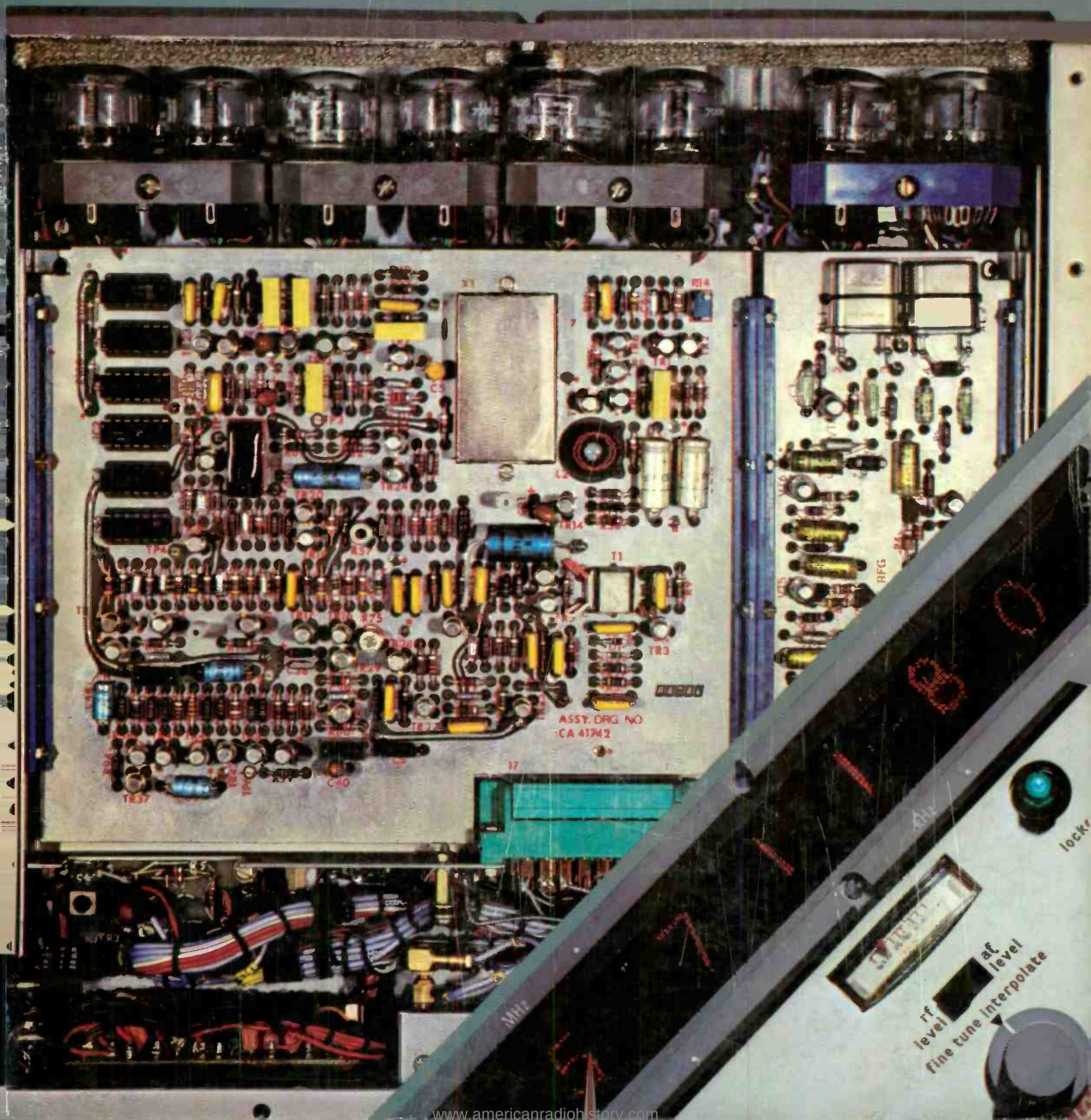
Wireless World

June 1970 3s 6d

- Tester for diagnosing transistor faults
- Communications receiver survey



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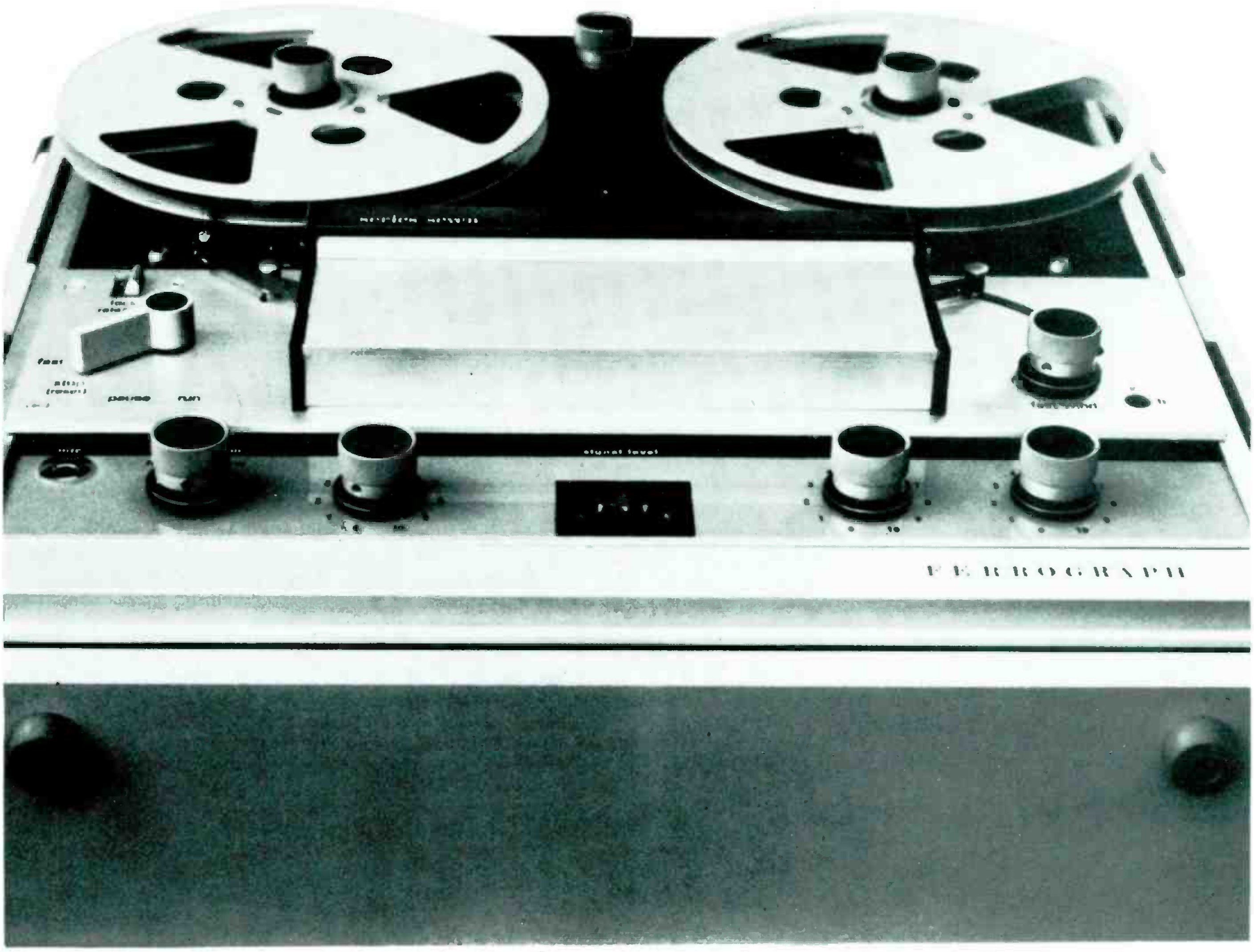

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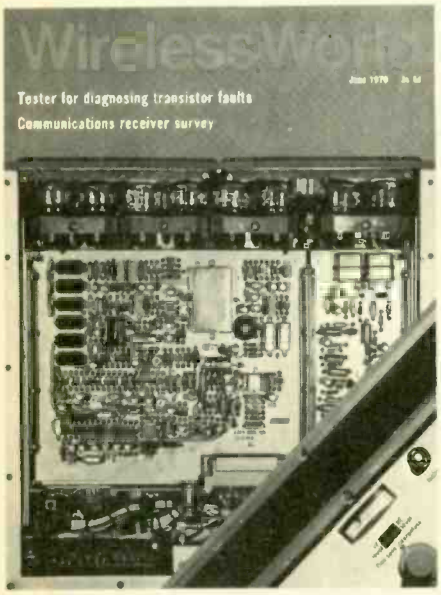

Communications receivers being the theme of the first article in this issue, our **cover illustration** is of part of the chassis of the Racal RA1220 on which is superimposed the "Racalok" digital frequency readout.

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Constructional details for a simple stereo **pre-amplifier** based on two integrated circuits. **Class AB audio amplifier.** Having discussed the pros and cons of class A and B amplifiers in this issue (p.278) J. L. Linsley Hood gives details of an amplifier with class A performance but reduced thermal dissipation.
Understanding and using **operational amplifiers.**

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Electronics in medicine—the future

The recently published report by the Electronics 'Little Neddy' giving an economic assessment of the U.K. electronics industry, to which we referred in last month's leader, includes a section headed "A strategy for the 1970s". In this the E.D.C. suggests potential growth areas; it has not however, attempted to give an analysis of the areas of concentration as this would involve a "full scale technological forecasting exercise and a detailed assessment of the international competitiveness of the entire industry". None the less, it is interesting to see that one of the growth areas is medical electronics.

The report cites evidence given to the Zuckermann Committee on Hospital Scientific and Technical Services in support of its forecast that the main growth is likely to be in the spread of automation in the fields of biochemistry, hematology and microbiology; the development of engineering technology and instrumentation in medical physics; and the application of computer techniques to medical practice.

The E.D.C. states, however, that there are a number of serious weaknesses which are hampering "the development of a viable U.K. capability in this growing market".

The first is a weakness in maker-user relations. It is pointed out that technologists are not spread thickly or widely enough through the Health Service to facilitate the widespread application of advanced techniques. This sometimes results in a failure to exploit effectively the results of specialized research teams, and research alone cannot constitute an adequate demand on which to build up a U.K. industry. The recommendation of the Zuckermann report to create a Hospitals Scientific Service and to give scientists and technologists a greater say in the running of the Health Service should help to improve maker-user relations. Although the E.D.C. understands that the report is still under discussion within government, it urges the rapid implementation of the main proposals.

The second is the problem of finance. Limits on the money available for hospitals are said to be a powerful encouragement to the use of equipment which reduces costs. Finally, the E.D.C. says, there is a serious weakness in the industrial structure of this part of the industry and rationalization is urgently required. Some firms in this field are the traditional suppliers of medical equipment with little or no capability in the newer technologies involved. Others are large concerns primarily engaged in other areas of electronic engineering for whom this market is a residual one in which they have little specialist expertise. The object of rationalization should be the grouping of specialist firms producing broad ranges of related products and systems.

Dr. Vladimir Zworykin, who has devoted much of his later life to furthering the applications of electronics in the field of medicine, has spoken of the gap which exists in the application of engineering knowledge to medical problems. This gap is primarily in the development of new devices for large-scale use in clinical practice and Dr. Zworykin has suggested that it may be attributable to the long period of testing and evaluation which, in medicine, must intervene between the construction of an engineering model and the large-scale distribution of the final device. He pointed out in an article in *Wireless World* in 1965 that the resulting expense and delay in marketing, which finds no counterpart in other branches of industry, discourages private enterprise from ventures in the development of medical instrumentation. He suggested the setting up of specialized institutions "to close the gap between theoretical understanding and practical utilization in the application of engineering knowledge to medicine".

With the very limited budgets at the disposal of most hospitals and medical research establishments they are unable to finance major new electronic projects. It is, therefore, understandable that manufacturers find it difficult, if not impracticable, to maintain an expensive R & D department with little or no prospect of seeing any return. One must not, however, think solely in terms of electronic equipment designed and developed specifically for biological purposes. There are many electronic devices used in other fields which are applicable to medicine. It would appear, however, from correspondence we have had with one medical research establishment that the attitude of major manufacturers to orders for closed-circuit TV and associated sound equipment was anything but encouraging. Perhaps the £50,000 budget was considered small fry by comparison with the vast sums being spent in the entertainment field.

