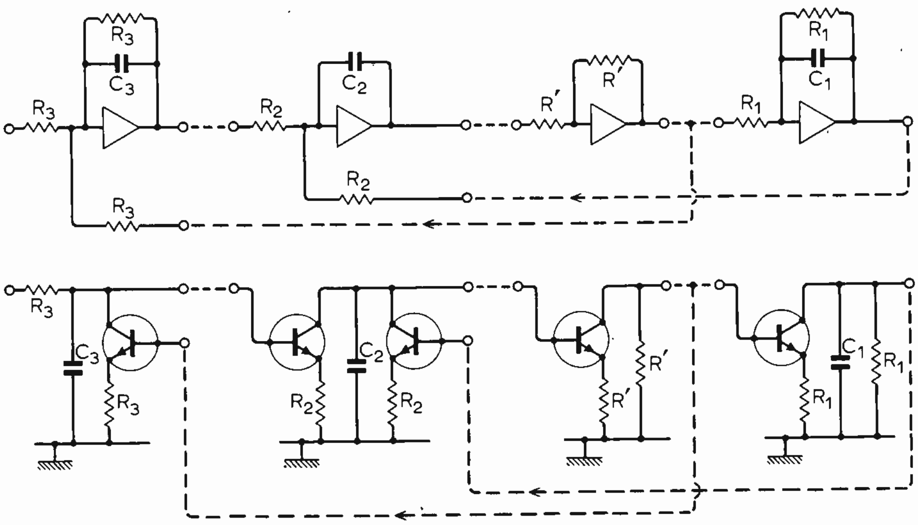


Fig. 14. Replacing the operational amplifiers in a standard leapfrog or active ladder filter by voltage-operated current sources. The constant-current circuits which supply collector current are omitted. As they are in parallel with current sources in the signal path, they should present impedances at least as high.

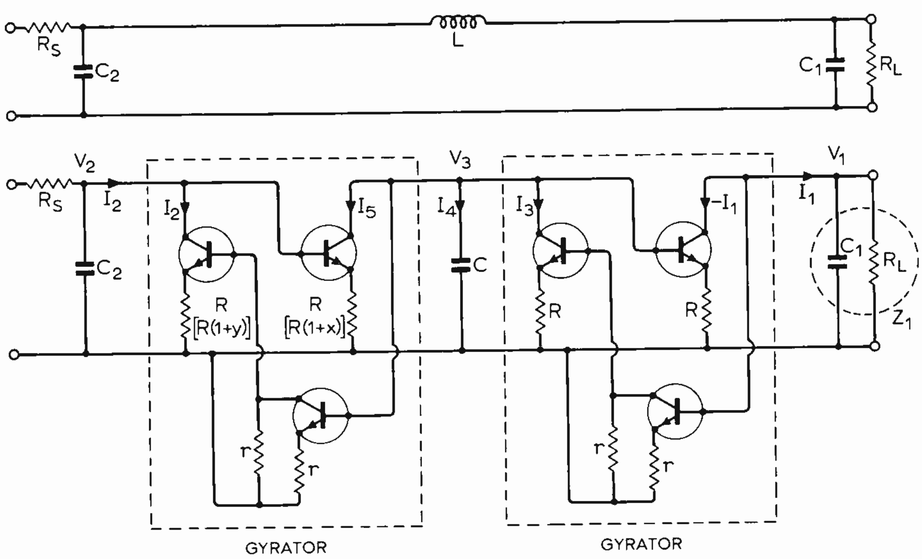


Fig. 15. A method of simulating an unearthed inductance.

For Fig. 15

$$V_3 = -I_1R \quad (14)$$

$$I_3 = -V_1/R \quad (15)$$

$$I_4 = V_3pC = -I_1RpC \quad (16)$$

$$I_5 = -I_3 - I_4 \quad (17)$$

$$= V_1/R + I_1RpC \quad (18)$$

$$V_2 = I_4R = V_1 + I_1pCR^2 \quad (19)$$

which is of the form

$$V_2 = V_1 + I_1pL \quad (20)$$

and $$I_2 = -V_3/R = I_1. \quad (21)$$

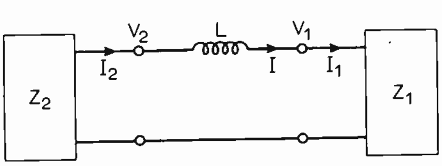


Fig. 16. Two parts of a network joined by a series inductance.

These last two equations repeat eqns (12) and (13), so the proof is made.

If the l-h loop does not match the r-h loop, say because two resistors are in error as marked, eqn (17) gives

$$V_2/(1+x)R = V_1/R + I_1pCR \quad (22)$$

i.e. $$V_2 = (V_1 + IpL)(1+x). \quad (23)$$

$$I_2 = I_1/(1+y). \quad (24)$$

So, the impedance presented,

$$V_2/I_2 = (V_1/I_1 + pL)(1+x)(1+y) \quad (25)$$

$$= (Z_1 + pL)(1+x)(1+y). \quad (26)$$

Thus the nature of the impedance is not affected, but scaling factors are introduced. This means, unless $(1+x)(1+y) = 1$, that $R_S = R_L$ will no longer exactly represent optimum power matching; but for small errors the departure from the desired low-sensitivity condition will not be great. The effect is of course the same as for a parallel error in one of a pair of nominally equal resistors in a standard active ladder, Part 12, Fig. 13. It should also be understood that Figs 14 and 15 are intended only to give a notion of practical circuits. For precision and near-ideal performance the single transistors will probably have to be replaced by compounds, perhaps of a junction f.e.t. and a bipolar transistor. Whether the property of being able to transmit signals in either direction is of practical use or no, we leave to our readers.

Derivations from the conventional two-integrator loop

Examples have been given showing that active circuits which behave as inductances are often easier to recognize when made into a resonant loop by the addition of a tuning capacitance. Conversely, the search for an active inductance may begin from consideration of an undamped resonant loop from which the tuning capacitance is removed. This self-evident proposition is shown in Fig. 17; and for a good practical circuit it is important that the one-to-one correspondence principle be observed (so that the value of the simulated inductance is directly proportional to a single capacitance in the active circuit).

The two integrator loop using operational amplifiers in the conventional virtual-earth type of connection meets the requirements in all respects (Fig. 18) save that both capacitors are floating. There is therefore no convenient way of connecting it as an active inductor into a filter network, even one using only earthed inductors. To correspond with Fig. 17, and so to be of

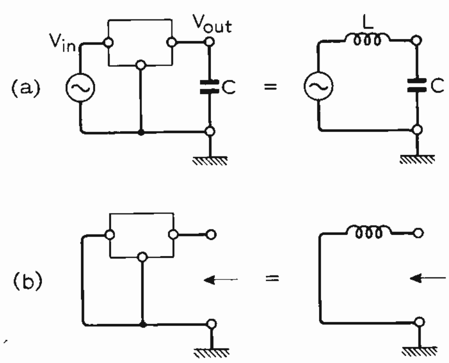


Fig. 17. If the tuning capacitance is removed from a tuned circuit, what is left is an inductance.

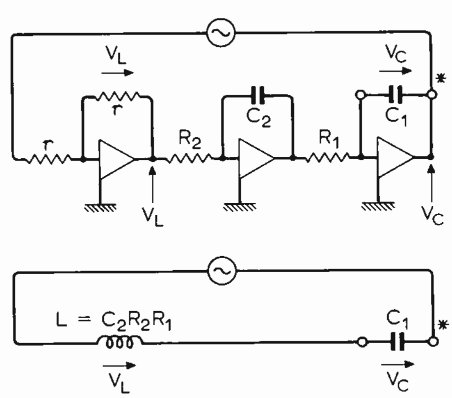


Fig. 18. The principle shown in Fig. 17 applied to the two-integrator loop.

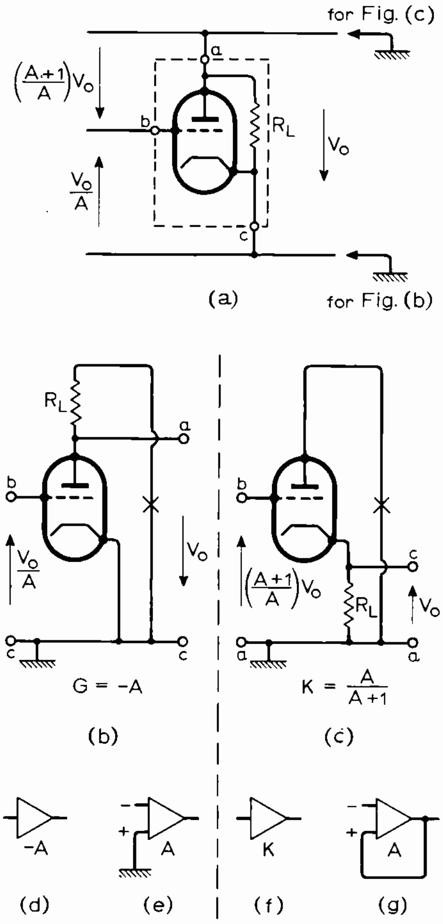


Fig. 19. Relationship between various amplifier symbols.

practical value, the circuit must be re-arranged so that the starred terminal can be earthed.

A model 3-terminal amplifier

A convenient amplifier model is required which allows choice of earthing point without changing the internal working. As in Part 6 a triode valve is suitable. It is a three-terminal amplifier, and it is to be understood that the broken-line boxes (Fig. 19) enclose self-contained amplifiers complete with power supplies and biasing arrangements—though as these must be assumed to show negligible impedance at signal frequencies they are replaced in the diagrams by short circuits. The amplifiers are assumed to have output impedances negligible compared with any load, and to have infinite input impedance. The anode load resistance R_L is shown so that a complete circuit for the anode current may be seen even when there is no other load.

When terminal c is earthed $G = -A$; when a is earthed, and the input still applied between b and earth, the cathode-follower connection is obtained and $K = A/(A+1)$, Figs 19(b) and (c). X marks the usual positions for the h-t battery. But for signal currents the anode circuit is unchanged—and current in the grid is assumed to be zero. Corresponding diagrams for op. amps are shown at (d), (e), (f), and (g).

Bootstrapping

Substituting the triode-valve symbol into Fig. 18 gives Fig. 20(a), and the required change is the cutting of the earth connection

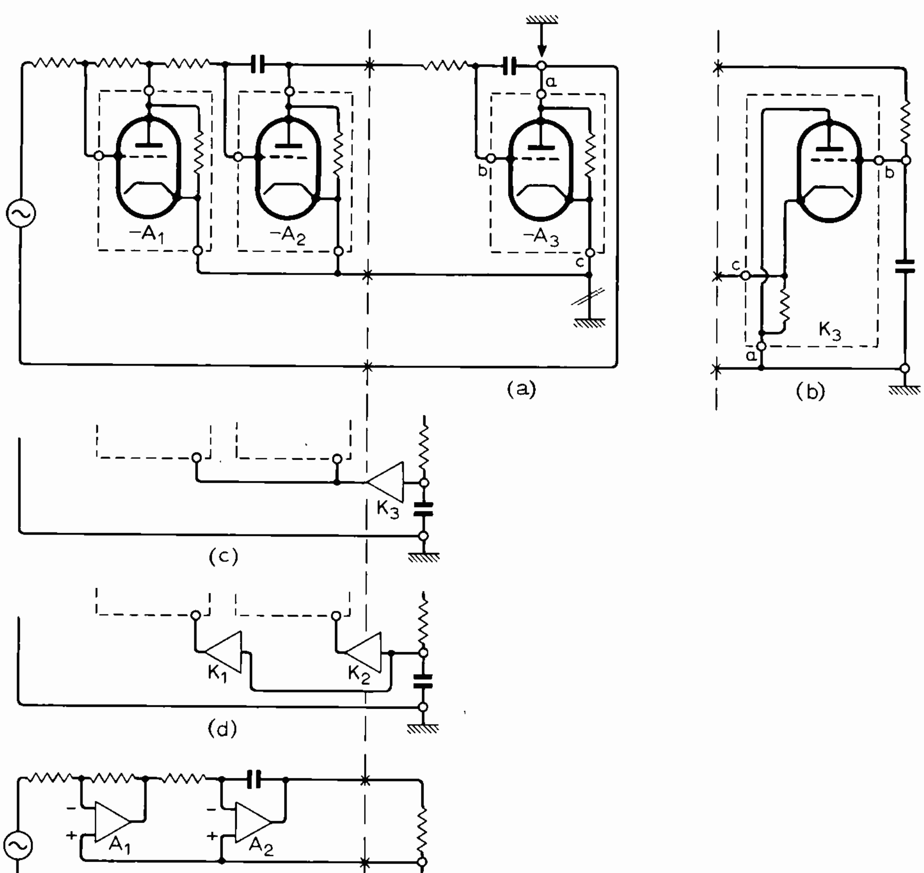


Fig. 20. Derivation of a circuit in which one of the capacitors is earthed.

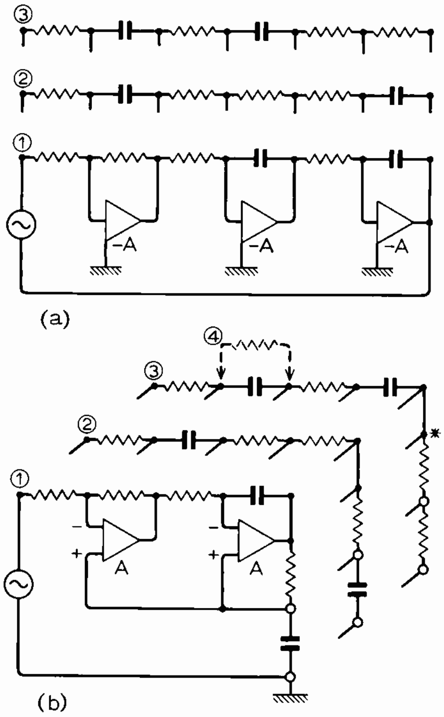


Fig. 21. By changing the order of the three stages of the two-integrator loop, and then applying the same re-earthing procedure, other versions of the circuit can be derived.

to terminal c of amplifier 3 and the making of an earth connection to terminal a, as indicated. Terminal c is then the live output terminal; and as it follows the potential of terminal b, redrawing of amplifier 3 to the conventional layout of a cathode follower as at (b) and (c) may be helpful. Amplifiers 1 and 2 with their power supplies now ride on the live output terminal and to avoid this inconvenient form of bootstrapping, amplifiers 1 and 2 may be replaced by amplifiers with differential input and working from earthed power supplies. If they are modern high-performance amplifiers, the input impedance at both input terminals will be very high and the need for amplifier 3 disappears. We are thus left with a two-amplifier version of the two-integrator loop, Fig. 20(e), in which, as required, one of the two capacitors is earthed. Except for the minor difference that the positive input terminal of amplifier 2 is fed directly from the earthed capacitor instead of from the same point as the negative input terminal of amplifier 1, it is the same circuit as Fig. 6(c).