In the early days of wireless it was seen as the saviour of the man of the sea; when will the potential of electronics in medicine be fully exploited?

Communications Receivers

An examination of the extent to which circuit design and cost are being influenced by increasingly stringent performance requirements

by Pat Hawker, G3VA*

Many of the basic features of m.f./h.f. communications receivers originated 35 to 40 years ago, initially in large part to meet the requirements of amateur radio operators. In the early 'thirties, single-conversion superhets were developed, with adequate signal-frequency amplification to overcome the high noise of the early multi-electrode frequency-changer valves. The application by Lamb of the Robinson "stenode" crystal filter to provide "single signal" reception of c.w. signals, coupled with electrical and mechanical band-spreading, resulted in a new class of radio receiver designed for communications purposes. Costs were not excessively above those of good domestic receivers. By the mid-thirties, the National HRO, the Hammarlund Comet-pro and Super-pro, several Hallicrafters' models, some early professional-user models by RCA had all appeared, and were soon followed in the U.K. by receivers for similar applications by Peto-Scott and Eddystone.

With the outbreak of war in 1939, receivers of this category were soon found useful for many communications applications: the HRO was even paid the compliment of being closely copied by both the Germans and the Japanese. Since then, increasing emphasis on the professional users has resulted in a succession of designs of increasing complexity, and the blurring of the former distinction between 'communications' and the more complex 'commercial' receivers used on point-to-point circuits.

While, in some respects, the requirements of the h.f. amateur remain every bit as rigorous as those of other communications services, the professional user has demanded ever-higher standards of stability, dynamic range, adjacent channel selectivity, accuracy of tuning and frequency read-out, resulting in receivers at prices well beyond the reach of most amateurs. There has thus been a marked tendency for communications receiver designs to split into several categories: simple and relatively cheap general purpose receivers primarily intended for the keen "short-wave-listener"; more advanced amateur-bands-only receivers in which high-performance at medium cost can be achieved by limiting the total frequency coverage; and higher-cost general-purpose l.f./m.f./h.f. receivers for professional users at prices ranging up to well over £1000. A further professional category is the v.h.f./u.h.f. receiver for monitoring and surveillance, with Eddystone as the main U.K. firm in this field.

The merging of 'communications' and 'commercial' receivers is still continuing with modern techniques making it possible to build receivers of the highest attainable performance in quite compact units. For example, the recently announced Marconi 2900-series, intended for the most demanding commercial circuits, is packaged virtually in the style and size of a general purpose communications receiver. It can be tuned in steps as small as 0.1 Hz.

It might be thought that, after some 35 years of continuous development, the design of each of these classes of receiver would by now have reached the ultimate either in performance or in cost-effectiveness, and that few significant improvements can be expected. In reality, this is far from the case. Each advance in receiver design has been accompanied (or preceded) by increasingly stringent user demands in terms of stability, ease of tuning, dynamic range, and absence of spurious responses and reliability under arduous conditions.

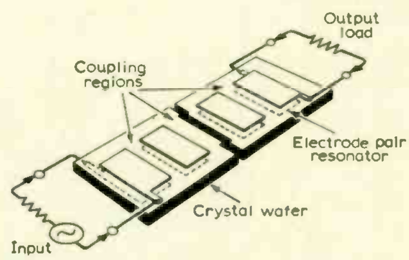


Fig. 1 Monolithic h.f. crystal bandpass filter.

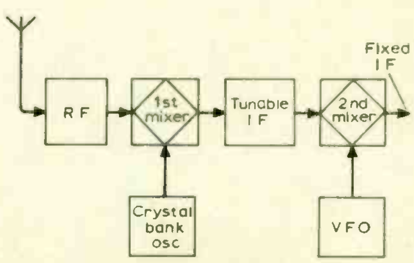


Fig. 2. Multi-conversion superhet having crystal-controlled first oscillator.

Not all design changes have been uniformly beneficial. Although the development of h.f. semiconductors (and more recently integrated circuits) has opened the way to compact receivers of extremely high stability and impressive "mean time between failures", these devices have posed serious "front-end" problems. These include limitations to dynamic range due to increased susceptibility to cross-modulation and inter-modulation, and damage from static charges and local transmitters. Other drawbacks are increased loading of tuned circuits, lower stage isolation and greater spread of characteristics. The availability, during the past few years, of single- and dual-gate field effect transistors, with near square-law transfer characteristics, and the increasing impact of hot-carrier (Schottky) diodes in wideband, double-balanced mixers are reducing these problems.

In some respects, the concentration on all-semiconductor designs came at an unfortunate time, when, for example, the availability of beam-deflection valves (7360, 6JH8 etc) for use as low-noise mixers made possible the elimination of signal-frequency amplification and offered a useful improvement in dynamic range; factors which have been exploited in only a very few designs. An exception was the Squires-Sanders SSR1 receiver for the amateur market.

Even today, in the lowest price ranges, it is usually possible to achieve a higher standard of front-end performance with valves than with semiconductor devices. The continuing demand for low-cost valve or "hybrid" designs of sufficient stability and low-enough tuning rate for s.s.b. reception has increasingly been met by Japanese firms. British, European and American firms tend to concentrate more on the professional user.

A marketing problem in all these fields is that, to achieve financial viability, the receiver design needs to remain basically unchanged for a time-span approaching a decade (often spawning many variations on the basic chassis). More complex

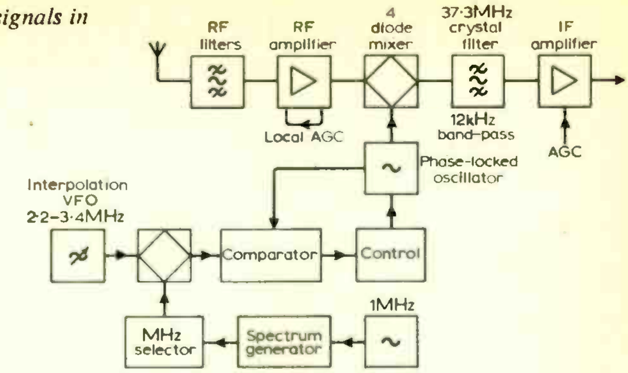
* Independent Television Authority.

receivers may take several years to reach production. This means that, at the initial planning stage, the needs of users for at least a decade ahead must be taken into account. No easy matter when device, filter and component developments continue to follow in rapid succession.

In the past, impressive operational lifetimes have been achieved: models dating from the early 'forties (RCA AR88 National HRO etc) continue in use in vast numbers; the G.E.C. BRT400 series, introduced in 1947, were marketed for 20 years. The Racal RA17-series, which pioneered the 1950 Wadley triple-mix, drift-cancelling loop, came out in 1954 and remained in production for more than 10 years. Several current amateur designs (for example the Collins 75S series) date back 10 years.

Long operational lifetimes often depend as much on the mechanical as on the circuit design. It was no accident that James Millen, designer of the original HRO, had studied mechanical rather than electrical engineering. The need to combine good mechanical with good electrical characteristics, to achieve a receiver which is ergonomically pleasant to operate, is still not always appreciated. One of the more successful basic designs of recent years—the Plessey PR155 series—resulted from extensive investigation into control features required by operators.

Fig. 3. Synthesis of 1MHz signals in Plessey PR155 series.



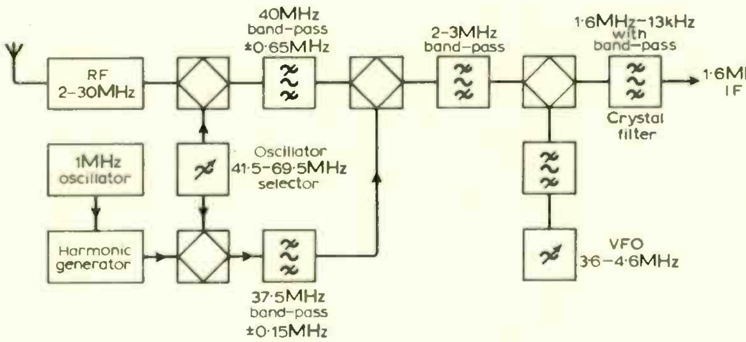


Fig. 4. Wadley drift-cancelling loop technique as used in many Racal receivers.

Choice of intermediate frequencies

The continuously-tunable superhet receiver, whether single- or multi-conversion, must have its first i.f. outside its tuning range. For a typical receiver covering say 2 to 30MHz, this limits choice to below 2 or above 30MHz. On the other hand, models with a non-continuous tuning range (such as amateur-bands-only designs) have a far more flexible choice, and often adopt frequencies between 3 and 9MHz. To reduce image response, without increasing pre-mixer selectivity, the professional designs are increasingly using a first i.f. above 30MHz, resulting in up-conversion in the first mixer.

This trend has been encouraged by the development of h.f. and v.h.f. crystal filters having good selectivity characteristics and suitable for use as 'roofing filters' (filters included early in a receiver to reject out-of-band signals but with final selectivity characteristics usually determined by a subsequent filter). Several current designs use initial crystal filters above 30 MHz—as high as 40.5 and 73 MHz in some Rohde & Schwarz models.

Recent filter developments have included multi-section ceramic filters having good "shape factor" (ratio of bandwidths at −60dB to that at −6dB) and the introduction of monolithic crystal. filters. The monolithic crystal filter (MXF) promises to reduce size and cost of high-frequency s.s.b. filters by a significant factor. It consists of a quartz wafer on which pairs of metal electrodes are deposited on opposite sides of the plate. The quartz acts as a piezo-electric transducer, converting input signals into mechanical vibrations, and vice versa. The quartz also provides the coupling medium between the pairs. The metal electrodes lower the resonant frequency of the transverse shear-wave in the plated regions only, so that this resonance does not extend into the areas without electrodes, but remains "trapped" under the thin metal film electrodes. Filters having 12 coupled resonators may have a shape factor of about 1.5 to 1 in the upper h.f. region, and the technique can be applied to filters up to u.h.f.

Stability

The resolution of s.s.b. speech requires that a receiver should be capable of being set, and remain, within about 30Hz of the nominal frequency: about one part in 10^6 at 30MHz. For commercial applications both long- and short-term stability are important; for amateur use good short-term stability is the main requirement.

It has been the need for stability of this order which has brought about many of the receiver developments of the past decade or so. It led initially to much greater use of the form of multi-conversion superhet having switched crystal-controlled first oscillator and tunable first i.f., a form of receiver popularized by Collins and Drake and now widely used. The tuning rate remains the same on all frequencies, with a degree of electrical bandspreading determined by the tuning range of the i.f. which may be 1MHz, 200kHz or even 100kHz. The reduction of the tuning range requires progressively the use of more crystals, until—at least for general coverage models—it becomes

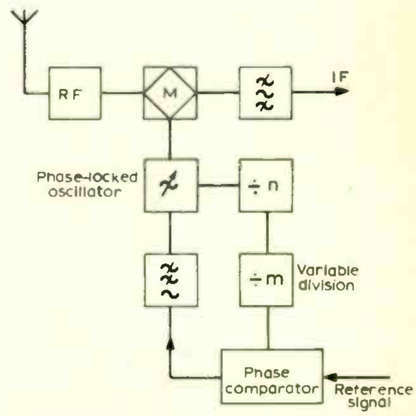


Fig. 5. Phase-locked synthesizer using digital techniques.

more economical (and offering potentially higher stability) to replace the individual crystals with some form of frequency synthesizer to provide the spaced first-oscillator frequencies.

With this type of arrangement, the second local oscillator providing the tuning span, remains a simple *LC* oscillator. Such a system is often called "partial synthesis". One of the first all-semiconductor general-purpose receivers of this type, using a phased-locked synthesizer, was the National HRO-500 although this was soon followed by many alternative designs using synthesis based on phase-locked oscillators (often including a variable digital divider) or variations of the Wadley drift-cancelling loop as in the Racal RA217 and subsequent all-semiconductor designs.

A rather different simple partial-synthesis technique, providing a stable variable-frequency oscillator for the first (and sometimes only) frequency changer has been used in several amateur-bands-only receivers, including the Hallicrafters SX146 and Drake R4 series. This synthesizes the injection frequency from a relatively low-frequency tunable oscillator combined with a series of crystal-oscillator frequencies chosen for the band in use, forming what is often termed a heterodyne-type v.f.o. with equal tuning rate on all wavebands.

The stability of a partial-synthesis receiver is usually adequate for conventional s.s.b. reception. However, increasing use is being made of narrow-band frequency shift keying, phase-coded data transmissions and signal-processing techniques such as Lincompex and Piccolo. Several of these systems demand a frequency stability in the receiver of from 1 to 3Hz, or at 30MHz, a few parts in 10^8. Long-term stability of this order cannot normally be achieved with partial synthesis although techniques for stabilizing a v.f.o. to within one part in 10^7 have been developed (e.g. Racalok). A Racalok unit forms a built-in facility in the latest Racal RA1220 receiver and frequency locking to within ±2Hz is also provided in the Plessey PR1551 and PR1553.

The more conventional method of achieving stability beyond that available with partial-synthesis is by means of full synthesis, in which all high-frequency oscillator frequencies are derived from a single temperature-compensated crystal standard. Until recently, such synthesizers have usually been built as separate units to the receiver proper, but G.E.C. achieved the distinction of developing the first general purpose h.f. receiver (type RC410) to use full frequency synthesis in such a manner that the tuning has much the same 'feel' as a normal continuously tuned receiver. The synthesizer, of the variable ratio divider type, is controlled by mechanical gearing of the synthesizer 'switches' in conjunction with servo-motor control of the signal-frequency tuned circuits. A similar facility is provided in the Collins 651-S, which can also be remote-tuned by computer techniques.

Tuning in steps of only 1Hz, and with a stability of 0.5Hz, has been achieved in the Marconi H2900 series, in which a highly stable *LC* oscillator is controlled by means of assembly and subtraction of pulses.

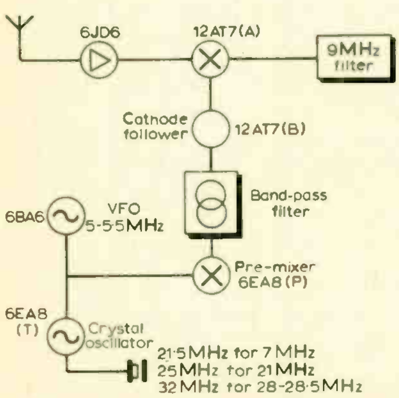


Fig. 6. Pre-mixer arrangements of the Hallicrafters SX146.

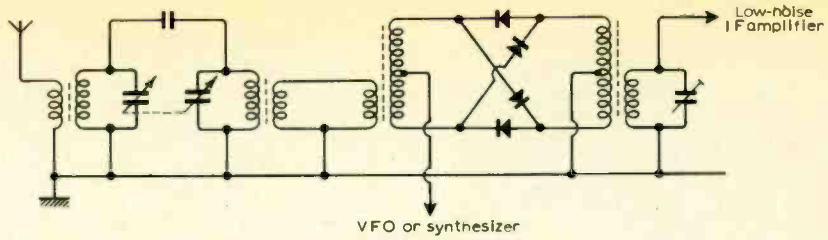


Fig. 7. Even without an r.f. amplifier, diode-ring mixers using Schottky (hot-carrier) diodes can give low-noise performance with wide dynamic range.

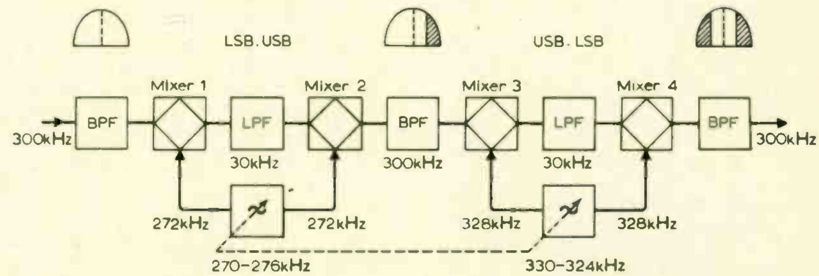


Fig. 8. Rohde & Schwarz variable-bandwidth i.f. filter shown set for ± 2kHz bandwidth.

A possible limitation on adjacent channel operation of any receiver is oscillator 'noise' or 'jitter', although, in practice, this characteristic becomes important only after a large dynamic range and high order of frequency stability have been achieved. In general terms, the noise sidebands associated with low-power oscillators appear to be about 6dB higher for bipolar transistors than for valves, which in turn appear to be about 6dB more noisy than field-effect transistors. For these and other reasons increasing use is likely to be made in future of f.e.t. devices for oscillators as well as in the signal path. The phase-locked oscillator has an inherent jitter which can impose limitations, and digital synthesizers also involve high-frequency pulses which must be carefully screened from the signal path. Noise, jitter and spurious response levels of synthesized oscillators are likely to be of increasing importance in the coming decade.

Frequency read-out

Accurate setting and read-out of frequency has always been a problem on h.f. Traditionally, the slow-motion dial, using mechanisms of varying degrees of ingenuity, often in association with a considerable degree of electrical band-spreading, has been the solution. The practical problems have included limitations of scale length of the dial and the backlash and discontinuities associated with reduction gearing. The film strip, or—as in the recent Eddystone 958—a finely printed film disc optically projected and magnified, can provide a film scale the equivalent of several feet in length. Veeder Root and other counter-type read-out mechanisms have been used, for example by Racal and Collins. A significant advance, however, has come with the widespread introduction of built-in or add-on digital frequency counters providing direct read-out of frequency on numerical display (Nixie-type) tubes, even though this approach adds appreciably to the cost of a receiver.

Dynamic range

The extremely wide range of signals—from fractions of a microvolt up to volts from a local transmitter—demands good cross-modulation and inter-modulation characteristics particularly where broadband input filters are used. This calls for an extremely high degree of linearity in all signal-path stages up to the final selectivity shaping filter (for extreme narrow-band reception using a.f. filters this implies the need for a detector with extremely good linearity). Unless the selective filter can be placed early in the receiver (usually possible only with single-conversion designs), this means careful distribution of gain, keeping signal levels low at least as far as the roofing filter. The limiting factor is often the signal handling capabilities of the first mixer, although where extremely strong signals are present, the linearity of the signal-frequency stages, if any, become important.

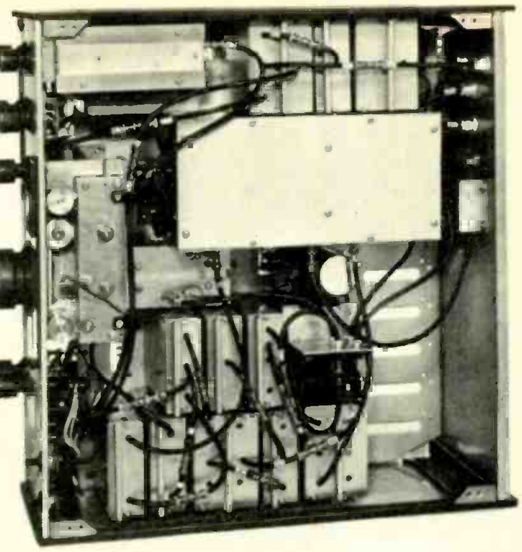
The limited performance of the bipolar transistor as mixer and amplifier has led to a determined search for alternative techniques (for valve receivers the beam deflection valve and balanced triode mixers have good dynamic performance). Bipolar mixer performance is improved by using a high level of local oscillator injection, so that the device operates in the switching mode.

One means of dispensing with signal-frequency amplification and achieving a mixer dynamic range of over 130dB is the use of parametric diode up-conversion: this technique has been used in American designs by National, Avco, RCA, etc. The parametric up-converter can be likened to a cross between a balanced modulator and a coupled pair of circuits. This approach is limited to up-conversion; and to achieve maximum linearity requires substantial pump power. The parametric up-converter can pass up to a few volts of input signal. A possible future alternative for both up- and down-conversion, with low-power oscillator injection, is the square-law resistor (space-charge-limited diode) which follows an accurate square law characteristic.

At present, a more practical approach consists of using a special f.e.t. amplifier in conjunction with a wideband double-balanced diode ring mixer using hot-carrier diodes. Amplifiers of this type, capable of handling linearily signals up to over a volt, have been introduced by Comdel. Several current receivers use field-effect r.f. amplifiers employing the cascode arrangement, either with dual-gate m.o.s.f.e.t. devices or with two separate f.e.t. devices, since the junction f.e.t. appears to be less susceptible to static puncture than the dual-gate m.o.s.f.e.t.

Where bipolar transistors are used in r.f. amplifiers a useful extension of dynamic range can often be achieved by the use of r.f. overlay power transistors, an approach found in some recent Redifon receivers, which also make use of voltage-controlled diode attenuators in the input circuits. Manual attenuators are fitted in many semiconductor designs.

Sub-unit constructional techniques used in Plessey PR155 series.



Front-ends

The protection of front-end devices remains a difficult problem, since the widely adopted solution of incorporating back-to-back diodes across the tuned circuit can introduce cross-modulation on strong local signals. Silicon diodes are much better in this respect than germanium diodes, but a more satisfactory solution may be the use of neon tubes in the receiver, or gas-filled surge arrestors in the feeder lines.

Electronic tuning diodes represent another possible source of non-linearity, and this is one reason why mechanical tuning remains popular, except for receivers for frequency-hopping and similar military techniques.

Little need be said about the basic noise performance of receiver front-ends. In practice, for many years, there has been no difficulty in achieving the lowest usable noise factor, since over most of the l.f./m.f./h.f. spectrum galactic and site noise makes it pointless to strive for a noise factor of less than about 10dB (where emphasis is on performance between 20 and 30MHz this can be usefully reduced to about 8dB).

Since any improvement in the noise performance of an amplifier usually involves a reduction of dynamic range, most receivers have a noise figure of about 10dB. For the reception of extremely weak signals, it is better to limit the noise bandwidth to the minimum appropriate to the information rate. Correlation detection and integrating techniques can result in recovery of information from below the noise level.

A valid reason for including r.f. amplification in front of a low-noise mixer is to facilitate the provision of pre-mixer selectivity. Several designs now use double-tuned input circuits with a cascode f.e.t. amplifier.

Spurious responses

The susceptibility of the superhet to various spurious responses, of which image response is the best known, to direct i.f. breakthrough and to internally generated 'birdies' calls for careful choice of intermediate and oscillator frequencies, effective pre-mixer selectivity and generous use of screening within the receiver. Recent years have seen increasing use of wideband and sub-octave filters in the input circuits; this approach imposes even more stringent linearity requirements. Screening, however, has been facilitated by the wider adoption of modular sub-unit construction with low-impedance coaxial interconnections.

While image, direct i.f. breakthrough and other forms of spurious response should ideally be better than 120dB down on the desired signal, most users would be happy with 80 to 100dB of protection. In practice, even for high-performance receivers, image may be only 50 or 60dB down at 30MHz, and on the lower cost models may be restricted to about 35 to 50dB.

Especially severe conditions exist on board naval vessels where several transmitters may be operating in close proximity to the receiver. It is worth recalling that a G.E.C. h.f. receiver developed for the Navy in the early 'sixties achieved an image and spurious response better than 130dB down by using six signal-frequency tuned circuits with single conversion (i.f. 1600kHz). This had two low-gain cascode valve amplifiers and a double-triode balanced mixer. It seems doubtful whether this performance has yet been bettered with conventional forms of all-semiconductor front-end, despite the benefit of up-conversion to v.h.f.: special selectivity units are offered by some firms for use near powerful transmitters.

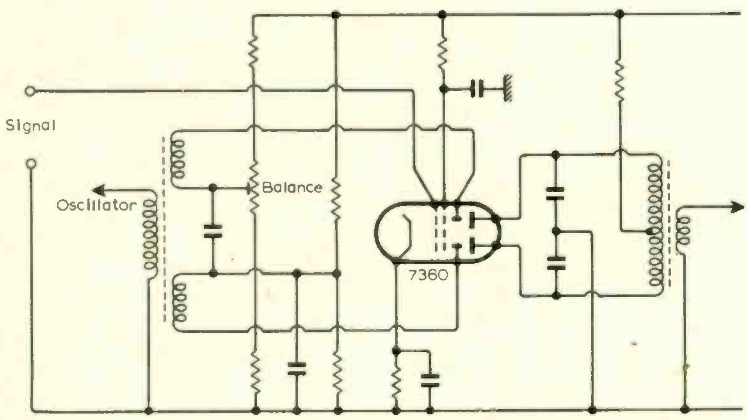


Fig. 9. Balanced mixer using 7360 beam deflection valve can provide low-noise and extremely wide dynamic range.