By permuting the sequence of the three stages of the basic two-integrator loop, and by applying the same re-earthing procedure, two more two-amplifier derivatives are obtained, Fig. 21—and from these, by making alternative connections, further variations. To a first approximation, i.e. if the signal voltages between the amplifier input terminals are assumed infinitesimal, all, like the basic loop, have an ideal intrinsic Q factor of infinity. When finite gain is allowed for differences are found.

For the circuit with triode valves, Fig. 20(a), it is assumed that an input voltage between terminals b and c is a fraction $(-1/A)$ of the output voltage developed between a and c. For an amplifier with earthed power supplies and differential input the assumption is that the voltage between its plus and minus input terminals is $1/A$ of the voltage between its output terminal and earth. Therefore the two are not identical except when $A \rightarrow \infty$.

The effect of finite gain is that with differential-input amplifiers the bootstrapping is incomplete and equivalent to feeding back fractions K_1 and K_2 to the floating triode amplifiers (d), where $K_1 = A_1/(A_1+1)$ and $K_2 = A_2/(A_2+1)$. This effect can be set against the elimination of the factor K_3 (i.e. the disappearance of amplifier 3). Thus for the particular case $A_1 = A_2 = A_3$ (and hence $K_1 = K_2 = K_3$) Fig. (d) is equivalent to (c), and consequently Fig. (e) with two amplifiers has the same damping as the original circuit with three.

Alternative connections to the input terminals of the differential amplifiers, e.g. Fig. 6(c), result in differences in the magnitude and sign of the additional damping terms. In some circuits the negative damping terms can outweigh the positive terms, giving a circuit which is unstable until damping is added.

It will be noticed that in Fig. 21(b) only two of the circuits can yield an earthed inductance (by removal of the earthed capacitance). All three, however, can act as a 2nd-order low-pass filter (or quadratic factor), and the most useful is then circuit 3, from which the output can be taken at low impedance from the output of the second amplifier as marked with an asterisk. Damping can be given by connecting a resistance as shown in addition 4.

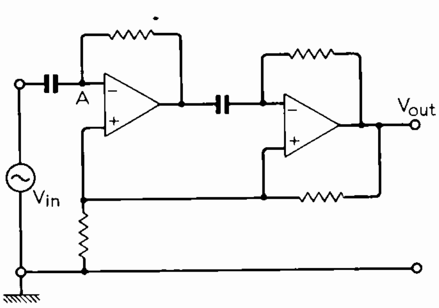


Fig. 22. Two-amplifier derivative of two-differentiator loop, shown connected as h-p filter. Damping may be added by connecting a resistor from point A to earth.

A dual of the two-integrator loop is the two-differentiator loop. By following the same scheme of changing the earth point, and bootstrapping, circuits such as Fig. 22 may be obtained. With such circuits, however, difficulties with noise and instability may be found, because for each amplifier negative feedback at high frequencies comes via the other amplifier and not through a local feedback path.

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2. Gorski-Popiel, J., "RC Active Networks", *Electronics Letters*, Dec. 1965, Vol. 1, No. 10, pp. 288-9.
3. Holt, A. G. J., and Taylor, J., "Method of Replacing ungrounded inductors by grounded gyrators", *Electronics Letters*, June 1965, Vol. 1, No. 4, p. 105.

Engineers' Salaries

Guide to salaries and responsibility levels

Recommendations for salaries of professional engineers have been published by the Engineers Guild. Suggested salaries for 1970/1, shown in the diagram together with responsibility levels, are intended to guide professional engineers and employers throughout the U.K. engineering profession.

These recommendations are made possible by completion of a study† of responsibility levels in engineering by the Guild with backing from the Organisation for Economic Co-operation and Development and MinTech. It is applicable to professional engineers as defined by associate or corporate membership of the 14 engineering institutions federated in the Council of Engineering Institutions.

One of the obvious advantages of having a guide of this kind is that it should remove doubts as to what a professional engineer does. All too often engineers are paid a technician's rate for a job because people do not understand what an engineer is.

The practice of rewarding engineers by promoting them out of engineering into management, where they may not be at their best, can now be circumvented as a result of the salary recommendations and the classification guide. The importance of a career ladder intended to run parallel with a management ladder is stressed so that engineers can continue up to the highest salary level, still remaining as engineers.

In the past, recommendations on salary levels have often been tied to age, data being taken from surveys made by the Guild and later by C.E.I./MinTech. The new recommendations, wisely, do not attempt to do this and in fact the only correlation point is the graduate starting salary level, currently about £1200, but recommended as a first step to be an absolute minimum of £1350.

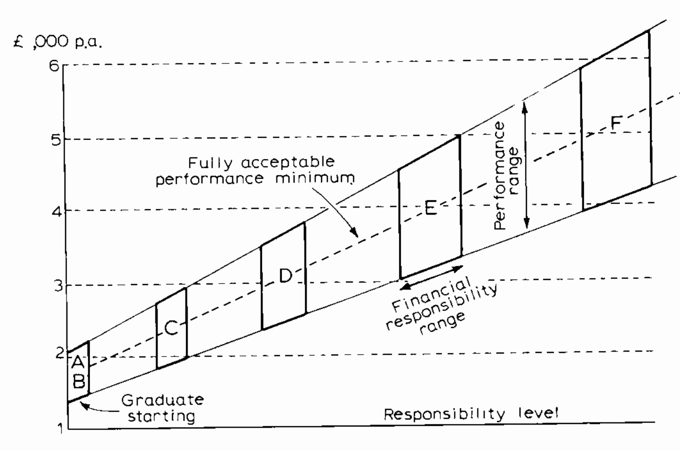
Information extracted from the latest C.E.I./MinTech survey relating salary to age is not entirely satisfactory as a guide because of the lack of correlation with responsibility. In the survey respondents were asked to give their own interpretation of responsibility and the responses are usually over-estimates. A new survey being planned by the Engineers Guild/PEAL‡ will relate these by asking questions about responsibility and then coding the answers. This survey will give the first true indication of how salaries relate to responsibility in practice. We await the results with interest.

To establish levels of responsibility, the O.E.C.D. sponsored a study carried out by the Engineers Guild in 1965. Objectives were to identify principal responsibility levels from post-graduate to the highest technical level by reference to, for example, qualifications, duties, supervision and financial responsibility. Job descriptions were to be formulated for each level identified. This work was helped by publication of a Canadian classification guide which was simplified and extended to the U.K. situation by the Engineers Guild under a MinTech contract. This produced, in 1968, 116 model job summaries setting out requirements for civil, mechanical, electrical and chemical engineering in each of six levels of responsibility. Similarities between job summaries in any one level throughout the engineering disciplines made it possible to condense this unwieldy information into one simple guide comprising 46 job summaries in five responsibility levels for job functions in engineering. Functions are divided into research, development, design, production engineering, production control, maintenance, construction/installation, and marketing/sales.

*Recommended Salary Levels for Professional Engineers 1970-71, Engineers Guild Ltd. Price 5s.

†Guide to the Classification of Professional Engineering Responsibility Levels, Engineers Guild Ltd. Price 35s.

‡PEAL—an acronym for Professional Engineers Association Ltd, see p.428, September issue.



New Goonhilly Station uses Microstrip Circuits

Model of third Goonhilly aerial showing new technique of effectively bringing the ground up to the dish fulcrum.

Third aerial for the satellite station at Goonhilly Downs, Cornwall, has been ordered by the Post Office from Marconi. Worth about £2.25M the order is for an aerial system to work with Intelsat IV satellites to be launched in 1971. The other two aerials work with Intelsat III satellites; one over the Atlantic and the other over the Indian Ocean. Even without the development of Intelsat IV a third aerial would have been needed to cater for the growth in Atlantic traffic. International communications are growing at 20% p.a. but the number of satellite circuits used by the U.K. rose from 30 to 276 over the last four years from the end of 1965 and is expected to reach 450 by the end of this year.

The system will probably make the Goonhilly station the world's busiest when it comes into operation in May 1972. The Post Office estimates this to be the economic time for bringing this third system into operation.

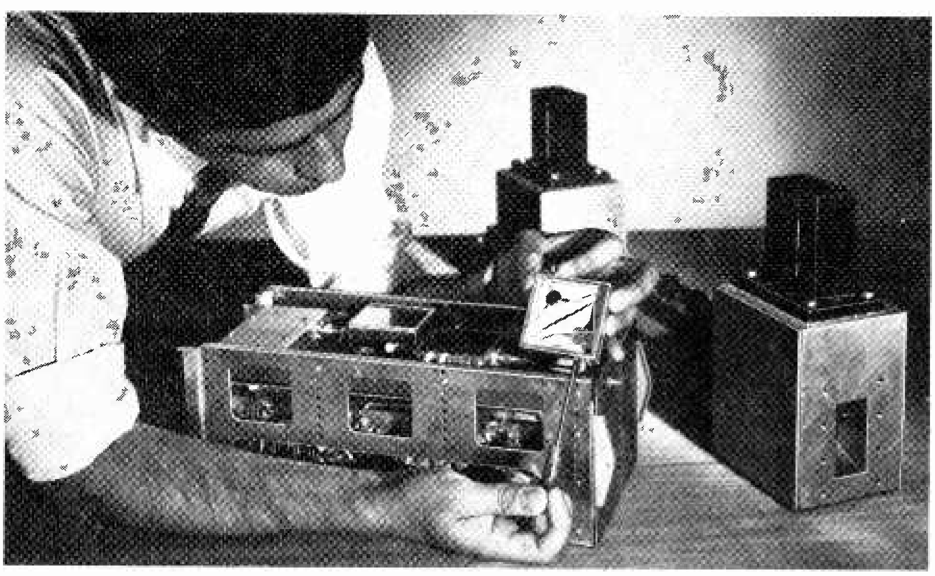
Its receiving equipment will at first cater for 400 channels from 21 stations, but capacity can be increased to at least 1800 telephone circuits on seven transmitted carriers and 33 received carriers by plugging in new modules. Although use of frequency modulation and frequency division muliplex will continue, Goonhilly 3 will be suitable for pulse code modulation and phase shift keying.

Microstrip receivers

This new aerial system, the eighth Marconi system for Intelsat, has a number of differences from the existing ones at Goonhilly—also Marconi designed and built. Microstrip techniques are used for the channel branching circuits and in the mixer/amplifiers, which convert the received signal (3.7–4.2GHz) to 770MHz and then to 70MHz. Microstrip techniques mean that much of the bulky waveguides are eliminated (see photograph for size comparison), and this is the first time they have been used in a satellite ground station. Each carrier is then demodulated and the signals routed by conventional techniques.

Construction of the steel-backed aluminium dish and cabin is different from its predecessors—a concrete mass taking the force from the dish. Another difference, which helps keep reliability high at 99.8%, is the replacement of the mechanical conical-scanning feeds by four stationary horns. Performance of the system, measured by gain/noise temperature ratio, is better than the existing ones at 41.5dB. There are four 6-GHz transmitters with peak output power of 10kW each, two for telephone traffic, one for television and the fourth for standby.

A station similar to this design has recently been ordered by Cable & Wireless. For use with the Atlantic Intelsat IV it will be installed in Barbados and is due for completion in February 1972.



Prototype double converter for new Goonhilly aerial comparing Marconi microstrip package against conventional waveguide equivalent (right). Microstrip circuit includes two circulators linked by bandpass filter on an alumina substrate.

Conferences and Exhibitions

Further details are obtainable from the addresses in parentheses

LONDON

Nov. 4-6 & 9-11 — Royal Garden Hotel
Airlines Electronics Meetings
(Airlines Electronic Engineering Committee, 255 Riva Rd, Annapolis, Maryland 21401)

Nov. 4-8 — Alexandra Palace
Communication 70 Exhibition
(E.T.V. Cybernetics Ltd, 56 Poland St., London W1V 3DF)

Nov. 10-12 — Middlesex Hosp. Med. Sch.
Laboratory Automation
(I.E.R.E., 9 Bedford Sq., London W.C.1)

Nov. 19 & 20 — 26 Portland Place, W.1
Materials for Biomedical Use
(I.P.P.S., 47 Belgrave Sq., London S.W.1)

OVERSEAS

Nov. 5-11 — Munich
Electronica Exhibition
(Münchener Messe und Ausstellung, D-8000 Munchen 12, Theresienhohe 13)

Nov. 9-11 — Munich
Congress on Microelectronics
(Internationaler Kongress Mikroelektronik, D-8000 Muchen 12, Theresienhohe 15)

Nov. 5-15 — Argentina
British Industrial Exhibition
(Industrial and Trade Fairs, Commonwealth House, New Oxford St., London W.C.1)

Nov. 12 & 13 — Montreal
Symposium on Communications
(I.E.E.E., 345 East 47th St., New York, N.Y. 10017)

Nov. 15-19 — Washington
Engineering in Medicine and Biology
(William T. Maloney, 6 Beacon St., Suite 620, Boston, Mass. 02108)

Nov. 20-26 — Milan
Automation & Instrumentation Conference & Exhibition
(F.A.S.T.—Piazzale Rodolfo Morandi 2, 20121 Milano)

EVR to PAL from RBM

Player for reproducing Electronic Video Recording films on British colour or monochrome television sets

A machine for playing EVR vision records into British 625-line television sets, colour or monochrome, has been developed by Rank Bush Murphy and will be in production next year. The Rank Teleplayer, as it is called, will be sold directly by R.B.M. at a price of £360. An explanation of the EVR (Electronic Video Recording) system was given by Dr. Peter Goldmark in our August, 1970, issue, and this included a description of a prototype colour player for working into an American (N.T.S.C.) colour television set. The R.B.M. player is similar in broad principle but differs in engineering design and particularly in its chrominance translator which, of course, must provide an output signal conforming to the British 625-line PAL colour television standard.

The EVR film is scanned by a Brimar 3-inch flying-spot scanner c.r.t. at the normal 15,625Hz line scan frequency and 50Hz field scan frequency. The field scanning circuit is normally synchronized with impulses derived from the sync 'windows' in the film, but when the film is stopped to give a still picture, and, consequently, there are no sync pulses available from it, the field circuit is synchronized with the supply mains.

The Rank Teleplayer for reproducing EVR vision records, with a film cartridge on the right

Light transmitted through the film and optical system, as described in the August issue, is picked up by two photo-electric cells incorporating electron multipliers. Each electron multiplier, itself providing signal amplification, is followed by an integrated circuit head amplifier which has a large range of adjustable gain so that the spread of amplification of the photo-cells can be equalized. The signals are then passed to stages of amplification which provide amplitude law correction. This compensates for the EVR film characteristic, which exaggerates tonal range near to white in order to reduce noise.

The PAL chrominance translator differs from the chrominance translator described in the August issue (p.370) in two main respects: the local oscillator operates at 4.43MHz instead of 3.58MHz; and the required alternating phase of the PAL colour television signal is generated. In the translator (Fig. 1) the composite signal derived from the film is applied to a filter giving separate outputs of chrominance and pilot carrier signals. The pilot carrier is doubled in frequency to bring it to the same frequency as the chrominance carrier, approximately 1.8MHz. The resulting signal is mixed with the output of a crystal oscillator operating at 4.43MHz and gives rise to sum and difference products: the output in either case is a chrominance signal translated to the wanted output frequency spectrum, i.e.,

1.8MHz + 2.6MHz = 4.43MHz
6.2MHz − 1.8MHz = 4.43MHz

Although the 6.2MHz and 2.6MHz components both translate the EVR signal to the wanted band, there is an important difference in the resulting signal. When the sum signal is generated, simple translation

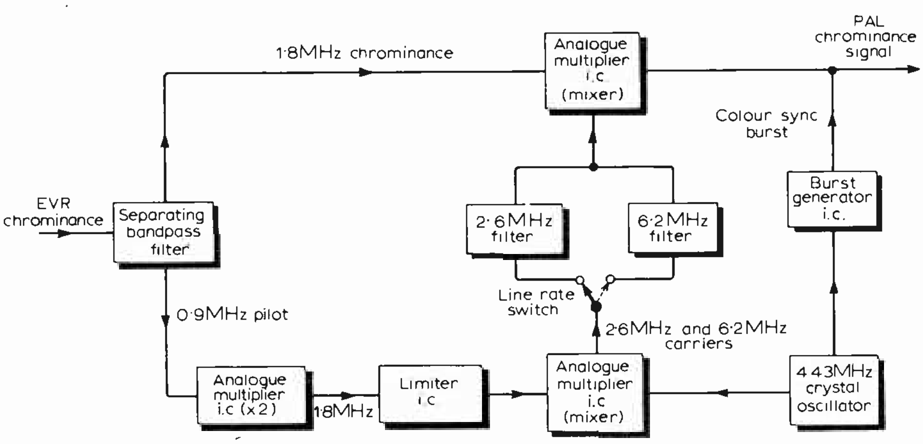


Fig.1. Block schematic of the chrominance translator (EVR to PAL) in the R.B.M. player

occurs; when the difference frequency is used the sign of the phase modulation components of the chrominance signal is reversed. These two output signals represent the alternating phase of a PAL signal. Thus the 6.2MHz and 2.6MHz components are electronically switched on a line sequential basis as shown schematically, and so the phase of chrominance signal alternates in sign, giving rise to a PAL chrominance signal.

A requirement of the separating filters is that, over the range of frequencies involved due to scanning effects, the signal must remain precisely in phase step, and the R.B.M. player uses a filter technique that fulfils this requirement. The mixers also have needed special attention since the input signals must not be passed to the output circuits and no spurious products must be generated. Spurious products could not be eliminated by selectivity since the input and output bands are very close together or overlap. The problem has been solved by the use of an analogue multiplier integrated circuit working as an accurate mixer.

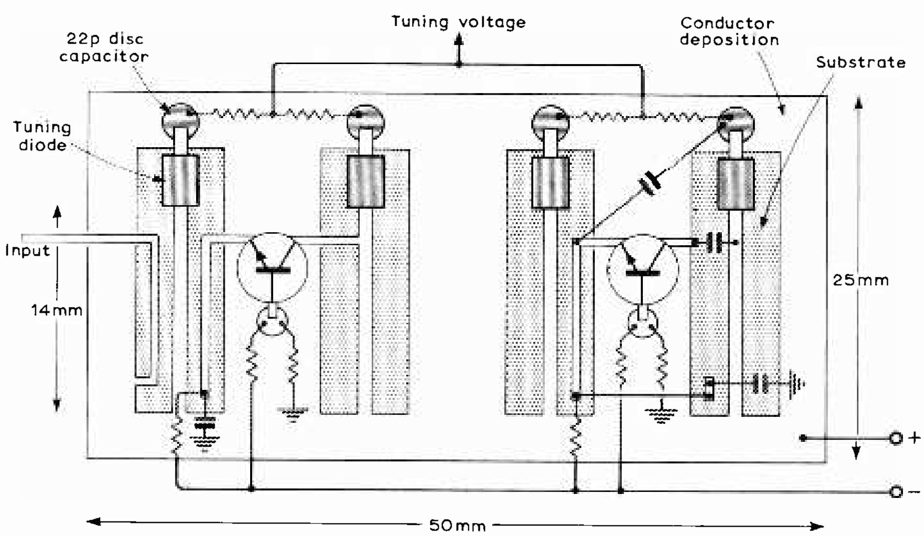
A colour synchronizing burst is generated in the player and added to the chrominance signal, which, in turn, is added to the luminance and scanning sync signals to give a composite PAL video signal. The sync pulses and blanking signals are generated from the scanning waveforms. The composite signal is applied to a modulator, together with the sound signal frequency modulated at the intercarrier frequency, finally producing a complete r.f. double-sideband signal for feeding into a television set (at u.h.f. or v.h.f. as required). The video response of the luminance channel is claimed to be 5MHz.

Controls seen in the photograph of the player are as follows. The large knob on the left is labelled 'search' and enables a still picture to be moved up or down on the screen; the next knob to the right is a three-position selector labelled 'auto' (scanning c.r.t. raster same size for moving and still pictures), 'normal' (raster for moving pictures twice the size as for still pictures), and 'repeat' (allowing a selected sequence in the film, located with the aid of a counter, to be repeated); the next knob to the right is 'focus' (for the flying-spot scanner tube); and the knob on the extreme right is a selector switch labelled 'off', 'colour' and 'mono', which are self-explanatory. On the left of the top of the control panel is a row of five push-buttons. These are marked with symbols meaning: 'play' (for threading the film and starting it running); 'fast forward'; 'fast reverse'; 'still' (to obtain a stationary picture); and 'stop' (which must be used before 'fast forward' or 'fast reverse').

U.H.F. Tuner Design

Circuit with novel temperature compensation

Strip transmission-line resonant circuits are deposited by thick-film techniques in a new u.h.f. tuner design for television receivers. Four tuned circuits, deposited onto a ceramic substrate with palladium-silver conductive material, are each tuned by a variable capacitance diode. The design was produced by B. L. Harcombe of Glamorgan Polytechnic in conjunction with AB Electronics as a higher-degree thesis and presented at the International Broadcasting Convention.



The line—shown in Fig. 1—is 14-mm long so that, with the diode, it can be accommodated on a standard 25-mm wide alumina substrate. Needing a capacitance of 2pF at 850MHz and 8.5pF at 450MHz, the line is terminated with a 22-pF capacitor in series with a tuning diode to give the required range, conveniently blocking the tuning voltage and increasing Q. Series bulk resistance (of the order of 0.5 ohm) and series lead inductance of the diodes limit Q factor to about 25 at 850MHz. It seems there is little that can be done to reduce bulk resistance, governed by junction structure, so to keep Q high lead inductance must be kept low and a way of doing this is to use diodes with a type of beam-lead construction—such plastic encapsulated devices are recommended in this design.

Using this method of construction a single r.f. amplifier has a loaded Q factor of 47 at 470MHz and 80 at 850MHz. To ensure correct tracking between the four tuned circuits diode capacitance curves are matched to within $\pm 3\%$ at four points. The four tuned circuits and associated resistors, capacitors and transistors are mounted on 50mm of substrate, the complete tuner measuring 25×50mm. Coupling to the mixer oscillator and to the r.f. amplifier are made with inductive pick-up loops close to the tuned circuit (Fig. 1). Transistors used in the common-base circuits are BF262/3 or BF279.

The most unusual aspect of this circuit is the temperature compensation method. This is necessary because of the temperature sensitivity of the voltage-variable capacitors. Also the oscillator frequency is susceptible to supply voltage variations—by changing transistor operating conditions and diode tuning voltage. Normally, variations in supply voltage are minimized by using a stabilized supply for the diodes, often with an i.c. regulator connected across the supply.

Another way of doing this is to bond a zener diode to the substrate to give a stable reference for the tuning potentiometers. The high thermal conductivity of the substrate and its low heat capacity allows its temperature to be readily stabilized by one of two methods. A bi-metallic strip can be attached controlling a thick-film heating element bonded to the substrate. Alternatively, the change in base-emitter voltage of a transistor can sense substrate temperature changes by comparing it with a voltage from a thick-film potential divider across the reference zener diode. The change in voltage can be amplified by a transistor acting as the heating element. Both methods have been tried and can stabilize substrate temperature to 40 $\pm$ 1°C, for an ambient temperature of 5-35°C.

With two transistors, this design has an image rejection of 43dB, which falls short of the recommended 52dB. Addition of a further amplifying stage would increase this sufficiently, at the same time increasing power gain from 18-20dB and decreasing the noise figure by 1dB, from about 7dB.

Battery Applications and Developments

International Power Sources Symposium, Brighton

Majority of business in supply batteries for cordless appliances is for Leclanché cells, amounting to something of the order of £200 million, with other types amounting to about only 25% of this figure. Perhaps the biggest advantage of the Leclanché cell is its relatively low initial cost compared with rechargeable systems. But its obvious disadvantages are its poor low-temperature performance, its voltage is variable and it has to be replaced. These factors no doubt account for the 12% p.a. growth (U.S.A.) in the market for sealed nickel-cadmium rechargeable cells.

Batteries for portable equipment

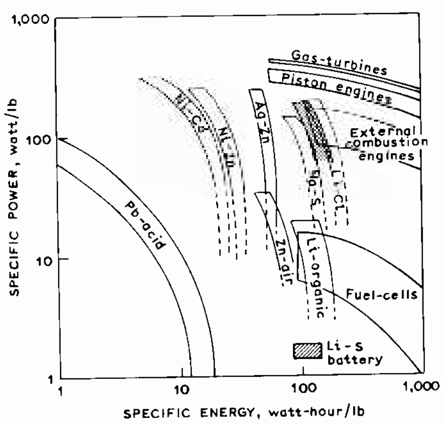
Competing with these power sources are unspillable and maintenance-free lead-acid batteries and although demand is small, it's expected to grow appreciably in the next ten years. There are applications of such batteries where energy density, extreme temperature, storage life and constancy of voltage reduce the advantage of low initial cost of the Leclanché cell and in these circumstances appliance makers are faced with deciding which of the nickel-cadmium, lead-acid and Leclanché systems is best. It turns out[1] that the choice-depends on the load and whether the chief concern is continuous or intermittent discharges, temperature effects or open-circuit losses.

Comparing Leclanché, lead-acid and nickel-cadmium cells of the same size (R20 or "D" size—the size of the HP2 cell), it has been shown that for continuous loads of >0.5W rechargeable cells give better discharge durations for shallow discharges, and >0.8W for deep discharges. Leclanché cells are superior for loads of 0.15W or less and for loads of 0.5W or less under deep discharge. For intermittent loads—say 2h per day—the primary cell is better on deep discharge at loads of 1W or less and on shallow discharge at loads of 0.3W or less. At loads higher than these, rechargeable cells—especially nickel-cadmium—are superior.

Over a three-month storage period at 25°C, the primary cell losses were 35%—less than either of the rechargeable cells, but this comparison is hardly fair as this is irreversible only in the case of primary cells. For applications where weight must be kept to a minimum, energy density is important and the Leclanché cell is far superior to storage cells below 1.5W.

Taking cost per cycle as a basis for comparison, there is a changeover point at about 10-30 cycles, below which Leclanché cells are cheaper per cycle—1.5s per cycle—but above this rechargeable cells are cheaper. Taking account of cost of a charger and charging electricity only adds 0.04s to the cost of each cycle.

These figures relate only to R20 (D-size) cells, and there are many applications not limited to this particular size of battery. There are four main areas, depending on power demand. For low-power uses—e.g. torches, portable radios, toothbrushes—the Leclanché cell is likely to remain supreme. For record players, dictaphones, and tape recorders, with average power demands of 3.5W and with regular discharge patterns of less than 3h at any one time, the alkaline cell is cheaper, provided initial cost is carried by the product. For televsion sets, military instruments, power needed could be 12W for a 5-h period and again nickel-cadmium batteries are favoured because of their 500-cycle life. But for military use, where mechanical damage can limit life to 40-50 cycles, the lead-acid cell would be an attractive alternative. For higher-power applications—electric drills and gardening equipment—where power demand is usually greater than 20W, either rechargeable battery is suitable but the lower initial cost of lead-acid batteries may be the deciding factor where the power source cost is a significant proportion of the total.