Variable i.f. filters

The final selectivity characteristics of most modern receivers are determined by one or more crystal or mechanical i.f. filters (although some lower-cost models still depend on a final i.f. of about 50kHz). High-grade s.s.b. filters have a shape

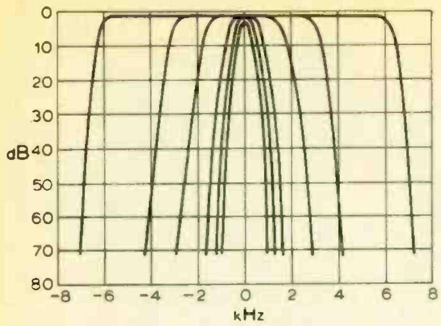


Fig. 10. Claimed selectivity curves for one of the Rohde & Schwarz filters.

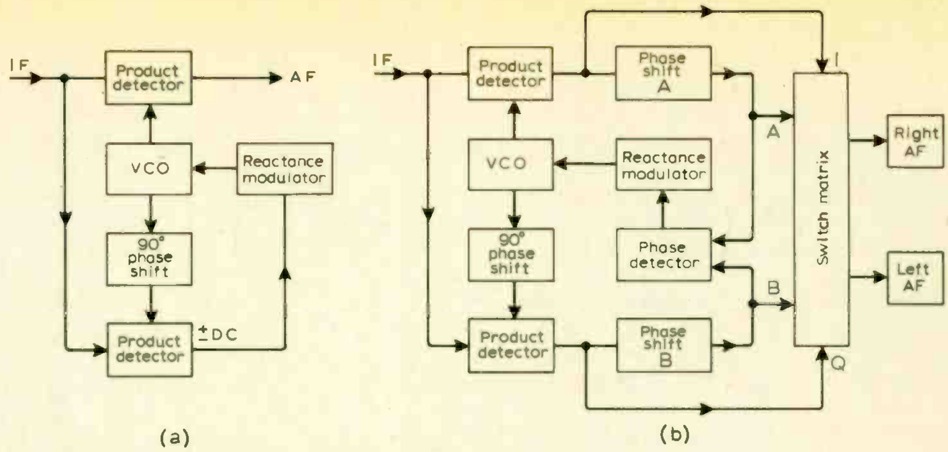


Fig. 12. Block diagram (a) of phase-lock loop synchronous demodulator; (b) bi-aural demodulator. Matrix switch positions; a.m./d.s.b. right A.F.I., left A.F.I.; u.s.b. both A + B; both sidebands right A + B, left A − B; l.s.b. both A − B. f.m. both Q.

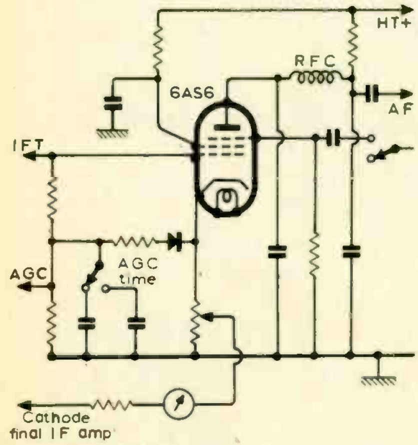


Fig. 11. Philco combined a.m./s.s.b. demodulator.

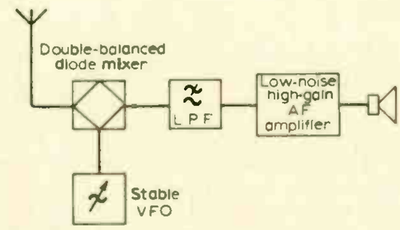


Fig. 13. Basic outline of simple homodyne (direct conversion) receiver for s.s.b./c.w. reception.

factor approaching unity with low pass-band ripple; even with such filters it is important that there is no signal leakage around the filter, or any sudden fall-off below the 60dB level. Typically, however, an overall s.s.b. shape factor below about 4 must be considered good.

There are still attractions in a continuously variable bandwidth filter, and several techniques to achieve this have been developed, mostly involving some form of pass-band i.f. tuning to stagger the relative position of successive bandpass filters, for example in the Redifon R408 marine receiver.

An arrangement capable of providing almost ideal selectivity characteristics is used in several Rohde & Schwarz receivers, based on a dual-mix system in conjunction with high-grade 30kHz low-pass filters. The incoming i.f. signals can be shifted away from or towards the sharp cut-off edges of the two filters, using sideband inversion to permit the slicing action to occur on the upper and lower sideband: see Fig. 8. At ±6 kHz a shape factor of 1.07 is claimed.

Demodulation and a.g.c.

Almost all recent designs have incorporated heterodyne (product) detectors for s.s.b. and c.w. reception, although envelope detection must usually also be provided for a.m. Fig. 11 shows a combined s.s.b./a.m. detector developed by Philco for valve receivers. High-performance product detectors have also used 7360 beam-deflection valves and hot-carrier diodes.

Considerably greater flexibility and improved performance on some modes is possible, though at an increase in complexity, by the use of lock-loop synchronous demodulation (or preferably by bi-aural demodulation comprising a lock-loop demodulator with independent presentation and selection of the two sidebands). Such demodulation can be highly effective not only on s.s.b., c.w. and a.m. but also on narrow-band f.m. and double-sideband-suppressed-carrier modes. Synchronous demodulation is incorporated in the recent Marconi H2900 series.

The coming of integrated circuits has almost certainly opened the way to much greater use of synchronous detection, since almost all components for a phase-lock loop can be provided on a single chip.

Synchronous demodulation also makes possible an extension of interest in homodyne (direct-conversion) and synchrodyne type of receivers as an alternative to the superhet. Already simple forms of direct conversion receivers (including some which phase-out the audio image) have been developed for s.s.b. and c.w. reception by amateurs, providing reasonably good performance at relatively low-cost. Many have used hot-carrier diode ring mixers to heterodyne the incoming signal directly to audio frequency.

Another receiver function which lends itself to the use of integrated circuits is audio-derived a.g.c. with 'pedestal' or 'hang' characteristics. Hang a.g.c. systems using discrete components have been widely used, but the development of integrated-circuit generators, such as the Plessey SL621, makes possible sophisticated systems with a minimum of contructional problems. Timing characteristics are governed by the values of the few external components.

Microelectronics

Digital integrated circuits are widely used in frequency synthesizers and in frequency locking and digital readout counters. The development of linear integrated circuits, monolithic and thin-film, has resulted in high-performance 'pocket' communications receivers (prototype models of this type have been described by MEL Equipment and by Avco).

Recent price reductions in linear integrated circuits, however, now make this form of construction increasingly attractive for almost all classes of receiver. There are still a few functions where the advantages remain with discrete devices, so that a hybrid discrete/integrated approach can be anticipated. One practical problem has been the rapid development in this field, often making it necessary to reconsider ideas during the development of new models. A major advantage, now that linear integrated circuits are becoming standardized, will be the appreciable reduction in design and development time, since many receivers will be variations of discrete components fashioned around a set of linear modules.

For example, the Plessey SL600 series of linear integrated circuits make possible receivers using SL610 r.f. amplifier; SL641 diode-ring frequency changer; block crystal filter; untuned SL612 i.f. amplifier; SL641 product detector; SL621 a.g.c. system and SL630 a.f. amplifier. By utilising such combinations a great deal of the detail design work is eliminated. Indeed, this factor could well encourage, in the coming decade, more home-construction of high-performance receivers, meeting individual requirements with a minimum of design problems.

Abridged specifications of some 50 communications receivers are given on pages 305-310.

Transistor Tester

A simple instrument which measures beta and leakage, and indicates how faulty transistors have failed

by D. E. O'N. Waddington, M.I.E.R.E.*

The way in which a transistor failed is often important in the diagnosis of circuit faults. The simple tester described in this article indicates which junction has failed and in what fashion. Good transistors can be tested for leakage, and beta from 20 to 1000 can be measured. Additionally rectifiers and low-voltage zener diodes can be checked.

The range of transistor testers currently available is quite large and, as expected, they are all designed specifically to test for good transistors. Some of the more sophisticated testers, notably the curve tracer variety, are also capable of diagnosing what is wrong with a faulty transistor. This kind of information can be quite valuable and the tester to be described was designed with this in mind. However, it does test good transistors as well!

Beta test circuit

The tester is based on the emitter follower circuit of Fig. 1. The measurement of beta is made by adjusting the value of the base resistor RV_1 so that the meter reads 25% of full-scale deflection (f.s.d.). Under these conditions the circuit can be approximated by the equivalent circuit shown in Fig. 2 which can be analysed as follows:

$V_E = V_B/3$ (Condition set by adjusting RV_1)

$$V_E = V_B\frac{(\beta+1)R_2}{R_1+RV_1+R_2(\beta+1)}$$

$$3R_2(\beta+1) = R_1+RV_1+(\beta+1)R_2$$

$$3R_2(\beta+1)-R_2(\beta+1) = R_1+RV_1$$

$$\beta+1 = (R_1+RV_1)/2R_2$$

$$\beta = R_1/2R_2+RV_1/2R_2-1$$

$$(R_1 = 2R_2 \text{ or } R_1/2R_2 = 1)$$

$$\beta = RV_1/2R_2.$$

Thus, if a value of 500 Ω is chosen for R_2 and 1 kΩ for R_1 a linear variable resistor of 250 kΩ can be used to give a linear beta measurement range up to 250. If a higher beta range is needed, a higher value of variable resistor could be employed for RV_1. Alternatively, the method of use could be modified; instead of setting RV_1 so that the meter reads 25% of f.s.d. it is set so that the meter reads 50% of f.s.d. By an analysis similar to the one above it can be shown that under these conditions:

$$4 = (VR_1/2R_2)+0{\cdot}75.$$

The effective measuring range is multiplied by a factor of four times. (The 0·75 in the equation is so small that it can be ignored.)

This method of measurement is obviously not precise as it ignores the effects of V_{EB} and r_E. In the practical circuit shown in Fig. 3, V_B is slightly increased to reduce the error caused by V_{EB}. The inaccuracy of measurement using this modification is of the order of ±5% although it could be reduced if the tester were designed to test only silicon transistors or only germanium transistors. Another source of error is I_{CBO} flowing through RV_1 and causing an apparent change in the value of V_B. With silicon transistors this error will be negligible but with germanium devices the error can become quite appreciable.

The measurement conditions have been chosen so that they are suitable for most small-signal transistors. The supply voltage is 9 V. On the normal beta range (meter set to 25% of f.s.d.) the voltage drop across the transistor under test is 6·75 V and the current through it 4·5 mA. With the ×4 range, the voltage falls to 4·5 V and the current rises to 9 mA. This change in operating conditions will probably cause the beta readings on the "normal" and "×4" ranges to disagree slightly. However, for most practical purposes, this is not important.

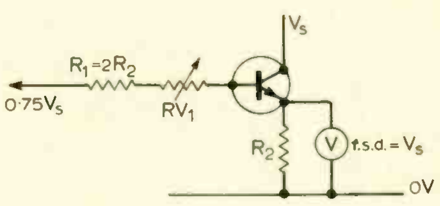


Fig. 1. The basic measuring circuit.

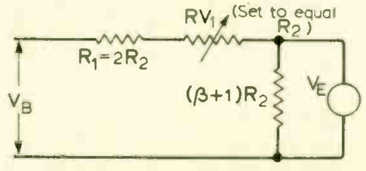


Fig. 2. Simplified equivalent circuit.

Leakage current

I_{CEO} is measured in the conventional manner with the base of the transistor disconnected. In order to simplify the construction of the tester, the basic leakage range is the same as that for the beta measurement—18 mA. Germanium transistors will usually show some leakage on this range but only a very bad silicon transistor will give any reading. For lower-leakage measurements, a push-button switch, S_2, is used to disconnect the meter shunt giving a full-scale deflection of 50 μA.