Power and energy-density ratings of typical energy storage systems showing in particular how the lithium-sulphur battery relates to others. (From a paper by Ng & Appleby.)

Military application

Although sealed† nickel-cadmium batteries with thin sintered plates have energy densities (24-31Wh/kg) less than either zinc-carbon (77Wh/kg) or silver-zinc batteries (120Wh/kg) their low temperature performance makes them preferable in military applications. Their good shelf life is important too in peace time. Their large cycle life might be thought an advantage too, but it seems that because of mechanical stress their useful life in combat is limited to 50 cycles. Typical uses of these batteries include wire-guided anti-tank missiles, electrically firing the Chieftain tank main gun, Olifant back-pack radar sets, Clansman v.h.f. back-pack sets.

A departure from normal in the Clansman sets, is the retention of the battery in circuit when used off a vehicle battery. As well as keeping the battery fully charged this has the advantage of acting as a ripple sink and surge absorber. The method of determining end of charge in this set is by sensing the increase in temperature which results from the increase in heat generation. This is done by hot and cold sensors in a bridge circuit, inside and outside the battery. The sensors are two silicon diodes in one envelope giving a temperature coefficient of 4mV/°C. Optimum differential is 7°C.

One problem with this method occurs when the battery is deeply discharged at a high rate and then connected to the charger. Nothing happens, because the rise in internal resistance when the battery is in this state results in a temperature rise, actuating the end-of-charge cut-out! This is of no consequence as the vehicle

†In view of the Trade Descriptions Act, makers must, we suppose, be careful in calling nickel-cadmium batteries "sealed" when a pressure release valve is incorporated.

charging unit provides the operating power.

Other power sources

New hope was given for nickel-zinc batteries, one of the better known alkaline systems along with nickel-cadmium, silver-cadmium and silver-zinc. Often thought of as combining the worst of nickel with the worst of zinc, this system is attractive because of its higher energy and power density compared with nickel-cadmium. In spite of limitations of cycle life and discharge capability, related to construction and charging method,[2] the system is claimed to be well suited to numerous industrial applications where high cell voltage and high discharge rate are needed. By limiting voltage on both charge and discharge a life of 150-250 cycles can be achieved for deep discharges —the same order as the high-energy silver-zinc couple. Separator degradation appears to be the most significant single factor in limiting life and research is under way to fabricate a non-cellulosic separator to give the long cycle life of nickel-cadmium batteries.

Main point of discussion on lead-acid batteries, still a focus for much research in spite of its ubiquity, was about grid composition. Grids are usually an alloy of lead and antimony, with amounts of antimony varying between 4.5 and 12% by weight. Lead by itself is too soft and addition of antimony gives strength. It has recently been shown that this also increases cycle life. Snag is that it's the main cause of self-discharge through poisoning the negative electrode. A critical review[3] gives an up-to-date picture of the mechanism of this antimony transference, and will be published in the symposium proceedings. A possible alternative to antimony is lithium and although alloys would not be quite as strong as either antimony or cadmium, lithium is more electro-negative to lead and should not cause self-discharge. There are difficulties in using lithium alloys though[4] and its performance in overcharge and cycling tests needs to be improved before it could be a serious contender to antimony. Ternary lithium-lead alloys may be the solution and work on these is in progress.

The sodium-sulphur cell, suggested in 1967 by workers at Ford in the USA, is one of a family of high-energy density rechargeable systems. It is thought to be the most promising kind for electric vehicles, especially for buses and rail traction. The cells have an alkali metal as anode (sodium or lithium having lowest atomic weight and highest specific energy per unit weight) and usually a "chalcogen" as cathode (usually sulphur, selenium or tellurium, avoiding problems of handling compressed halides) with an electrolyte of a mixed halide (e.g. lithium iodide, floride and chloride). They operate at 300-400°C and at this temperature both reactants and products are liquids. Like other proposed high-temperature batteries it has a much higher specific power than aqueous or organic electrolyte systems. Lithium-sulphur couple is one stong contender in this family, with the promise of a reduced weight, but higher cost, than sodium-sulphur.

A recent development in this kind of battery is a solid or paste electrolyte. Although the paste electrolyte has been tested successfully with lithium tellurium and selenium cells, results with lithium-sulphur are not yet available. Estimated specific power and energy of this battery based on recent cell designs are 415Wh/kg and 287W/kg. It will be interesting to see whether batteries based on these cells live up to their expectations.

An interesting novel power source, though not reported at this symposium, is the biological cell. Not new by any means, cells using yeast with carbon electrodes were described as long ago as 1911. Six parallel cells gave a current of 1.25mA. A bacteria battery reported in 1931 gave a current of 2mA. More recently work on a variety of fuel cell systems has been reported using hydrocarbons, fatty acids, alcohols, carbohydrates and even with bacteria catalysts. The most recent we have heard of uses blood sugar. With gold-palladium electrodes, glucose is broken down into hydrogen ions, an acid and electrons at the anode. At the cathode blood oxygen takes up these electrons forming hydroxyl ions. Laboratory cells have produced 20μW of power and tests on animals are planned.

Gradual development is taking place in a number of other areas, for example, solar arrays for satellite transmitters and ground use, fuel cells, solid-state batteries, and readers with interest in these can follow-up the topics in the symposium proceedings.

Earlier symposia were also reported in *Wireless World* (December 1958, November 1962, 1964, 1966, and December 1968) and copies of the Proceedings for some are still available. The eighth symposium will be 26-28 September 1972 in Brighton.

References

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2. Kober, F. P. & Charkey, A. "Nickel-zinc: a practical high-energy secondary battery". Paper No. 18.
3. Dawson, J. L., Gillibrand, M. I. & Wilkinson, J. "Chemical role of antimony in the lead-acid battery". Paper No. 1.
4. Mao, G. W., Oswald, T. L. & Sobczak, B. J. "Lithium-lead grid alloy in lead-acid batteries". Paper No. 4.

R.F. Resistance and Electroplating

The conductivity of silver is higher than that of copper. At high frequencies skin effect comes into play and current tends to flow mainly in a thin outer layer of a conductor, which is the chief reason why the r.f. resistance of an inductor is much greater than the d.c. resistance. Silver is more costly than copper and so it is a common practice to use silver-plate on a copper base, the idea being that the current flowing only in the thin outer layer of silver this is as good as a solid silver conductor.

Although this practice has been common for many years, it is pointed out in a recent article (A. M. Fowler, "Radio Frequency Performance of Electroplated Finishes", *Proc. Instn Radio & Electronics Engns Australia*, Vol.31, No.5 May 1970 Pp.148-164) that silver-plating a copper conductor does not, in fact, reduce the r.f. resistance but increases it. The reason is that electroplated silver and pure wrought silver are not the same.

It is brought out in the article that a very thin plating, of either very high or very low conductivity, on a copper base will have negligible effect on the r.f. resistance. If the plating has about one-half the conductivity of the copper base its effect is greatest.

In explaining how the practice of silver-plating copper conductors grew up, the author says "It was more than likely, in the early days of radio, that silver plating a coil would increase its Q because: (a) the available copper tubing had a higher inpurity content, and hence resistance, and (b) the silver plating processes available at the time produced a very pure silver deposit of high conductivity." The conductivity of modern copper has improved, while the bright silver plates in common use have a much lower conductivity than pure silver. The condutivity of pure silver is 62.5 M℧/m; that of a plate-deposit is 0.07-55 M℧/m!

The position has thus changed and a silver-plated copper conductor may now give a higher r.f. resistance than a copper conductor alone.

World of Amateur Radio

Interference to television

Latest Minpostel statistics show that interference to television and radio reception by amateur stations continued to increase during 1969, although amounting to only 2% of all interference. Of a total of 71,311 (70,254 in 1968) cases closed by Post Office investigation teams during the year, 1442 were ascribed to amateur transmitters compared with 1151 in 1968. The distribution of these complaints was: l.w./m.w. radio, 48 (−13%); Band I, 821 (+13%); Band II, 44 (+29%); Band III, 492 (+54%); Band IV, 18 (+100%); Band V, 8 (+166%); mobile radio, 11 (+83%). The substantial increase in interference in the higher frequency bands appears to result partly from increasing v.h.f./u.h.f. operation by amateurs but can also be ascribed to the significantly increased susceptibility of transistor TV tuners and v.h.f./f.m. sets to strong local r.f. fields, compared with the older valve sets. Amateurs, however, remain hopeful that the gradual change to television viewing on Bands IV and V instead of Bands I and III will improve the situation.

American generation gap

With over half of the world's radio amateurs in America, trends there play a major role in determining the future of the hobby. Over the past 20 years, the total of U.S. amateurs has more than trebled (from 86,662 in 1950 to over 260,000) but recent years have seen a marked slowing down (and even a reversal in some years) of this growth, accompanied by a noticeable redistribution of age groups. Many of the more active stations are those belonging to "senior citizens" or to teenage newcomers, with a sharp falling off of the important 20 to 40 age group—"those young enough to be enthusiastic but old enough to be doing something interesting and productive with it" to quote a recent article by John Frye on the future of amateur radio in *Electronics World*. While this trend is far less noticeable in Europe, there is some evidence of a weighting towards the upper age groups.

Frye points out that in the past "amateur radio has had a great deal to do with U.S. leadership in the field of electronics—whistle CQ on the campus of any great engineering university, in any major electronic research lab, or in a N.A.S.A. control centre, and you will get an answer; probably several answers". He believes that the apparent slackening of interest in the constructional and technical aspects of the hobby could be overcome by placing more emphasis on what amateur radio has to offer in the way of challenge to intelligence and skill, in world-wide comradeship, and in the diversity of amateur activities.

Minpostel licence figures for the year to the end of July, 1970, show the uneven distribution of new British licences. Although the overall increase in licences is about 5% per annum, Class A licences rose in the year from 13,221 to 13,537 or +2.4%, whereas Class B licences shot up from 1595 to 2188, an increase of 37%. The latest batch of convictions for unlicensed operation show fines and costs in 22 cases reaching almost £1100, plus forfeiture of equipment in 18 cases.

R.S.G.B. president 1971

F.C. Ward, G2CVV, is to be the 1971 president of the R.S.G.B. For more than 20 years he has been honorary secretary of the Derby & District Amateur Radio Society which, since it incorporates the original Derby Wireless Club of 1911, can claim to be Britain's oldest radio society. F. C. Ward obtained his amateur licence (initially for "artificial aerial" operation) in 1937 and during the 1939-45 war served in R.E.M.E. and the R.A.F. After demobilization, he joined the Post Office Engineering Department and is currently with the radio investigation service. He operates on all bands from 1.8 to 144 MHz.

Microwave activity

Good tropospheric "openings" in late September resulted in many U.K./Continental contacts on v.h.f. and u.h.f., including a two-way 1296 MHz contact between G8AUE in Derbyshire and DL9LU in West Germany. Almost 50 stations were operating on the 23-cm, 13-cm, 9-cm and 3-cm bands during the first R.S.G.B. "microwave contest" this summer; winner was Les Sharrock, G3BNL, operating near Cheltenham. For a recent contact with the Dutch station PAØDTL, Phil Reynolds, G3PQR, used a 1-watt all-semiconductor transmitter on the 23-cm band, with a 2N4429 transistor power amplifier driven by a BAY66 varactor tripler. Earlier this year, two-way amateur contacts in the United States pushed the microwave DX records for both 3300 and 5650 MHz to 214 miles. On 2300 MHz, American stations K1JIX and K2GRI have been regularly making contact over a 175-mile path from locations 500 ft and 700 ft above sea level, despite intervening hills rising to over 3000 ft.

Slow-scan television

Slow-scan television (s.s.t.v.) transmissions can be heard most evenings at 19.00 G.M.T. on 14230 kHz. One of the leading European operators in this field is Franco Fanti, I1LCF, of Bologna, Italy, who has now received pictures from many countries including New Zealand (ZL1DW). He asks British phone amateurs to try to avoid causing interference to these s.s.t.v. transmissions, which are often not recognized as amateur signals. They sound like a warbling tone with a low-frequency buzz component and a blip every eight seconds. Also well received in the U.K. is Swedish s.s.t.v. station SM5DAJ. An s.s.t.v. monitor is being used by the British amateur station G3ZGO (G6ADJ/T).

In brief

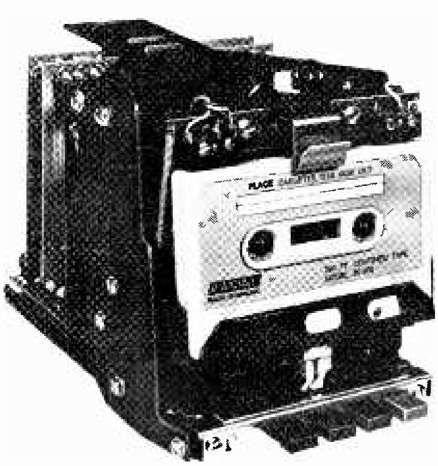
John Stace, G3CCH, made a 144-MHz meteor-scatter contact with the Estonian station UR2BU during the Perseids meteor shower in August . . . Mergers have been announced recently by several major American suppliers of amateur equipment: Hy-Gain have linked with Galaxy; Radio Shack with Allied Radio . . . The 145.95-MHz beacon station GB3ANG is now operating from a new location at the I.T.A. transmitter near Tealing in the County of Angus . . . During the recent exhibition tour of the United States of the Flying Scotsman, an amateur station WX5RRX operated from the train . . . The 25th Top Band Club Contest (MCC) organized by *Short-wave Magazine* takes place during the weekend November 7 to 8—a weekend which also sees the R.S.G.B. 7-MHz (phone) contest . . . The c.w. section of the CQ World Wide DX contest is on November 28 to 29 . . . British winners of the recent Bermuda Contest were H. E. Perkins, G3NMH (phone), and W. E. Russell, G5WP (c.w.)—both will receive complimentary visits to Bermuda . . . More than 600 stations were known to be active on 144 MHz during the 1970 open contest, with over 270 contacts made by two contestants . . . With the conclusion of the 1970 programme of mobile rallies, plans are being announced for next year—Maidstone Y.M.C.A. Amateur Radio Society will hold a rally at the "Y" Sportscentre, Melrose Close, Maidstone on May 30, 1971 (enquiries A. S. Walter, G3WXL, 31 Lansdowne Avenue, Maidstone).

PAT HAWKER, G3VA

New Products

Digital Data Recording Equipment for Mini-computers

A medium-price computer tape handler, claimed to be cheaper than existing handlers of its kind, is announced by Racal-Thermionic Ltd. With a storage capacity of 60,000 characters per second it is suitable for use with any standard data processor and special purpose data collection equipment in, for example, nuclear research, stock control and payroll accounting. Designed for small and medium-size computer systems, the basic cost of the transport, type TDR7, is £1250. Racal-Thermionic, who are entering the computer peripheral market with this and digital cassette recorders, expect to exceed the current growth rate in this area of 20% p.a. The cassette recording system uses a Digideck, made at present by International Computers in Texas, which is a two-track digital data read/write transport system measuring about 11 × 13 × 17cm; it is much smaller than paper tape equipment. Using the standard Philips-type cassette it automatically moves the tape in either direction under program control. Although this deck can use the Philips audio cassette, giving a raw error rate of 1 in 10^5, it is strongly recommended that certified Racal-Thermionic cassettes are used, which use a better quality tape to give a raw error rate of 1 in 10^7. Available in four versions the basic deck costs around £200. A complete desk-top recorder using either one or two of these decks (called Digicorder) can be easily interfaced with existing or projected computer installation and is especially useful for program storage. These peripherals are aimed at the mini-computer market, estimated to be worth around £3,000M in Europe by 1975, with peripheral equipment amounting to about a half of this. Mini-computers are usually interpreted as computers costing under £20,000.



Racal-Thermionic Ltd, Hythe, Southampton SO4 6ZH.
WW 309 (tape handler), WW 310 (cassette decks) for further details.

Low-voltage Neon Indicator

Neon indicator operates from low voltages by virtue of a simple transistor converter built into the indicator package. Indicators are available for 5, 6, 12 and 24-volt operation taking a current of between 20 and 35mA. Life is claimed to be 10,000h

and special versions are available, one which responds to a 2-volt trigger pulse and another with a life of 15,000h. Neon type is NE-2, NE-200 or NE-2H. Unit price is $3 and 1000-up price is $2.50. Solitronics Engineering Ltd, 1531 Star House, Harbour Centre, Kowloon, Hong Kong.
WW 307 for further details

Logic Function Analyser

The Metrix TX905A analyser from ITT tests the logic functions of d.t.l. and t.t.l. integrated circuits. It does this by comparing the circuit under test with a standard logic circuit. Interconnections can be made by inserting connection pins into the appropriate positions on an "xy" spreader matrix, or pre-wired circuits can be plugged directly into the matrix. Four operating modes are provided.

1. Automatic. The instrument produces inputs to the i.c. under test continuously throughout the test cycle, and will then automatically recycle if necessary. Test results are shown by red and green indicator lights.
2. Stop on defect. Once the test cycle has started it will continue until a fault is found. This allows the operator to investigate the reason for the fault.
3. Step-by-step. This mode cycles the test combinations one by one to allow switching characteristics to be observed. Static analysis of the circuit under test is also permitted.
4. Predetermined. A test combination can be chosen to suit a particular circuit, which is then tested automatically until the final parameter has been reached.

The unit can accommodate custom-built word generators for testing complex circuits with sequences out of the ordinary cycling, and two or more instruments can be arranged in series for testing complex circuits. ITT Electronic Services, Edinburgh Way, Harlow, Essex.
WW 312 for further details

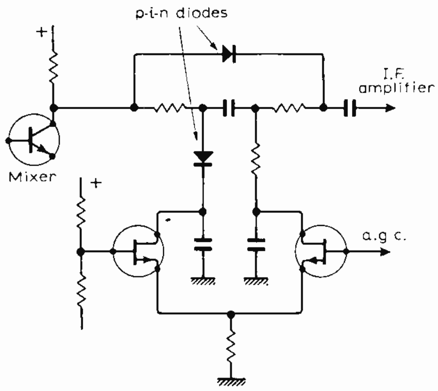
Six-digit Systems D.V.M.

Model 5233/553 dual-slope integrating d.v.m. from Dana is designed specifically for systems use. The basic model is d.c. only, with a programmable 3-pole active filter which, together with the integrator, gives 100dB of normal-mode rejection at 50Hz. Optional plug-in cards are available to provide facilities that enable the user to build up a comprehensive systems instrument. A microvolt-sensitivity version is available—model 5233A/353A. A 'superfast' facility gives the user the unusually high display potential of up to 100 readings per second, although at reduced scale length. This figure includes settling time. B.c.d. output and programming are t.t.l. compatible, and command signals may be either direct or delayed. Delayed signals are programmed automatically in the d.v.m., and so remove the responsibility of delay generation (waiting for a.c. convertors etc. to settle) from the system. Price of the basic Model 5233/553 is £880. Dana Electronics Ltd, Bilton Way, Dallow Road, Luton, Beds.
WW 317 for further details

1-MHz p-i-n Diode as R.F. Attenuator

A p-i-n diode design from Hewlett-Packard operates as a current-controlled r.f. attenuator down to 1MHz. Previous devices were intended for use at frequencies of the order of 100MHz. The new devices, designated 5082/3080, have application in a.g.c. circuits, communications receivers, TR switches and in many other areas where r.f. power needs to be controlled.

Cross modulation products are typically less than 0.5% and second-order distortion products are below 0.05%. Diode is cheaper by about a factor of two over earlier devices —just over £1 10s for 1-99. Resistance is variable between 5 and 2,500 ohms depending on forward bias current.



Current carriers are retained in the middle layer of intrinsic semiconductor material after the applied voltage is switched from forward to reverse bias, the carriers giving a reverse current flow until depleted. If the voltage is changed to forward before all carriers are swept out the diode behaves as a resistor. The longer the lifetime of the carrier the longer the diode can be reverse biased before carriers disappear. Lifetime of 1.3μs allows the diodes to be used down to 1MHz before rectification introduces distortion. The circuit shows diodes varying resistance of bridged-T attenuator. Hewlett-Packard Ltd, 224 Bath Road, Slough, Bucks.
WW306 for further details

Simple Oscilloscope

Single-beam oscilloscope, type MSB-100, uses new rectangular c.r.t. with 5 × 4cm display. Vertical amplifier amplitude response extends from d.c. to 4.5MHz at 100-mV/cm sensitivity and has an f.e.t. input stage. Sweep generator covers the range 10ms/cm to 100ns/cm in six ranges

with a 15:1 variable control. Synchronization is automatic for deflections greater than 1cm, eliminating stability and trigger level controls. Price is £56. Meteronic Ltd, Birchen Napps Platt, Sevenoaks, Kent.
WW 322 for further details

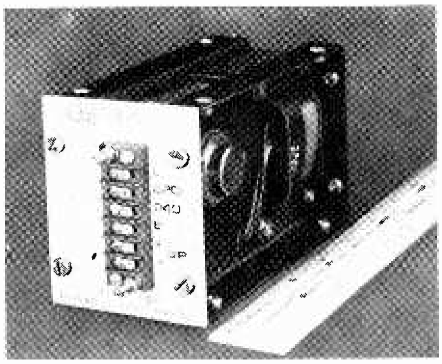
18-GHz Detector Diode

New germanium 'backward' diode is made by AEI Semiconductors, part of GEC Semiconductors Ltd. The device—type DC3015—is intended for broadband strip-line detector applications. Typical lead inductance of 0.2μH is achieved with a beam-lead construction, as opposed to 1μH for an inverted device. AEI Semiconductors Ltd, Carholme Road, Lincoln.
WW 324 for further details

Power-supply Unit

Two types of current-limited power supply in the £19-£25 range are made by Farnell Instruments. One, described as a sub-unit, provides 15-30V or 5-15V without any form of indication, and the other is continuously variable from zero and includes a voltage and current meter. In the second case either voltage range can be selected.

The M series sub-units have four variants giving 15-30 V at 0.5A or 1A and



5-15V at 1A or 2A. Price is £19-£21. The E30 model, with case, costs £25.

The sub-unit is stabilized to 3mV for ±10% mains variation (1mV for the E30) and load voltage is regulated to 10mV from zero to full load (5mV for the E30). Ripple and noise content is less than 1mV r.m.s. Farnell Instruments Ltd, Sandbeck Way, Wetherby, LS22 4DH, Yorks.
WW304 for further details

50MHz Counter

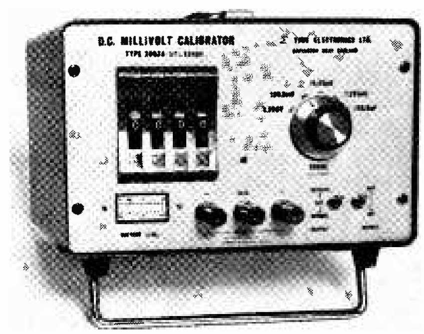
A 50-MHz counter type 3022B from Dawe Instruments has four functions—frequency, period, count and time. It gives four-digit indication from zero to 50MHz with an input sensitivity of 250mV. Features included are a.c./d.c. input selection and control over trigger level. Internally the type 3022B is constructed from plug-in replaceable printed circuit boards. The performance is achieved using high-speed t.t.l. microcircuits together with a field-effect transistor input and tunnel-diode trigger circuitry. All functions are selected by push buttons. The price is £185. Dawe Instruments Ltd, Concord Road, Western Avenue, London W.3.
WW 320 for further details

Inductor Cores for P.C. Boards

A range of high-quality, inexpensive inductor cores for direct mounting on printed circuit boards is announced by Mullard. The cores in this range, called LA4000R have the characteristics of the Vinkor series. They are, however, designed to achieve a greater packing density and to reduce the time and cost of assembly. Each core consists of two halves held together by metal clips. As well as providing a quick and easy method of assembly, this arrangement has the advantage that it enables a faulty coil to be replaced by a good one, and the whole assembly need not be thrown away as happens when the halves are cemented together. The cores are held on a printed circuit board with a grid spacing of 2.54mm (0.1in) by means of pins in the coil former; these are also used as terminations for windings. Consequently, flying leads and the need for their identification are eliminated. An adjuster enables the inductance to be varied, thus facilitating either close control of inductance or the use of windings with wider tolerances. The adjuster, like the holding clips, is completely recessed within the ferrite cores. Mullard Ltd., Mullard House, Torrington Place, London W.C.1.
WW 318 for further details

D.C. Voltage Calibrator

The 2003 d.c. millivolt calibrator from Time Electronics employs a standard reference cell. No standardization is required, and up to 20mA of output



current can be drawn without loss of accuracy. The price is £90 for an instrument having ±0.1% accuracy (£110 for 0.05% accuracy). Time Electronics Ltd, 199a High Street, Orpington, Kent.
WW 331 for further details

Versatile Power Supplies

Variable-output power supply for general laboratory work, especially for schools and colleges because of its simplicity and low cost, is available from Advance Electronics. Voltage and current limit can be set and monitored by the panel meter. Two models give

	PP31	PP32
voltage	0-30 or 60V	0-15 or 30V
current	0-0.5 or 0.25A	0-1 or 0.5A
line reg.	±(0.01% ± 1mV) for ±10% a.c. change	
load reg.	0.02% + 5mV	
ripple	1mV pk-pk	
price	£27	£25

Two further models meet more de-

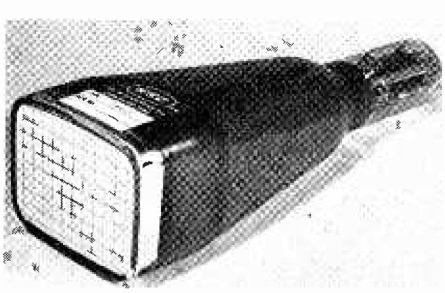
manding applications. Voltage can be set accurately in 10, 1 and 0.1V steps with a digital thumbwheel switch, and down to 0V with a continuously variable fine control. Output current is limited and monitored of course and a variable over-voltage control is provided together with an over-voltage indicator. Two versions give maximum current of 1A (PP41) and 3A (PP42).

voltage	0-60V
current	0-1 or 3A
line reg.	
voltage mode	±(0.001% ±30μV) for ±10%
current mode	±(0.20% ±200μA) for ±10%
load reg.	
voltage mode	0.02% + 1mV
current mode	0.1% + 2mA
ripple	
voltage mode	400μV pk-pk max
current mode	0.1% pk-pk
output Z	0.25Ω at 100kHz
price	£85

These new units will eventually replace earlier models PP10, 11 and 16. Facility for remote control is provided and the supplies can work from 110V mains. Advance Electronics Ltd, Raynham Road, Bishop's Stortford, Herts.
WW328 for further details

Instrument C.R.T.