Constructional details

The circuit of the tester is so simple that very few precautions are necessary. However, one or two details may help. The battery used is an Ever Ready type PP9 which has a comparatively stable output voltage and a good shelf life. In practice the life of the battery in the tester is essentially the same as its shelf life. To ensure this is so, the on/off switch should be of the biased type—it is too easy to leave an ordinary toggle switch on.

High-frequency transistors sometimes oscillate when connected as emitter-followers. To reduce this possibility, slip a ferrite bead over each lead to the transistor test terminals as close as possible to the terminals. Better still, slip the beads over the transistor leads if oscillation is suspected. It is usually possible to detect whether a transistor is oscillating in the tester as touching the transistor will cause the meter reading to change. The only consolation is that an oscillating transistor must have a beta even if it cannot be measured!

RV_1 has to be calibrated. The best way to do this is to measure its resistance and divide by 1000 ($2R_4$: Fig. 3). The controls are self explanatory but do not forget to set S_3 to "Calibrate" and adjust RV_2 for f.s.d. before starting tests.

Transistor faults

With the "Function Switch" S_1 set to the "Test" position, a good transistor (i.e. one with a beta of 20 or more) will give a reading

* Marconi Instruments Ltd.

of approximately 75% of f.s.d. The exact reading will depend upon the beta of the transistor and whether it is made of silicon or germanium. (The base-emitter voltage of a silicon transistor is approximately 0·6 V while that for germanium is approximately 0·2 V). Specific fault conditions will be indicated as follows:

Collector-emitter short-circuit: The meter will read full scale.

Collector-base short-circuit: The meter will read f.s.d. less the base-emitter voltage of the transistor.

Collector open circuit: The meter will read fractionally less than 25% of f.s.d. This is because the emitter-base junction of the transistor acts as a forward-biased diode so that current from the junction of R_1 and R_2 can flow through R_3 and R_4.

Base-emitter short-circuit: The meter will read 25% of full-scale. To positively distinguish this fault from a collector open circuit reverse the n-p-n/p-n-p switch S_4. If the fault is an open-circuit collector the meter reading will fall to near zero, the actual reading depending upon the zener break-down voltage of the base-emitter junction. But if the fault is a base-emitter short-circuit, the meter reading will be substantially unchanged.

Emitter open circuit: The meter will read zero; even if the n-p-n/p-n-p switch is reversed.

Occasionally faulty transistors will cause the meter to give completely unpredictable readings. When this happens it is not at all easy to identify the fault although it is sometimes possible to find out what is wrong. For example, it is not unknown for p-n-p transistors to be marked with an n-p-n type number! When this occurs, the tester will give a reading which is proportional to the reverse emitter-base breakdown voltage of the transistor.

Base open circuit: The meter will read zero (leakage current I_{CEO}). This fault can sometimes be identified by reversing the n-p-n/p-n-p switch S_4. The meter will give a reading depending on the zener break-down voltage of the base-emitter junction in series with the forward-biased collector-base junction.

Zener diode testing

The tester can be used for making rough measurements on zener diodes with voltages of up to 8·9 V. For this purpose the meter is calibrated linearly from 9 to 0 V with the 9 V point at zero deflection and 0 V at f.s.d. (See Fig. 4.) The anode of the diode to be tested is connected to the "collector" terminal and the cathode is connected to the emitter terminal of the tester. With S_4 set to p-n-p the zener voltage can be read directly from the meter scale. This type of test can also be applied to diodes to check whether they are working and to identify silicon diodes from germanium. The main differences are that silicon diodes generally show a greater forward voltage drop (0·6 V approx.) than do germanium (0·2 V approx.) and that silicon diodes normally have negligible leakage current when reverse biased whereas the leakage of the germanium diodes is usually measurable. This is not true for microwave diodes which should not be tested on this instrument.

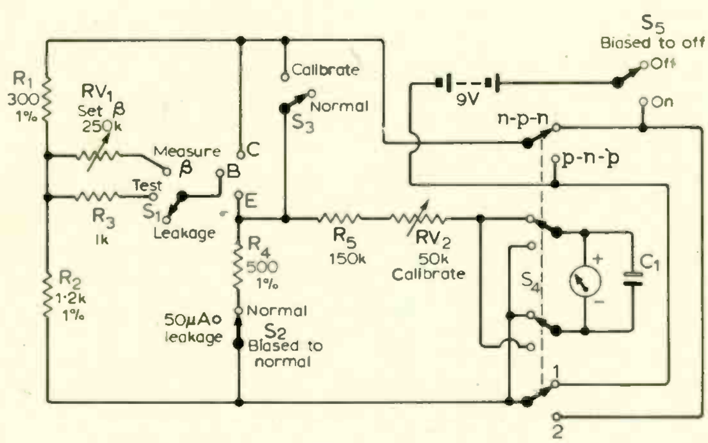


Fig. 3. Complete circuit diagram.

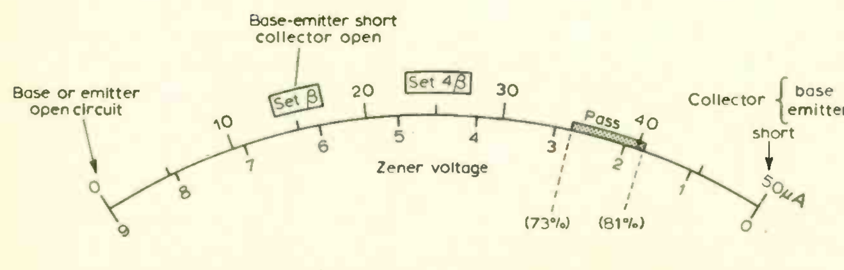


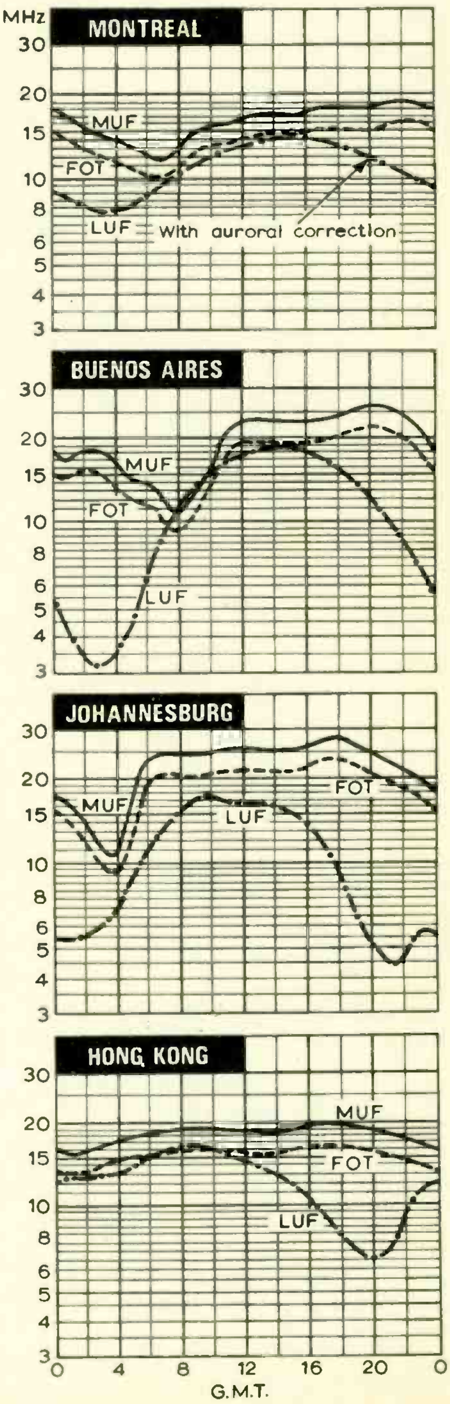
Fig. 4. The meter scale required.

H.F. Predictions—June

The prediction charts show median standard MUF, optimum traffic frequency (FOT is taken as 85% of MUF) and lowest usable frequency for reception in the U.K. Unlike MUF, the LUF is closely dependent on e.r.p., atmospheric noise and type of service. Those shown were drawn by Cable and Wireless Ltd for commercial telegraphy using several kilowatts of power with rhombic type aerials.

Predictions are based on an Ionospheric Index (IF2) of 94 and comparison with June 1969 (for which the measured IF2 was 119) shows that FOTs are lower and closer to LUFs. Without the auroral correction Montreal LUF would be about 3MHz lower.

Ionospheric and magnetic disturbances have been fairly frequent in recent months and can be expected to continue, without serious effects.



Ralph West reviews the

Low-cost Horn Speaker

Having long been an admirer of Voigt and his teaching, and a keen follower of subsequent work on horn loading and allied techniques, it was with great interest that I read the recent articles by Klipsch, Harwood, and "Toneburst" (February, April and May issues of *Wireless World).* The big surprise came when I was invited to hear, criticize and write about the new baby*.

The first test was to connect up a tape machine and listen. First impressions with a *known* input signal give very valuable information, not the whole story, but little subtle clues to peculiarities and shortcomings that may not be sorted out and recognized until after hours and hours of investigation both objective and subjective. This first burst of reproduced sound catches the ear in its most sensitive state as regards artificiality or unreality.

The first impression was good, surprisingly good when one considered the low cost, simplicity and numerous compromises in design. The word that came to mind was 'wholesome' and this impression persisted throughout the session.

To digress for a moment, what do we expect of a loudspeaker? On the assumption that no loudspeaker can be perfect, all loudspeakers then have something wrong. Of all the possible wrong things, some worry our senses, and some do not worry them unduly, sometimes not at all. A little buzz or tizz from the loudspeaker cone would worry everybody. On the other hand, except when we are out in open country, we are *x* inches away from some reflecting surface or other. This upsets the frequency response, boosting some frequencies a little, and attenuating others a little, but our senses are not the least bit disturbed. If a loudspeaker does this (they all do!), then our senses should be equally happy. They are, if this is all that is wrong.

The recipe for a good loudspeaker then is a design that incorporates only those *wrong* things that do not worry our senses. It is on this basis that "Toneburst's" loudspeaker was judged.

The bass performance was checked both by listening and by measurement. Apart from the last few notes of the bottom (organ pedal) octave, nothing was missing. With the sound level meter close up to the speaker, and with a low-distortion audio generator as source, it was possible to take valid readings over the lower end of the spectrum. Down to about 100Hz, where the horn as such more or less stops working, the level remained within a range of about 6dB. Including the range down to 40Hz extended the meter needle excursions to a total range of 10-11dB. This is very good, as some of these dips and peaks are due more to the room than the speaker itself—as Harwood points out in his April article. Below 40Hz response fell off rapidly, but nevertheless at one or two points in the room there was useful output down to 35Hz, or below. In rooms of just the right size—length or diagonal about 18 feet—30Hz would probably be O.K., though one must listen at the right place, and this is *not* in the middle of the room!

I had heard the speaker for a short time before the back of it was closed in to form what Klipsch calls the compression chamber.

Below the cut-off frequency the horn no longer provides a nice meaty acoustic impedance for the cone to push against. The cone therefore moves much farther, in fact more or less as it would on an open baffle. It therefore starts pumping large amounts of almost out-of-phase sound from its rear. As the horn, fed from the front of the cone, is folded into a compact space and moreover opens up to the outside air very close to the rear of the cone, it amounts to a pretty complete acoustic short circuit. Hence the original dramatic fall off below about 100Hz. (The reported earlier 40Hz performance is as yet unexplained.) Boxing up the rear of the cone of course stops this cancellation but one has to be careful to use the correct volume. In this range the speaker 'deteriorates' to an infinite baffle type. 'Deteriorates' is in quotes, because though this is a perfectly satisfactory system it has a much lower efficiency. In this range, transient response will be inferior, but fortunately this is of little consequence as most sounds in this range start and stop gradually any way! In other words, the necessary compromise in the design at the very bottom of the frequency scale, causes negligible degradation. A *little* bit of bass lift can be used—say not more than + 1 on most pre-amplifiers.

The only detectable slight colouration was in the 150-200Hz region. This was not serious, adding a little extra warmth to the sound. Whether it was due to speaker design or the room was not ascertained and not worth doing. Corner mounting of *any* sound source always throws up a few irregularities. Though I would thus agree with Harwood, in general I would agree with Klipsch. Corner mounting always improves bass in quantity, and in quality too, as the speaker is enjoying better acoustic loading. If there is a honk—the troublesome frequency usually lies somewhere between 140Hz and 200Hz—then it can easily be attenuated and effectively lost by a suitably damped tuned circuit in series with the speaker.

At the top end, the performance was equally dramatic. It is amazing how horn loading 'cleans up' a response and makes a reasonable but by no means outstanding drive unit into a first-class performer. The sound was more like that from some of the recent electrostatic arrays on the score of smoothness. This was confirmed again with the sound level meter, close to the horn mouth. Above the frequency where the drive speaker diameter (horn throat strictly) is about a wavelength (3-4kHz) horn loading is again lost and efficiency falls to something nearer its 'open air' performance. Not enough to upset balance, but making the use of slight top boost worthwhile. This Eagle unit is smooth enough to take this without any need to worry about crossing over to a third super tweeter unit.

Most of the listening was done with 15-in and 7½-in master tape recordings plus a few superb copies dubbed by Terry Long. These covered a fairly wide variety of material, all in stereo of course.

One very revealing test (learned from Joseph Enoch) is to sit with one's back towards the speakers. If it sounds and *feels* like an orchestra, or choir, etc. behind one, there is not much wrong. "Toneburst's" speakers produced a most realistic sensation.

Another very valuable clue comes from the incidental background noises in between items—people turning over pages, moving in their seats etc. The pages were obviously made of paper, not tinfoil!

Applause too shows up resonances and any large frequency irregularities. The audience rarely wears protective gloves, leather or tinplate covered, during a concert and with this speaker they were heard to be properly dressed!

Another telling observation was the fact that one was never conscious of the loudspeakers themselves. One's whole attention was always drawn to 'between and beyond', where it should be.

This design shows that for a modest outlay (£34, plus a little hard work, for a stereo pair) it is possible to produce results truly comparable with those obtained from first grade commercial designs, provided the essential requirements are met. There is no doubt that horn loading really does do something nothing else quite manages to do.

*"Low-cost Horn Loudspeaker System", by Toneburst", *Wireless World*, May 1970.

News of the Month

obvious that it is a wonder nobody has tried it before; it employs standard semiconductor production machinery and materials that may be found in any basic chemistry laboratory. Cost of the interconnect patterns is less than £10 per square foot.

The technique may be used in place of wire bonding to connect a monolithic integrated circuit chip to its package connections or it may be used to form sub-systems by interconnecting many chips on a single substrate. Single side or multi-layer interconnection patterns can be formed.

Emley Moor aerial contract

The Independent Television Authority has placed orders worth approximately £120,000 with E.M.I. for the u.h.f. and v.h.f. aerials for the new tower at Emley Moor, Yorkshire. The contracts cover the supply of two u.h.f. aerials (for I.T.A. and B.B.C. services) and a v.h.f. aerial for the I.T.A. service. The u.h.f. aerial panels and the full-wave v.h.f. dipoles will be mounted on a 180-ft triangular supporting lattice. The lattice will be erected on a self-supporting concrete tower 900-ft high, 80-ft in diameter at its base, tapering to 20-ft at the top. E.M.I. collaborated in the design of the lattice aerial support structure with Ove Arup and Partners, consulting engineers who were responsible for the construction of the tower (*Wireless World*, Aug. 1969, p.358).

The two two-channel u.h.f. aerials on the top 50-ft sections will each radiate 800 kW per programme. The upper is for BBC-1 and BBC-2 colour services, the lower for the I.T.A. colour service, with provision for an additional colour service later. The I.T.A. v.h.f. aerial below these is designed to give a directional pattern specified to match the coverage of the original Emley Moor aerial. It occupies a 40-ft length of the lattice. The remaining 40-ft section is left free for the addition of another system later.

Shrouding cylinders of glass-reinforced plastic will enclose the structure but will allow access in all weathers. A replica of a section of the 180-ft supporting lattice has been erected by E.M.I. at Hayes and performance testing of the aerials has begun. Erection of the system at Emley Moor is due to start in August this year.

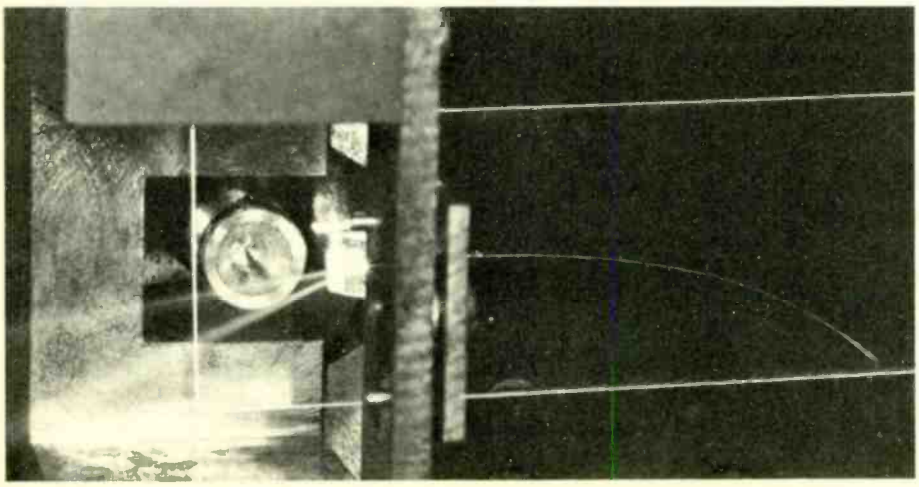
Printed through circuits

Logic Designs Ltd, of Ringwood, Hampshire, have invented a new method of interconnecting integrated circuit chips which provides an alternative to the beam-lead process. The company are being very guarded at the moment although they have provided just enough information to whet the appetite. The reason for this is understandable; they are waiting for their patent application to be processed.

In essence an interconnection pattern is printed on a dielectric. The conductors "can be persuaded to come through to the other side of the dielectric at any desired point". One drawing shows the conductors in the centre of a dielectric sheet with connection pads on both sides of the sheet.

Logic Designs say that the process is so

Bending a laser beam using a lightguide formed by depositing a crystal film on a glass sheet at Bell Telephone Laboratories in America. Such techniques may be used in the future to form light circuits to carry out computing and communication functions



British weather experiment in space succeeds

A British meteorological experiment is now circling the earth on the American Nimbus-D weather satellite, sending back continuous temperature information to help improve the accuracy of weather forecasts. Developed and built by GEC-Elliott Space and Weapon Systems (at Frimley, Berks) for scientists at the Universities of Oxford and Reading under a grant from the Science Research Council, it is the first British experiment to be included in an American Nimbus project.

The experiment is designed to measure the temperature at six different levels in the earth's atmosphere, by observation of the infra-red radiation emitted from atmospheric carbon dioxide. The frequency of this radiation changes for different altitudes, and the temperature at various levels of the atmosphere can therefore be derived by radiation measurements over this range of frequencies.

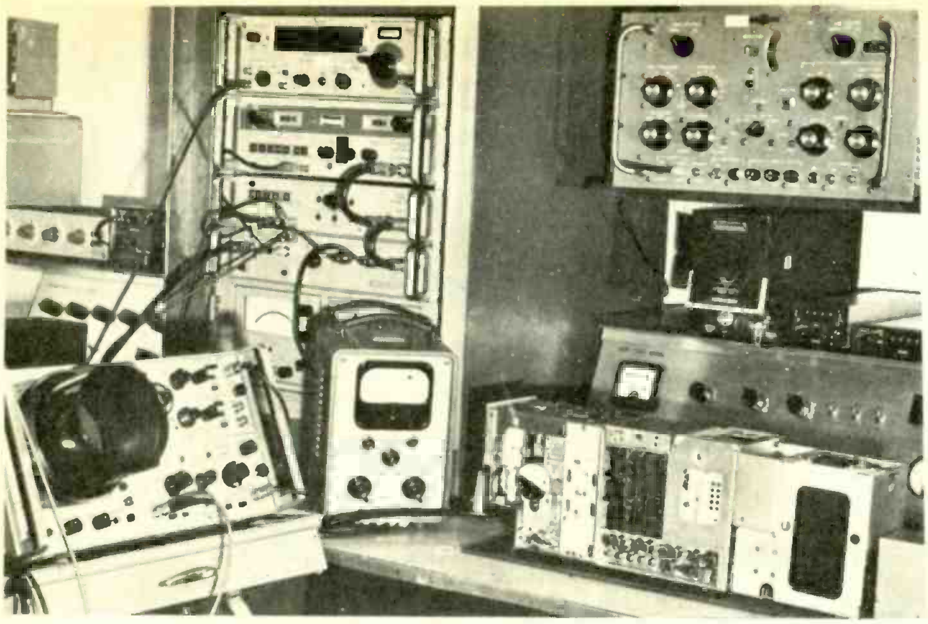
A very sensitive selective chopper radiometer is used, which detects tiny amounts of radiation over six very narrow frequency bands, and amplifies them, using a 'chopper' technique, to provide a measurable signal. The wavelength of the radiation is in the region of 15 microns, and temperatures are measured at altitudes of up to 50 kilometres.

Antigua station closing

The National Aeronautics and Space Administration of America has notified the governments of the U.K. and Antigua of its decision to close its tracking station in Antigua as the station is no longer required for support of the N.A.S.A. manned space flight programme.

Established under an international agreement signed in 1967, the station has been operated by N.A.S.A's Goddard Space Flight Center as a unit of the Manned Space Flight Network. The station includes an S-band radar and a 30-foot dish aerial.

Since it became operational the station has played a major role in tracking



A corner of a new avionic equipment service department recently opened by L. C. Hunting, vice-chairman of the Hunting Group, at London airport. The new department is owned by Fieldtech Ltd and is primarily intended to support the company's marketing activities although it will also be employed to service other equipment

functions for all Apollo flights up to Apollo 11. Following that event N.A.S.A. reduced tracking requirements for the Apollo Programme and the Antigua station reverted to a standby role. The agency has since determined that the station will no longer be required.

At peak operation, the Antigua tracking statio had a complement of 92 persons. Equipment from the site will be employed elsewhere.

Award for p.c.m. inventor

The International Telephone and Telegraph Corporation has awarded Alec Reeves, of Standard Telecommunication Laboratories (a subsidiary of I.T.T.) $ 5000 and a trophy for his invention of pulse code modulation.

The award—"In recognition of his contribution to the progress of telecommunication technology through the concept and development of pulse code modulation"—is the third given to Mr. Reeves in recent months. In 1969, not only was he made a Commander of the Order of the British Empire but also the Post Office honoured his invention with a special postage stamp and first-day cover.

B.B.C. local radio

Twelve new B.B.C. local radio stations are due to open in 1970. Their locations and operating frequencies (in MHz), are as follows: Birmingham (95.6), Blackburn (96.4), Bristol (95.4), Derby (96.5), Humberside (95.3), London (95.3), Manchester (95.1), Medway (97), Newcastle (95.4), Oxford (95), Solent (96.1) and Teesside (96.6). It is planned to provide reinforcement for the service on medium waves. The frequencies given are subject to approval by the Minister of Posts and Telecommunications.

Binocular head-up display

Elliott Flight Automation has delivered to the Royal Aircraft Establishment, Farnborough, a binocular head-up display which is at present being tested in a ground-based simulator prior to flight trials in a Comet, scheduled to start later this year.

The binocular head-up display projects two identical groups of symbols from two parallel cathode-ray tubes onto a wide, shallow reflector placed close to the pilot's eyes. The two groups are aligned so that they appear to the pilot as a single image. Main advantages of the system are that it provides a wider field of view than monocular systems and that it does not take up a great deal of space in the cockpit coaming.

Use of two cathode-ray tubes and lens systems makes possible a dual, fail-operative head-up display which is a necessity where the system is an integral part of, say, an automatic landing system. Should one tube fail, the full symbol pattern remains visible and brightness is hardly reduced. Only the field of view is reduced.