The M-O Valve Co. has introduced a new single-gun spiral-p.d.a. (post deflection accelerator) cathode-ray tube, type 1400C, for oscilloscopes. It has a flat rectangular face and an 80×100mm display. The screen has a thin aluminized backing for operation at 4kV, and side-



connected deflection plates give wideband operation. Maximum *X* and *Y* deflection sensitivities are 15.5 and 8.5 V/cm respectively. There is provision for deflection blanking, and a choice of internal graticules is offered. The M-O Valve Co. Ltd, Brook Green Works, London W.6.
WW330 for further details

High-level Logic Elements

Five devices have been added to the SGS range of high-level logic. The H103 is a triple 3-input NAND gate; the H113, a quad high-to-low level converter; the H114, a quad low-to-high level converter; the H122, a quad 2-input NAND gate with resistor pull-up; and the H124, a dual 4-input expandable NAND gate also with resistor pull-up. In addition to high input thresholds, advantages in using this family include large output logic swing, large supply voltage tolerance, and high fan-out. Encapsulation is ceramic dual in-line. SGS (United Kingdom) Ltd, Planar House, Walton Street, Aylesbury, Bucks.
WW332 for further details

Microphone with Interchangeable Capsules

Interchangeable omni-directional and cardioid capsules are one feature of the new B & O microphone. Called Beomic 2000, this moving-coil microphone has feet concealed in its slim body that can be released by spring action to form a desk stand. Cardioid capsule has a response conforming to DIN 45, 500 BL.5 and has 0.1-mV/μbar sensitivity (−80dB below 1V/μbar). Output impedance: 200Ω at 1kHz; front-back ratio 18dB. Price is £14 10s. Bang & Olufsen U.K. Ltd. Eastbrook Rd, Gloucester GL4 7DE.
WW337 for further details

1-amp Rectifiers

The SJO3H series of metal cased rectifiers from WEL Components has a range of 100-1200V at 1A and 100°C. Typical prices are 3s 1d each for a 400V 1A device when purchased in quantities of 100. WEL Components Ltd, 5 Loverock Road, Reading, Berks.
WW 308 for further details

Precision Microwave Resistors

By specifying the series resistance of Sylvania's new p-i-n diodes (available from Impectron) over their operating range the exact resistance at any current level is predictable. This results in a series of precision current-controlled microwave resistors that are useful from 10MHz to 10GHz. The peak power handling level is 10kW. Operating temperature is 150°C. Impectron Ltd, 23-31, King Street, London W.3.
WW329 for further details

Integrated Circuit Socket

A 50-lead dual-in-line socket has been introduced into the range of l.s.i., d.i.l., and m.s.i. sockets made by Jermyn. The body is injection-moulded from glass-filled nylon and is available with a choice of contact material: type Y, phosphor bronze with 0.125μm of gold over nickel; Z, heat-treated beryllium copper plated to 1μm of hard gold over a silver flash. Contact resistance is 5mΩ for type Z and 15mΩ for type Y, both offering up to 10,000 insertions. With row spacing of 2.25cm and 2.5mm between contacts, the A23/2027 has been designed for printed circuit board applications where high packaging densities are to be achieved. Jermyn Industries, Vestry Estate, Sevenoaks, Kent.
WW 314 for further details

Solderless Coaxial Plug

A solderless coaxial plug is now available from Belling-Lee. The plug has been designed specifically for cables with centre

conductor diameters up to 0.048in. Belling and Lee Ltd, Great Cambridge Road, Enfield, Middx.
WW334 for further details

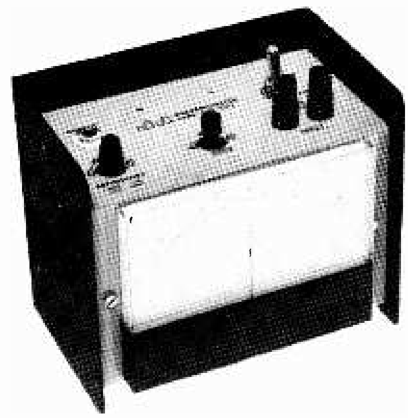
Electrolytic Capacitors

Steatite Insulations supply type EK plastic cased electrolytic capacitors with uniform lead spacing of 5mm. The epoxy sealing is safe against soldering process temperat-

ures. All internal connections and wire ends are welded. Polarized and non-polarized versions are available. Steatite Insulations Ltd, Hagley House, Hagley Road, Birmingham 16.
WW 333 for further details

Galvanometer for Education

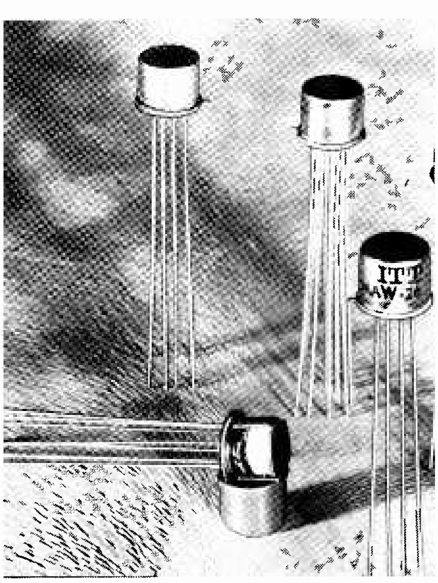
Incorporating a low-drift d.c. amplifier, this galvanometer from Educational Measurements has two calibrated ranges of 1 and 10mV. Any f.s.d. between these two figures can be set so that the meter can be used with thermocouples to read temperature directly. Because input resist-



ance is 1000 ohms current can be measured, giving ranges of 1 and 10μ. A Output socket allows the d.c. amplifier to be used separately. The meter is protected against overloads of 1 million times. Consumption is 3mA from a 9V internal battery. Educational Measurements Ltd, Brook Avenue, Warsash, Southampton, SO3 6HP.
WW301 for further details

Relay in TO-5 Can

Contact rating of 1A at 32V is a feature of change-over relays in TO-5 packages by ITT. Life of 10^5 operation can be increased to 10^6 on low-level signals. Intended for military applications, two types



are available; one with operating power of 125mW (MA type) and the other with operating power of 65mW (MS type). Both have contact resistances of 100mΩ and insulation resistance of 5000 MΩ. Operate and release times are respectively 2 and 1.5 ms (MA) and 4 and 2 ms (MS). Vibration tested to 30G and shock tested to 80G, the relays conform to U.S. MIL specification R5757 and U.K. DEF 5165. ITT Components Group Europe, Power Components Division, West Road, Harlow, Essex.
WW302 for further details

Trimmer Pot for P.C. Board

Manufacturers of potentiometers and thick film circuits, Reliance Controls Ltd of Swindon, have introduced a ⅜in square wirewound fully-sealed trimmer which is designated CW60, CW61 or CW62, depending on the pin configuration. Resistance range covers 10Ω to 20kΩ. Mechanical adjustment is 28 turns and the temperature range -55 to $+155$°C. Wattage rating (whole element uniformly loaded) is 0.75W at 70°C derating to 0 at 155°C. Insulation resistance is 1000 MΩ at 500 V d.c. Reliance Controls Ltd, Drakes Way, Swindon, Wilts.
WW 336 for further details

Plastic GaP Light-emitter

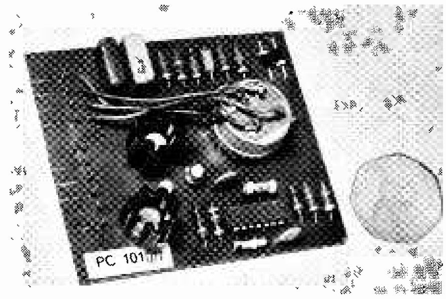
Gallium phosphide light-emitting diode has a typical luminance of about 1000cd/m^2 with a peak (red) emission at 0.66μm, and is intended for both indicator and modulator use. Dissipation is 100mW at 25°C. Plastic encapsulation. Price is 30s 11d for 1-24. Made by Motorola (type MLED 600) and available from Jermyn Industries, Vestry Estate, Sevenoaks, Kent.
WW 327 for further details

1-12GHz Mixer Diode

A Schottky-barrier gallium arsenide diode is intended for mixer and detector use in the frequency range 1-12GHz. The plastic-encapsulated device—type CAY17—has 'beam' leads giving low inductance and allowing easy mounting in strip-line circuits. When used as a low-noise mixer it has the advantage of being insensitive to local oscillator level changes. Mullard Ltd, Torrington Place, London W.C.1.
WW 325 for further details

3-W Audio Amplifier Uses I.C.

The latest packaged circuit from Newmarket Transistors is a 3-W a.f. amplifier and includes a μA709 operational amplifier. Designed to present a high impedance (10kΩ, balanced) to a 600-ohm line the amplifier has a sensitivity of 700mV for 3W at 1kHz. Frequency response is 3dB down at 70Hz and 12kHz. Three watts is delivered into an eight-ohm



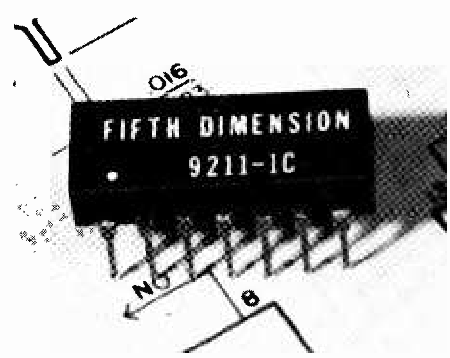
loudspeaker load and reduced power into a 15-ohm load. The power supply should be 21V, centre-tapped, and deliver 0.5A for full power. Newmarket Transistors Ltd, Exning Road, Newmarket, Suffolk.
WW303 for further details

Light-emitting Diode

Indicator with integral logic circuitry is now available through Litton Precision Products. As with other similar indicators, it interfaces with r.t., d.t. and t.t. microcircuit logic working from a 5-volt supply. The long-life, high reliability and resistance to shock and vibration make these devices suitable for harsh industrial environments, especially airborne systems. The lamp is Monsanto gallium arsenide-phosphide and the complete indicator is made by TEL Inc. Available at prices from £3 from Litton Precision Products, 95 High Street, Slough, Bucks.
WW 323 for further details

Dual-in-line Relay without Contact Bounce

Relays compatible with 5-volt d.t.l. and t.t.l. integrated circuits are available in 14-pin dual-in-line packages. The mercury film contacts are bounce-free and can handle currents from 1μA to 1A. There are various



types in the 9000 series—with normally open and changeover contacts, with and without suppression diodes, and monostable and latching types. Made by Fifth Dimension Inc, they are available at prices from about £4 through F.R. Electronics, Wimborne, Dorset BH21 2BJ.
WW 326 for further details

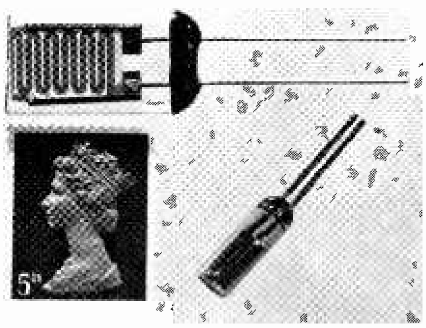
Programmable 'Zener'

The D13V from Jermyn is an integrated voltage regulator in a standard TO98 package. It can be programmed as a

reference element over a voltage range of 10 to 40 volts with a continuous rating of 400mW and withstand overloads of up to 1A. Typical temperature coefficient is 0.03% per °C with an operating T_j of —15°C + 125°C. Main uses are as a low-power settable zener reference which may be used simply or in conjunction with suitable power transistor(s) for regulated power supplies. It can also be used as part of a constant-current reference. Prices 8s 6d (1-24) and 4s 11d (500 and over). Jermyn Industries, Vestry Estate, Sevenoaks, Kent.
WW 313 for further details

Photoconductive Cells

A range of cadmium sulphide photoconductive cells has power ratings from 30mW to 600mW. They are available in glass envelopes or with a lacquer covering. Illuminated resistance at a nominal illumination of 50lux varies from 1.2kΩ to



125kΩ and dark resistance is 1500 times the resistance at 50lux. Smallest unit measures about 5 × 5 × 2mm. Guest International Ltd, Nicholas House, Bridstock Road, Thornton Heath, Surrey.
WW 311 for further details

Gunn-effect Devices

Three new Gunn-effect diodes have been added to the Mullard range of microwave solid-state devices. Two of them, types CXY19 and CXY20, are intended for use in the frequency range 8 to 12GHz; with an applied voltage of 8 to 15V and a current of 200 to 375mA, they will give an output not less than 50mW at 9.5GHz. The CXY19 is contained within a pill-type encapsulation, and the CXY20 within a threaded-type encapsulation. The third Gunn device, type 823CXY/A, is designed for use at 26 to 32 GHz. Output of not less than 4mW can be obtained with an applied voltage of 3.5V and a current of typically 250mA. Mullard Ltd., Mullard House, Torrington Place, London W.C.1.
WW 315 for further details

Low-cost Power-supply Modules

LTH Electronics have introduced a series of low-cost power supply modules, known as the LRB range, available with current ratings of 0.5A up to 30A and two voltage ranges up to 50V. The output from all models can be reset to any other voltage in the range. A fast-acting, automatic-reset, over-current circuit with re-entrant characteristics afford complete protection against short circuit and overload. LTH Electronics Ltd, Eltelec Works, Chaul End Lane, Luton, Beds.
WW 316 for further details

M.O.S. Shift Register for Delay Lines and Memories

Low-speed dynamic m.o.s. shift register has a capacity of 512 bits. Intended as a replacement for glass and magnetostrictive delay lines and drum memory stores, the device can also be used to provide low-cost c.r.t. memories. Devices are compatible with bipolar circuits and work from +5 and −12V power supplies. Minimum operating frequency is 600Hz at 25°C. Price ranges from £2 10s for 100 up of MM5016 (−25 to +70°C in TO-5 package) to £18 for 1-24 of MM4016D (−55 to +125°C, dual in-line package). National Semiconductor Ltd, Precinct, Broxbourne, Herts.
WW319 for further details

Cermet Potentiometers

A new range of potentiometers made by Bourns with cermet resistance tracks is designed to replace the carbon counterparts. Metal-ceramic composite tracks are smaller with better stability, temperature coefficient and power rating than their carbon equivalents.

Two models are available, 3862 with 12.5 mm diameter and 1W power rating and 3852 with 19 mm diameter and 2W power rating, claimed to have the slimmest profile of any on the market.