Bright future for electro/optics

By 1980 it is expected that 70% of Mullard's component output will be in optical and microwave devices. As early as 1975 44% of electronic devices will be totally new, not yet having seen the light of day. These predictions were given last month by B. R. Overton, plant director of Mullard Mitcham, when the technical press were invited to a preview of a number of new developments taking place at the Mitcham works. One of the new optical devices was an image intensifier being developed for military purposes but which is now off the secret list. Simply, it is a passive see-in-the-dark device which requires no more than starlight illumination of the object to be viewed. The image is seen by the observer on a small (25mm) screen. Using a wide diameter objective lens, the image intensifier collects as much reflected light as possible from the object under observation. Collected light is then focussed on to a photoemissive surface which converts the energy into electron emission. Emitted electrons are accelerated by a high voltage and are directed on

Mullard image intensifiers being assembled with a voltage multiplier unit

to a phosphor screen where they produce a larger light output than was received at the photocathode. The light intensity is further increased by adding two succeeding stages of amplification. All three stages are built into a single compact unit.

Colour receiver production

When presenting the annual report of the British Radio Equipment Manufacturers' Association to members, the president (Lord Thorneycroft) commented on the slow rate of production of colour television receivers in the U.K. in comparison with other European countries. For example, Germany, which started a colour service at approximately the same time as we did, is currently producing over a million sets a year—three times our own rate. Incidentally, Japan is said to be producing over six million a year. Lord Thorneycroft went on to remind manufacturers that they must "take advantage of the opportunities that entry into the European Common Market will afford whilst being fully aware of the growth of competition which will exist".

Referring to the home front the president spoke of the question of the timing and organization of exhibitions. It is almost certain that next year there will be a combined trade show in May.

Colour television deliveries still up

U.K. colour television deliveries for the first quarter of 1970 show no sign of any slackening in demand, according to the Economic and Statistical Division of the British Radio Equipment Manufacturers' Association. 84,000 colour sets were delivered in the first three months, a record 30,000 of these during March.

Monochrome television deliveries recovered slightly but continued the downward trend recorded in the latter half of 1969; 410,000 sets were delivered in the first three months compared with 416,000 in the same period of 1969.

The decline in deliveries of U.K. manufactured radio receivers, car radios and radiograms is continuing. Deliveries of 153,000 radio sets for the first quarter (161,000 in 1969) were down 5%; car radios showed a fall of 13%—75,000 in 1970 against 86,000 in the first three months of 1969; and radiogram deliveries of 41,000 up to March compared with 44,000 in 1969, a drop of 7%.

Telecommunication films

The International Telecommunication Union (I.T.U.), has a library of about 100 films available for loan. Some of these films were provided by the administrations of member countries and some were provided by telecommunication companies.

Two of the films from the catalogue (which is available) are devoted to the I.T.U. The first (ONU-4) was made in 1965 on the occasion of the union's centenary and is called "The International Telecommunication Union". It lasts 20 minutes and is available with a commentary in English, French, Spanish, Arabic or German. A copy of the film can be obtained on loan, or bought for $ 25 for non-commercial showings.

The second film (ONU-3), also made in 1965, is called "In Signal Honour" and it commemorates the development of telecommunications over the past 100 years. It lasts for 30 minutes and can be obtained on loan, or bought for $ 40.

Enquiries should be addressed to the United Nations Office of Public Information, Radio and Visual Services Division, Place des Nations, 1211 Geneva 20.

Avionic conference

For the second time meetings of the U.S. Airlines Electronic Engineering Committee are to be held in Europe concurrently with meetings of the European Airlines Electronic Committee. The venue is the Royal Garden Hotel, London, in November. The first European meetings of the A.E.E.C. were held in Brussels in October 1964.

The meetings will be arranged as follows: Airlines Electronic Engineering Committee General Session, November 4th-6th; European Airlines Electronics Meeting, 9th-11th. Readers interested in attending the meetings should contact D. M. O'Hanlon, Manager Avionics Design and Development Branch, Engineering Head Office, British European Airways, London Airport, Hounslow.

EXPO '70 with I.C.E.

Our sister journal, *Instrument and Control Engineering*, has arranged a visit to EXPO '70 in Japan departing June 13th and arriving back June 25th which will cost £446 10s. per person. This sum covers the cost of bed and breakfast in first class hotels, travel by air, two days at EXPO'70, sightseeing and excursions, the services of an English-speaking guide and a full range of technical visits. Interested readers should write to the editor, *Instrument and Control Engineering*, Dorset House, Stamford Street, London S.E.1.

Announcements

A three-day residential conference on industrial microwave and laser applications and instrumentation is being organized by our associate journal *Design Electronics*, in association with Sheffield University. The conference will be held from 22nd to 24th September at Ranmoor House, Sheffield University. Further details are available from R. A. Ganderton, *Design Electronics*, Room 121, Dorset House, Stamford Street, London S.E.1.

A **vacation school,** organized by the I.E.E., on radio-frequency electrical measurement practice will be held at The University of Kent, Canterbury, from September 6th to 18th. Further details from the secretary, LS(SE), I.E.E., Savoy Place, London WC2R OBL.

Bell & Howell has set up an Audio Products Division to market hi-fi equipment. They began by introducing at the recent Sonex 70 exhibition the range of products manufactured by **Acoustic Research Inc.**, of Cambridge, Massachusetts, U.S.A.

John E. Dallas & Sons are buying electrical equipment from **Hitachi**, of Japan, for sale in the U.K. Much of the equipment will be marketed under the **Elizabethan** label.

The Philco-Ford range of **solid-state microwave** products is now being handled in the U.K. by the Microwave Division of Auriema Ltd.

The Advance Filmcap division of Advance Electronics Ltd has signed an agreement with Societe Seco-Novea et Cie, the French **electrolytic capacitor manufacturers** allowing Advance to manufacture capacitors under licence at their plant in North Wales.

J. H. Associates Ltd, 1 Church Street, Bishop's Stortford, Herts, have been appointed U.K. agents for the range of **relays and components** manufactured by Alois Zettler GmbH, of Munich, W. Germany.

FieldTech Ltd, has been appointed exclusive U.K. distributor for the range of **high-frequency aerials** manufactured by Technology for Communications International (TCI), of California, U.S.A.

Techmation Ltd, 58 Edgware Way, Edgware, Middlesex, have been appointed sole distributors in the U.K. and Eire for **Fabri-Tek Instruments Inc**, of Wisconsin, U.S.A., manufacturers of modular digital signal averaging computers.

Ceta Electronics Ltd, 312 Bournemouth Road, Parkstone, Dorset, have been appointed exclusive U.K. agents for **TeleSciences Inc.**, and their subsidiary, Pulse Monitors Inc. American manufacturers of test equipment.

The Plessey Company has announced that the name of its subsidiary, **Plessey B T R Ltd**, has been changed to Plessey Telecommunications Research Ltd.

The Marine Division of **Dymar Electronics Ltd**, of Watford, has received an order worth over $260,000 from the Kelvin Hughes Division, Smiths Industries Inc., Maryland, U.S.A. The order is for the model 822 f.m. v.h.f. marine radio-telephone.

Labgear Ltd, has received two contracts, valued at £250,000, from the Nigerian Government for the supply of 400 single-sideband **man-pack radio telephones**. The company has also received a £160,000 contract from the Iraq Government for 250 s.s.b. radiocommunications pack-sets for use by the Iraq mobile police force.

Pye Telecommunications Ltd has received an order from the Government of Jamaica, worth £75,000, for the supply of **radiotelephone equipment** for use with the Jamaican police force.

Aircraft Supplies Ltd, of Bournemouth, have received an order to supply their **digital flight data recorder** for Air Canada's Boeing 747 jumbo jet fleet and Lockheed 1011 Tristar aircraft.

The Electronics & Instruments Group of Bell & Howell Ltd, Basingstoke, have been appointed exclusive U.K. agents for the range of high output piezo-resistive transducer elements and pressure **transducers manufactured by A. S. Akers Electronics**, of Horten, Norway.

Electrotech Instruments, the instrument division of Coutant Electronics, have moved to new premises at 7 Trafford Road, Reading, Berks. (Tel: Reading 582677).

Celdis Ltd has moved from Milford Road to 37-39 Loverock Road, Reading, RG3 1ED. (Tel: Reading 582211).

Letters to the Editor

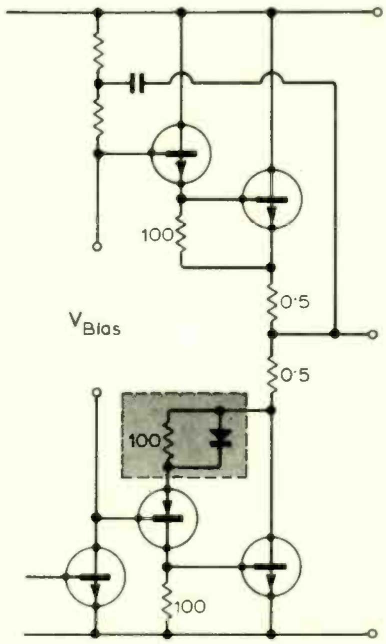
The Editor does not necessarily endorse opinions expressed by his correspondents

Some improvements in class B

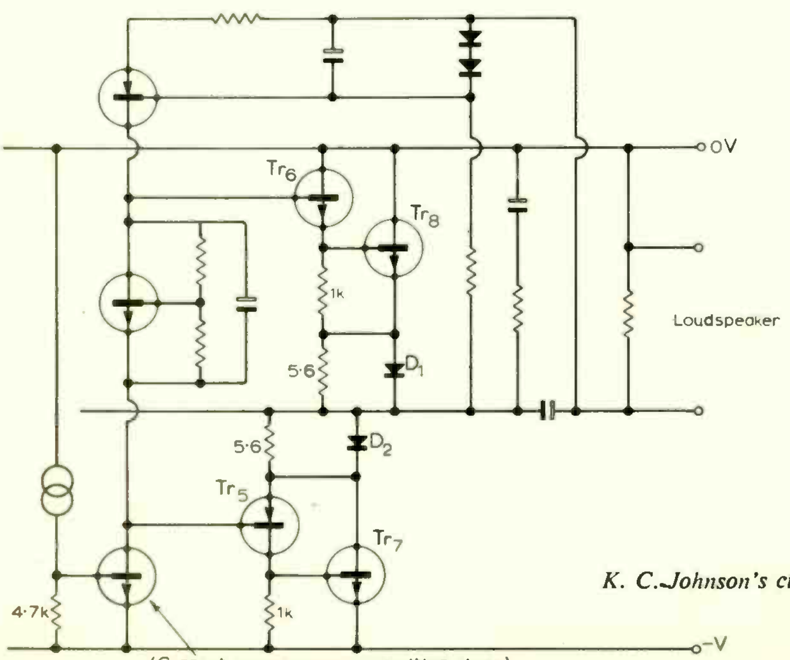
After reading Mr. Johnson's useful article in the April issue, describing his improvements to the basic Lin circuit, his omission of a neat modification surprises me. My interest was aroused after comparing para. 2 col. 1 page 160 with para. 2 col. 2 p.161 of his article.

In the former he defends the use of diodes D_1 and D_2 by stating that the signal to Tr_5 and Tr_6 is a current and that voltages are relatively unimportant: whereas the latter contains an analysis of the resistance levels in these stages which shows that the "current source" sees a resistance roughly equal to its own source resistance! I think that I have interpreted Mr. Johnson's figures correctly because he allows for a loss in gain of 0.55 to 0.45 at this point. If this is the case then we have a generator with non-linear internal resistance feeding driver stages with comparable, non-linear, input resistances. This is hardly a desirable situation for "current drive".

In view of this I would like to refer to a letter from Mr. Baxandall,[1] in which he suggests that the current drive transistor could be profitably replaced by a pair if a higher output resistance were sought and this modification I respectfully suggest might be useful in Mr. Johnson's circuit. This would result in two extra transistors being needed.



P. J. Baxandall's improved Lin circuit.



K. C. Johnson's circuit.

Mr. Baxandall's letter is also the source of another refinement. The diode-dodge, which is the main topic of his letter, may not bring such a pronounced improvement to K. C. Johnson's circuit (due to the different quiescent driver-currents in the different circuits Mr. Johnson's power transistors cut out at much lower signal levels) but it may be worth trying—particularly since the components are so few.