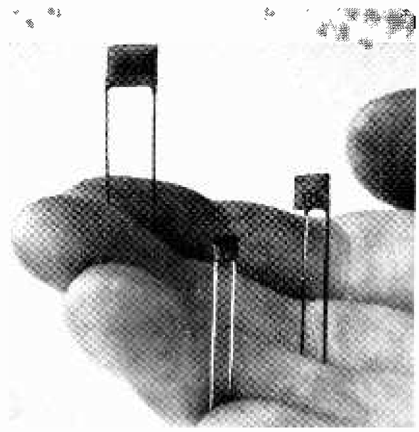
Linearity and tolerance is ± 10% and temperature coefficient is ±150 parts

	3862	3852
power rating	2W at 70°C	1W at 125°C
operating temp.	−65 to +150°C	−65 to +175°C
resistance range	50Ω – 1MΩ	100Ω – 1MΩ
diameter	1.25cm	1.9cm

per million. Bourns (Trimpot) Ltd, 17 High Street, Hounslow, Middx.
WW305 for further details

Ceramic Capacitor Range

A range of small ceramic plate capacitors is available from Steatite Insulations. Capacitance values are from 1pF to 0.05μF, and sizes range from 4 × 4mm up to 12 × 12mm. Two types—temperature compensating and high permittivity—are available, with capacitance tolerances of ±5, ±10 and ±20% for temperature compensating



types and ±10 to +80(−20%) for high permittivity types. The working voltage is 50V. Steatite Insulations Ltd, Hagley House, Hagley Road, Birmingham 16.
WW 335 for further details

Digital Panel Meter

Single-range panel meter using number tubes is intended for use in any instrument using this kind of display. Indicating up to 399 for an input of one volt, ranging circuits can be added to give readings from 399mV to 399V. With suitable external circuitry current ranges from 399nA can be obtained. Eight variants of the basic unit are available. Accuracy is ±2 digits giving ±0.5% of full scale reading. Sampling rate is 50 readings per second. Overranging is indicated by simultaneous display of 0 and 4 in the left-hand tube. Known as the Comtec DM1-1, price is from £45. Computer Techniques Ltd, Westminster Bank Chambers, Bridge Street, Leatherhead, Surrey.
WW 338 for further details

Flexible Magnetic Shield

High-permeability ferromagnetic shield material is thin enough (0.05mm) to be cut with scissors. Two cylindrical wrappings of Telshield around a component measuring 32 × 150mm dia. will give a shielding factor of 40. It can be used to shield meters, valves, c.r.ts, reed relays, cables, microphones and printed-circuit boards. Made by Telcon Metals Ltd, Manor Royal, Crawley, Sussex.
WW 321 for further details

Encapsulated Bridge Rectifier

Range of one-amp encapsulated bridge rectifiers are available from International Rectifier with repetitive reverse voltage ratings from 50 to 1000V. Package measures 15 × 15mm and is ideal for printed circuit mounting. With a maximum mean forward current of 1A, bridge will pass 40A for a single-cycle surge (20ms). Peak repetitive surge current, for capacitative loads, is 12A. Designated 1SB05—1SB100, devices have V_{RRM} of 50-1000V and V_{RSM} (for 5ms) of 100-1200V. Leakage is between 200 and 500μA. Forward current of 1A applies at 60°C ambient temperature, being linearly de-rated to zero at a temperature of 160°C. International Rectifier, Hurst Green, Oxted, Surrey.
WW 339 for further details

Literature Received

For further information on any item include the appropriate WW number on the reader reply card

ACTIVE DEVICES

A.E.I. Semiconductors Ltd, Carholme Rd, Lincoln, have published additional data sheets on thyristors and rectifiers for the A.E.I. Semiconductor Data Book (Filing instruction 17) WW401

WEL Components Ltd, 5 Loverock Rd, Reading, Berks, have sent us a publication which describes microwave integrated circuits manufactured by A.E.I. Semiconductors WW402

A 64-page catalogue and guide to E.M.I. photomultiplier tubes is available from the Tube Division of E.M.I. Electronics Ltd, Blyth Rd, Hayes, Middlesex WW403

The range of products produced by Hivac Ltd (Stonefield Way, Victoria Rd, South Ruislip, Middlesex) are described in data sheets received. The range includes electrometer valves, cold cathode tubes, barretters, spark gap tubes, numicators, decatrons, flash tubes etc.. WW404

A new book from the Educational Service of Mullard Ltd, Torrington Place, London WC1E 7HD, is called 'A Programmed Book on Semiconductor Devices'. It deals with the subject non-mathematically and costs 10s, including p. and p.

Siliconix Ltd, Saunders Way, Sketty, Swansea SA2 8BA, have published a book called 'An Introduction to Field Effect Transistors' which costs 17s 6d post free.

Many of the semiconductors mentioned in a publication called 'Hobby Circuits Manual' (HM90) are not commonly available in the U.K. An equivalents list may be obtained from LST Electronic Components Ltd, 7 Coptfold Rd, Brentwood, Essex WW407

The Industrial Electronics Division of Mullard Ltd, Torrington Place, London WC1E 7HD, have produced a 146-page book called 'MOS Integrated Circuits and their Applications' which is intended for engineers engaged on system design using m.o.s. i.cs. Requests for copies should be made on company headed notepaper quoting ref.TP1108.

Ferranti Ltd, Gem Mill, Chadderton, Oldham, have published a new semiconductor price list WW408

Series 54/74 t.t.l. integrated circuits are the subject of a 100 page book on m.s.i. complex arrays from Sprague Electric Co. (U.K.) Ltd, 159 High St, Yiewsley, West Drayton, Middlesex WW409

A data sheet describing a range of silicon transient suppressors, called TransZorbs, is available from The Semiconductor Division, Auriema Ltd, 23/31 King St, London W.3 ....WW410

PASSIVE COMPONENTS

We have received the following literature, mostly concerned with coaxial connectors and intended for inclusion in the Greenpar manual, from Greenpar Engineering Ltd, Electronics Division, Station Works, Harlow, Essex.

- Index/contents sheet WW411
- Cross ref. list, U.S. mil. to Greenpar number codes WW412
- Cross ref. list, N.A.T.O. to Greenpar number codes WW413
- Cross ref. list, Greenpar to U.S. mil. and N.A.T.O. codes WW414
- Interseries adaptor kit (55009) WW415
- G.P. range of miniature connectors WW416
- Series G.P. assembly instructions WW417
- Precision coaxial attenuators WW418
- Passive probe d.c. to 200MHz WW419

Precision coaxial transition (adaptors 50 → 75Ω and 75 → 50Ω) WW420

Electrosil Ltd, P.O. Box 37, Pallion, Sunderland, Co. Durham, have produced a wall chart dealing with wirewound trimming potentiometers WW421

Home Radio (Components) Ltd, 240 London Rd, Mitcham, Surrey CR4 3HD, have published a new catalogue which costs 10s.

Cambion Electronic Products Ltd, Cambion Works, Castleton, Nr. Sheffield, Yorks, have issued a leaflet which describes an assortment of accessories for integrated circuit handling WW422

APPLICATION NOTES

An interesting publication called 'Theory and Applications of Peak Electrical Measurements' has been produced by Sintrom Electronics Ltd, 2 Castle Hill Terrace, Maidenhead, Berks. WW423

'Uses of Shift Registers for Data Storage' published by General Instrument Microelectronics, Stonefield Way, Ruislip, Middlesex, describes, in simple terms, the use of m.o.s. shift registers. WW424

A second edition (first edition 1968) of a booklet 'Noise Measurement Techniques' by W. V. Richings is available from Dawe Instruments Ltd, Concord Rd, Western Avenue, London W.3. ....WW425

Application note 123 from Hewlett-Packard, 224 Bath Rd, Slough, Bucks, called 'Floating Measurements and Guarding' shows how guarded instruments will solve most common-mode problems. WW426

The following application notes have been received from Texas Instruments Ltd, Manton Lane, Bedford.

- CA101 'Operation and use of series 7520N sense amplifiers' WW427
- B167 'Second breakdown and power transistor area of operation' WW428
- B166 'Transistor output power test circuits at 175MHz' WW429

EQUIPMENT

Counting Instruments Ltd, Elstree Way, Boreham Wood, Herts, have published a leaflet which describes their counter and display board type 70. This contains a decade counter, buffer store and indicator, reversible and synchronous versions of the counter are available WW430

The first supplement to the Rhode & Schwarz communication equipment catalogue is available from Aveley Electric, Arisdale Avenue, South Ockendon, Essex WW431

A new Eagle Products catalogue is available from the Industrial Division, Adler Micro Electronics, Coptic St, London WC1A 1NR WW434

A leaflet describing radio equipment for the amateur and a revised price list are available from K. W. Electronics Ltd, Vanguard Works, Heath Street, Dartford, Kent

Western Electronics, 24 Hook St, Hook, Swindon, Wilts, have published a catalogue called 'Radio Masts and Towers for amateur and commercial use' WW438

North Atlantic Industries Inc., Terminal Drive, Plainview, New York 11803, have published a data sheet describing a phase-angle voltmeter which measures fundamental voltage, in phase voltage and quadrature voltage to 2% accuracy.................................. WW439

We have received the following data sheets from Calan Electronics Ltd, Crossroads, By Ormiston, East Lothian.

- Speed check test set for tape recorders or record players WW440
- Decade counter module WW441
- Temperature alarm CTR6 ....WW442
- 4-digit counter/timer WW443

A variety of test equipment is described in catalogue 1A from Hartman & Braun (U.K.) Ltd, 897 Harrow Rd, Wembley, Middlesex WW444

HARDWARE

Lub spray is an all-purpose dry lubricant which can be applied to any type of surface, wood, metal, plastic etc. It is described in a leaflet from A. V. Pound & Co. Ltd, Kemp House, 154/158 City Rd, London E.C.1 ....WW446

GENERAL INFORMATION

Information sheet 4006(2) 'U.H.F. Television Reception' obtainable from the B.B.C. Engineering Information Department, Broadcasting House, London W1A 1AA, describes the u.h.f. network and gives advice on receiving aerials and other matters concerned with television reception.

Full details of the u.h.f. and v.h.f. transmitter chain of the I.T.A. are given in 'ITA Transmitters—a pocket guide' available from the Independent Television Authority, 70 Brompton Rd, London S.W.3.

We have received the 1970-71 prospectus of courses run by the London Borough of Hounslow. Courses on electronics include radio hobbies, radio amateurs, basic electronics, and radio and TV servicing. Copies available from: Adult Education Office, Hounslow Manor School, Holloway St, Hounslow, Middlesex.

The 1970/71 prospectus of the Hendon College of Technology (The Burroughs, Hendon, London N.W.4.) is available.

The English Electric Valve Co. Ltd, Chelmsford, Essex, have produced a camera tube test chart for use with closed-circuit television systems. It comes complete with instructions for use WW452

We have received the following publications from Norwood Technical College, Knights Hill, London S.E.27.

- 1970/71 prospectus of the Science Department.
- 1970/71 prospectus of technician courses in applied science.
- 1970/71 prospectus of the Department of Telecommunication and Electronics.

'Bulletin of Special Courses in Higher Technology Management Studies and Commerce—1970/71' published by the London and Home Counties Regional Advisory Council for Technological Education, Tavistock Square, London WC1H 9LR is available price 10s.

BS833:1970 'Specification for Radio Interference Limits and Measurements for Electrical Ignition Systems of Internal Combustion Engines' is available, price 14s, from The British Standards Institution, 2 Park St, London W1Y 4AA.

Personalities

Stanley Mullard, M.B.E., Hon.C.G.I.A., F.I.E.E., who founded the Mullard company 50 years ago, has retired from the Board. He has completed nearly 72 years with the electrical and electronics industry. Mr. Mullard, who will be 87 on November 1st, was apprenticed to an electrical engineering firm at the age of 15. In 1910 he joined Ediswan. Three years later he became head of their Lamp Laboratory. During World War I he was commissioned in the Royal Naval Volunteer Reserve and attached to the Royal Naval Air Service. As a member of a small team of scientists and technologists at H.M. Signal School, Portsmouth, he was involved

Stanley Mullard

with the invention and development of high-power transmitting valves in fused silica bulbs which were urgently needed by the Navy. In 1920 after demobilization, Mr. Mullard was invited by the Admiralty to produce these valves in quantity. The first company to bear his name—the Mullard Radio Valve Company—was founded in 1920. Although he relinquished the leadership of the company nearly 40 years ago he has remained on the Board.

Edgar M. Lee, B.Sc., F.I.E.E., who founded Belling & Lee Ltd 48 years ago, is retiring from the position of managing director but he remains chairman of the Company. The new managing director of the company is **John W. S. Payne,** B.Sc., F.I.E.E. He was formerly director and general manager of A.E.I. Herr Ltd.

Charles B. B. Wood, head of the image scanning section of the B.B.C's Studio Group Research, has received an award from the Society of Motion Picture and Television Engineers for his paper "Some Considerations in the Television Broadcasting of Colour Film" published in the Society's journal. Mr. Wood joined the B.B.C. Research Department in 1946 after service with the Royal Air Force.

George W. Stephenson, appointed general manager of the plant of Emihus Microcomponents Ltd at Glenrothes, Fife, Scotland, is one of the original staff that formed the nucleus of the company when it was established as Hughes International (U.K.) Ltd four years ago. He joined as chief production engineer and in 1966 became production manager. Immediately prior to joining the Glenrothes plant, Mr. Stephenson, who is 41, was with Semiconductors Ltd, Swindon, for three years. From 1952 to 1957 he was with Plessey Co. Ilford.

J. P. Engels, chairman of Philips Electronic and Associated Industries Ltd, has been appointed a deputy president of the British Electrical and Allied Manufacturers' Association. Mr. Engels is also undertaking the chairmanship of the Europe Steering Committee being set up by B.E.A.M.A. to ensure that British manufacturers are kept informed of opportunities in Europe.

Alan E. Hutley has joined Advance Electronics Ltd as product marketing manager. Mr. Hutley served in the R.A.F. as an apprentice in aircraft electronics and later joined DeHavilland where he worked on guided missile test equipment. He was at one time sales manager of the Control Systems Division of Gresham Electronics Ltd, and latterly marketing manager of Lambda Electronics.

N. E. Weber-Brown, M.A., M.I.E.E., is general manager of the newly constituted Systems Division of IDM Electronics Ltd, of Reading. The Division combines the previous responsibilities of the Data Systems Division with the company's transducer activities. Mr. Weber-Brown, who was recently with Radyne, was previously divisional manager (metal industries) in the projects company of the GEC-English Electric Group.

Coutant Electronics have announced the appointment of two new directors to their board. **Miles Rackowe,** formerly technical manager, has become director and general manager of the company's Special Products Division in Reading, and **Ken Weedon,** previously works manager at the company's Ilfracombe plant, becomes works director at Ilfracombe. Mr. Rackowe, aged 34, joined Coutant as a senior design engineer in 1964, having previously spent two years with A.M.F. International Ltd as an electronics development engineer. He was appointed chief engineer of Coutant in 1964, and became technical manager a year ago. Mr. Weedon also joined the company in 1964, as production manager of their Prototype Design Department. He had previously been with J. Langham Thompson for nine years as a planning engineer. He has been works manager at Ilfracombe since 1969.

Frank Grimm, M.I.E.R.E., aged 50, has been appointed technical director of Pye Telecommunications Ltd responsible for the company's research and development facilities and its systems department. He joined Pye Ltd in 1950 and four years later went to Pye Telecoms becoming chief engineer of the mobile laboratory and two years ago was appointed engineering manager.

A. D. Hudson is appointed divisional manager of the newly formed Radio Division, within Plessey's Electronics Group. The new division will concentrate on radio communication and allied equipments for the civil market at home and overseas. Mr. Hudson joined the Plessey

A. D. Hudson

Company in 1969 prior to which he was managing director of International Marine Radio at Croydon (an S.T.C. company). His own company, Hudson Electronics, was acquired by S.T.C. in 1963.

Geoff Coston, Assoc.I.E.R.E., has been appointed marketing manager of Electrautom, of Maidstone, Kent. He was previously sales manager of GEC/AEI Telecommunications, Printed Circuit Division and was a founder member and sales manager of Tectonic Printed Circuits. He is to head the marketing of the Microelectronics and Components Divisions of Electrautom.

Tel Inc International Ltd, the U.K. operation of the Electronics Group of Tennant of New York, which offers purchasing services in respect of American components and materials, announces the appointment of **Bryan Kavanagh** as sales executive for the U.K. He was a senior sales engineer with Painton Ltd, of Northampton, and prior to that was with G.E.C.

Dr. Jeremy Bray, former Parliamentary Secretary at the Ministry of Technology, has joined Mullard Ltd where he will be responsible for personnel affairs and corporate planning.

After 41 years' service with Dubilier Condenser Company (1925) Ltd, **F. H. McCrea** has retired from the Board. Mr. McCrea has been chairman since 1955 having previously been managing director for 16 years.

Real and Imaginary

by Vector

Good will towards dealers

As I write, there are only sixty shopping days to Christmas—and that number will have shrunk considerably by the time you read this.

Now you, in your innocence, might imagine that the advent of the nation's annual spending spree would be a shot in the arm for a radio dealer. One can visualize him on the night before Christmas Eve, dreaming beautiful dreams of a queue of customers outside his shop, waiting for opening time to dash in and buy a colour TV set apiece for spot cash.

Having wafted the queue into the arms of his sales staff he supervises the unpacking of a gross of colour sets and two gross of monochromes, ordered only the day before yesterday. They all work superbly. Outside, in the loading bay, his fleet of vans glides away, loaded to the gunwales with serviced receivers. All over town his outside engineers are gaily clearing up the remnants of pre-Christmas calls. And so the merry day goes by, until by closing time a veritable army of satisfied customers sit snug and content in their homes, while the shop looks like Old Mother Hubbard's cupboard and two Securicor vehicles wait outside to transport the day's loot to safer lodgings.

Surprisingly, a dealer friend of mine with whom I was chatting recently doesn't altogether agree with this picture. A shade overdrawn, in his opinion. In real life, he says gloomily, the dealer would probably be living over the shop and is more likely to be awakened at 6.30 a.m. by a frantic banging on the door. Poking his head out of the window he sees, by the light of the street lamp, not a milling queue of colour-conscious citizens, but one irate night-shift worker just off duty, who demands to know when the asterisked 'ell his asterisked set is coming back—it came in for repair more than twenty-four hours ago.

Gathering his sleepy wits the dealer recalls that the set in question is a so-called "Civilian" of war-time vintage for which no valves are readily available. He says as much and tentatively suggests that the purchase of a new model is long overdue. This is met with impolite incredulity. 'The set was going fine up to the last time your out-of-wedlock service engineer mucked about with it. . . .' or words to that effect. Wearily the dealer bangs the window down and brews a cup of cocoa against what is patently going to be one of those days.

By lending a hand in the service department the mountain of repairs is reduced to a hillock and, by a superhuman effort, midnight sees the last one despatched in a borrowed van. Something attempted, something done, has earned a night's repose. Until 3.20 a.m. that is, when a thunderous banging on the door again brings him to the window. This time it is a gentleman in blue who courteously informs him that he (the aforesaid dealer, not the constable) has been the victim of a bad case of breaking and entering and may he (the constable, not the dealer) have some details for his notebook? It does not make the dealer's Christmas any happier to find that the bucket-shop up the road, which has opened up on an eight-week lease and a 20% discount on current models, is still *virgo intacta*.

Perhaps my dealer friend is taking too gloomy a view of the immediate future. It could be that the milk of human kindness, hitherto a marked feature of his character, has been soured by a recent series of unfortunate personal experiences, which with your permission I will relate (and here we depart rom fantasy to sober truth).

To start with, his shop has been done, not once, but four times by thieves, but this, curiously enough, is not the source of his depression. What does really gripe him is the cavalier attitude of some radio manufacturers who seem deliberately to go out of their way to lose the dealers' confidence. Two examples of this will show you what I mean.

The first underlines the whole matter of manufacturer-dealer-customer relationship. One of my friend's old-established customers wanted a stereo audio outfit but couldn't afford the outlay, so the dealer sold him a mono player which, in the maker's sales brochures, was advertised as being convertible to stereo by means of add-on units. Result—a satisfied customer.

Not long after the sale the customer reappeared and explained that a modest windfall now enabled him to convert to stereo. So my dealer friend ordered the add-on kit, only to be blandly told by the manufacturer that the units had been discontinued.

Not unnaturally, the wrath of the customer fell upon the dealer from a great height. Eventually, after some pretty acrimonious correspondence, the manufacturer supplied his latest version of the stereo add-on units, but these were more expensive than the ones required and did not physically match the original main unit. The story ends reasonably happily in that, after considerable placation, the customer was persuaded to accept the new units as an act of grace. But it could so easily have been otherwise.

And this isn't an isolated instance. Like many retail radio establishments, this one also sells electrical goods. By pressurized sales methods my friend was induced to take into stock a couple of quite expensive food mixers. Again, much the same thing happened. A customer bought one, only to return later for some advertised accessories. Back came the reply that the model had been discontinued and that no bits and pieces were available.

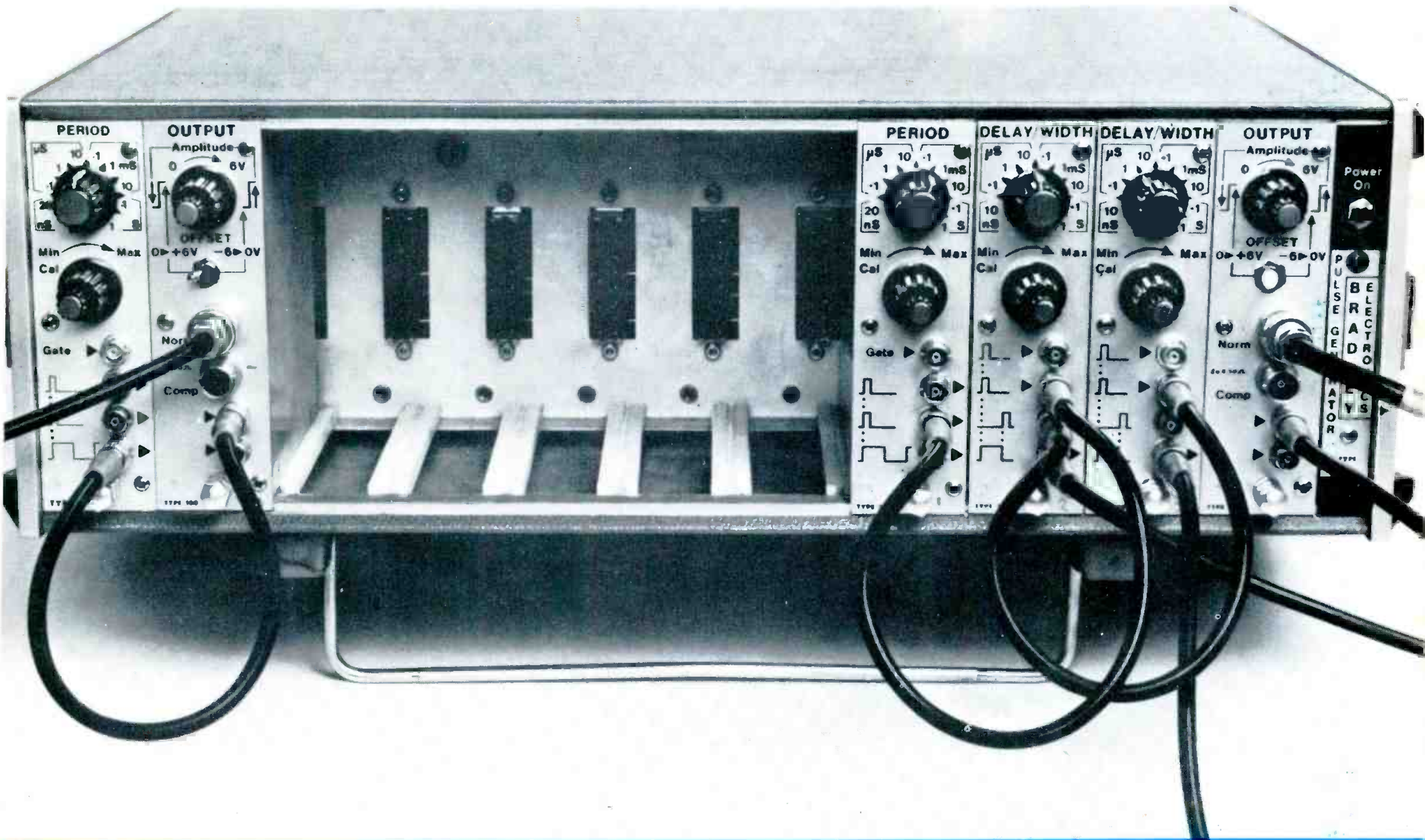
On this occasion the dealer raised Cain with the manufacturer's representative and that hapless buffer state scoured the area in search of the required unit. Eventually one was located in the window of a large store and in the fullness of time this was delivered in a tatty alien box with no instruction booklet. It was invoiced at the full retail price.

So the customer is happy and the representative can congratulate himself on a job well done. But both he and the dealer were badly let down, for both in turn came within an ace of losing a valuable customer. In the final analysis, however, it was the dealer who bore the brunt, having been forced into a situation whereby he had to make a profitless sale, throwing in the considerable time spent by himself and his staff as a bonus. Not only this, but he is left with another appliance of the same type on his hands.

Now, such incidents are particularly maddening because they are unnecessary. They would be more understandable if the goods came from some obscure source but they are products of British factories with names which are household words.

It is axiomatic that you can't win 'em all in business. Every fruitless demonstration which a radio dealer gives is a monetary loss to him; so also is under-guarantee maintenance and the location of ultra-sticky faults when the time taken cannot always be justified on the bill. These the dealer tries to minimize but accepts them as part of the business hazard. But he shouldn't be at the mercy of manufacturers who discontinue models without warning; a reasonable notice of intent should be obligatory. (Neither, incidentally, should he have to compete with the bucket shop up the road.)

From where I am—which is admittedly not on the field of play—it doesn't look as if the Radio and Television Retailers' Association is altogether on the ball. One—or even two—swallows don't make a summer, but I have a feeling that this dealer's experiences are not uncommon.



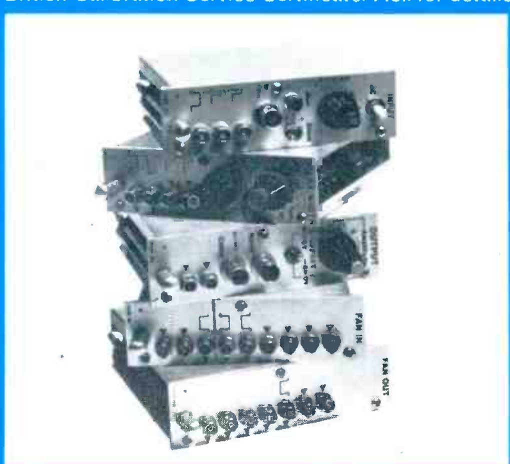
From Bradley. A Modular Pulse Generator

The two modules on the left form a complete square wave generator giving outputs up to 6V into 50ohms, over the range 1 Hz to 50 MHz

The four on the right form a sophisticated pulse generator giving full variable pulse width and delay facilities, with double pulse output over the same range of p.r.f.

If all this can be done with a blank space in the main frame, think what you can do when you add the other five missing modules . . . The Bradley 176 provides an almost limitless variety of complex pulse patterns. The UK price of this instrument is £350 in standard form.

All Bradley instruments can be supplied with a British Calibration Service Certificate. Ask for details.



G & E BRADLEY LTD
Electral House, Neasden Lane
London NW10
Tel: 01-450 7811 Telex: 25583

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