In conclusion I would like to thank Mr Johnson for his interesting account and apologize for so pedantically analysing the article. Unfortunately, I have been unable to build the circuit (and discover that all my fears are groundless) but Dr. A. R. Bailey[2] (who noted Early-effect distortion and some allied problems in 1968) does not use an enhanced common-emitter stage and so I can only conclude that the extra expense is not warranted at higher quiescent currents.

M. J. HAMER,
Ullingswick,
Hereford.

[1] "Symmetry in a class B amplifier" P. J. Baxandall. Letter to the Editor, *W.W.* Sept. 1969, pp.416-417

[2] "30-Watt High Fidelity Amplifier" Dr. A. R. Bailey, *W.W.* May 1968, pp.94-98

The author replies:

Mr. Hamer's letter raises a very interesting point concerning the fundamental theory of transistor circuits. Are the devices to be thought of as current- or voltage-controlled? In his letter in last September's issue P. J. Baxandall says that he has felt for many years that the almost universal tendency to regard transistors as basically current-operated devices has exerted a major retarding influence on progress. On this point I agree with him entirely. Indeed I wrote an article in this journal almost twelve years ago[1] in which just this point was made quite specifically, and I have repeated it many times since. Why then am I now advocating a current-controlled approach to the design of audio amplifiers?

The answer is that neither way of thinking should be followed regardless in all circumstances. When the base of a transistor is fed from a low-impedance source, that is to say one that is thought of naturally as a voltage, then its action will in general be faster and the various circuit tolerances easier. For switching circuits this is advantageous and voltage-control is the best way to think in their design. If, on the other hand, the base is left at high impedance, so that it is natural to think in terms of current, then more gain will normally be available together with better linearity particularly if modern transistors are being used. It is hardly surprising that most low frequency amplifiers have been designed on this latter basis.

With modern diffused silicon transistors the cut-off frequency is so high that even with current-controlled operation the speed is still perfectly adequate to cover the a.f. range and also leave a margin sufficient

[1] "On Understanding Transistors" K. C. Johnson *W.W.* Sept.-Oct. 1958

for rolling-off a large factor of negative feedback. This feedback takes care of much of the tolerancing difficulty, but in any case it is quite customary to select the final transistors for gain and to adjust the cross-over current on test with amplifiers of this type. Thus in this audio amplifier circuit the disadvantages of current-controlled working are not serious, whilst the advantages in gain and linearity are considerable, so that there is a strong case for considering the design on this basis. Once this conclusion is accepted then all the essential features of my circuit follow almost automatically.

But the extra diode in the emitter of Tr_5, that both Mr. Baxandall and Mr. Hamer advocate, now appears merely as a source of extra unnecessary distortion. It is not needed in my circuit for the protection of the emitter junction of Tr_5 against surges of reverse voltage, and on the current-controlled theory it simply raises the input impedance of the final stages over just that part of the voltage swing where the output impedance of TR_2 is falling lower than we would like. Thus it seems to me that there is a positive advantage in leaving it out.

As regards the suggestion that extra transistors could usefully be added in such a way as to increase the effective output impedance of Tr_2, this is the very possibility that I envisaged in the last sentence of the section "choice of cross-over current" (p. 161). Such an addition would certainly give an improvement, making the distortion both smaller and more symmetrical, but I decided on balance that the level of distortion is already so low in comparison with other parts of the system that the extra complexity was not justified. I have not tried any such arrangement, therefore, but suspect that there might be difficulties due to extra time-constants being brought into the feedback loop.

K.C. JOHNSON.

Electronic dice

Prompted by Mr. Crank's invitation to readers in his article "An Electronic Dice" (*W.W.*, April 1970), I have found an improved circuit.

By slight alteration of two of the "classical" dice patterns (Fig. 1, where the new ones are, I feel, equally aesthetically acceptable) the number of outputs required is reduced to three, and the Johnson counter outputs may be used directly. This leads to a saving of one lamp driver and the NOR gate (Fig. 2).

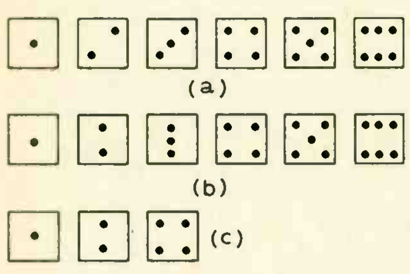


Fig. 1. (a) Classical dice patterns; (b) amended dice patterns; (c) the three patterns required to form (b).

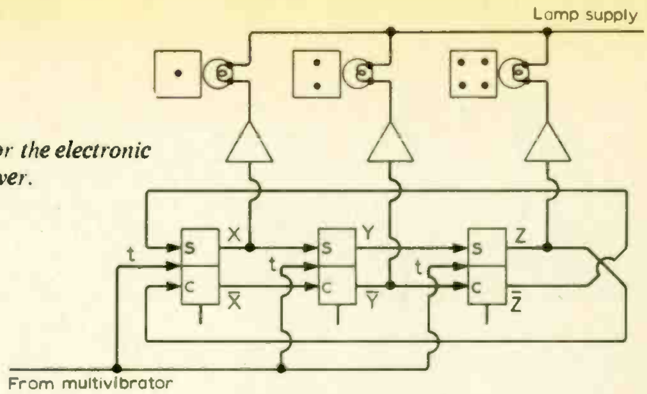


Fig. 2. Simplified circuit for the electronic dice suggested by S. E. Oliver.

Dice score	Patterns required	x	y	z
1	x	1	0	0
2	y	0	1	0
3	x y	1	1	0
4	z	0	0	1
5	x z	1	0	1
6	y z	0	1	1

(on/off patterns: x, y, z)

Rearranging and using the complement of y,

Dice score	x	$\bar{y}$	z
2	0	0	0
3	1	0	0
1	1	1	0
5	1	1	1
4	0	1	1
6	0	0	1

S. E. OLIVER,
Newport,
Mon.

The author replies:

Mr. Oliver has produced a very elegant solution to the problem of designing an electronic dice using logic circuitry. While I set myself the task of producing a circuit which would display the classical dice patterns Mr. Oliver's alternative patterns are very acceptable and many readers will consider that the saving in components justifies the alteration.

In answer to those readers who have complained about my use of "dice" instead of "die" I plead common usage.

BRIAN CRANK.

Industry and research in universities

I would like to object to part of your editoral on "Technology versus Education" in the April issue. In this article you stated "At Warwick itself, for example, the School of Engineering Science does research in microwave integrated circuits partly supported by G.E.C.-A.E.I. and Racal (and employees of these firms work in the School)". You must be referring to me when you mentioned support by Racal as I am the only person in the University who receives support from Racal*. I am working as a research student, on a Ph.D. thesis on "The Computer Aided Design of Microwave Circuits" and I have obtained a joint grant from the Science Research Council and Racal for an industrial studentship.

I think I should explain why I wished to obtain an industrial studentship. I joined the University about six months ago on a Science Research Council grant to study for a Ph.D. degree after working in industry for five years as a student apprentice and two years as a graduate engineer. I found that the move to University resulted in a huge drop in salary. I considered that, as well as obtaining a Ph.D. degree, I should be able to provide some useful knowledge to society through my thesis. Thus in this case I considered I was grossly underpaid. Also my final thesis may be lost in the archives of the University Library, or, if my work was finally published, it may be of no use as someone, possibly in industry, may have done the same work and made full use of it.

Thus I considered the only alternative was to obtain industrial support during my research work for a Ph.D. degree. The industrial studentship I now have gives me a higher salary, but still much less than I would be earning in industry, the security of a long-term job which will continue after I obtain my degree (*not at* the University) and I should be able to see my research work put to good use.

There are a few points which are essential with industrial support. These are that industry should not interfere too much with the research work, although I am always very pleased to accept advice and help from industry, and the research student should be able to publish any part of his research work. The amount each industry interferes with the work of the research student depends on the industry or on his particular managing director. At one extreme the research student may be left to do whatever research work he wishes and just told that he may take up a job in that industry when he leaves the University if he wishes to. At the other extreme the company may decide precisely what research work the student does at the University and may recall him back to industry to do some different work for them whenever they choose. Fortunately my industrial sponsor is much closer to the first extreme.

B. G. MARCHENT,
School of Engineering Science,
University of Warwick.

* We were told of the companies helping to support research but not the names of students involved. Incidentally, the disquiet expressed in our leader has been underlined in a book "Warwick University Ltd" (Penguin, 6s 0d) edited and written by people at that university. *ED.*

Crystal Oven and Frequency Standard

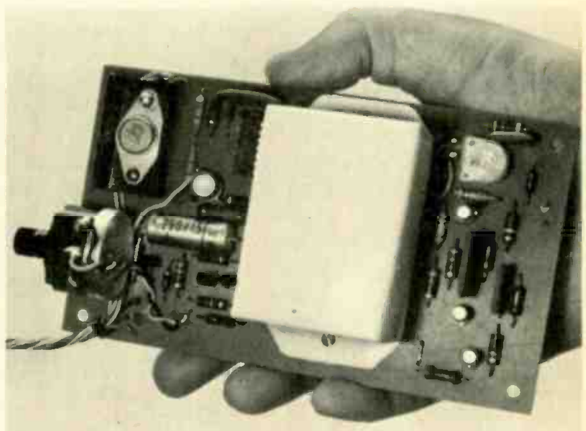
Easily built temperature-controlled oven, containing quartz crystal of 1-MHz reference oscillator

by L. Nelson-Jones, M.I.E.R.E.

The frequency standard described here was designed to provide a 1-MHz reference frequency for a digital counter-timer. It has automatic control of the crystal oven temperature, with a very simple circuit using an i.c. operational amplifier to provide the gain in the control system. The temperature sensor is a sealed thermistor. Full proportional control is provided, despite the simple circuit. The performance of the controller is of a high order for this type of circuit, as can be seen from the table.

In the design, emphasis has been kept on reliability and economy and on ease of manufacture of the crystal oven. This oven can be made using readily available parts, and needs only normal hand tools for assembly.

With a normal 1-MHz parallel resonant crystal an overall frequency stability performance of 0.008 part/million has been obtained, as against 1.1 parts/million for the uncontrolled crystal, for each degree centigrade change of ambient temperature.



Completed 1-MHz frequency standard on a single-side printed circuit board. The crystal oven is enclosed in the white metal case in the middle of the board. Components on the right are the oscillator while those on the left are the power supply regulator.

PERFORMANCE OF COMPLETE SYSTEM

Temperature coefficient of frequency of oscillator and oven controller	+ 8 parts in 10^9 per °C.
Effect of variations to the oven controller supply only, with constant supply to oscillator	too small to be measured (10-14V)
Effect of variation of 5V supply on oscillator frequency	+ 0.37 part in 10^6 per volt
Crystal ageing rate	−1 part in 10^6 per 1000h (after approx. 500h—from new)
N.B. The crystal ageing rate gradually reduces with age	
Setting accuracy	better than 1 part in 10^8 using trimmer specified
Warm-up time	12 minutes to within 1 part in 10^6
Short term stability	better than 5 parts in 10^8 total spread
Supply requirements	250mA at 12V to controller at switch-on, falling to 100mA av. during normal operation at 20°C. Approx. 7mA at 5V for oscillator

Temperature control systems

Bi-metallic thermostat. A bi-metallic thermostat with contacts in series with the oven heater is a common method of control. Such a system must always 'hunt' because it is an on-off system. The amplitude of the oven temperature oscillation can to some extent be controlled by careful attention to the structural design of the oven but, despite the simplicity of the system, the design of an oven is often difficult if high performance is needed.

Contact thermometers. Some of the shortcomings of the bi-metallic thermostat can be overcome by the use of a mercury-in-glass contact thermometer. This is a normal thermometer with wires sealed into the wall of the capillary so that a circuit is completed at the desired control temperature by the rising mercury thread.

A more complex system results, since the thermometer cannot be used directly to control the oven heater, first because it operates in the wrong sense (i.e. it closes at the operating temperature and above, and opens below the operating temperature) and secondly because the current carrying capacity of the mercury thread is very limited.

The contact thermometer is much more expensive than the simpler bi-metallic thermostat, but has a very much higher long term stability and reliability.

Change-of-state controllers. A control system which gives a much better performance, but still uses a simple on-off control of the heating current, is the Marconi change-of-state oven.

The oven uses the melting point of naphthalene as the temperature reference. The expansion that occurs when the naphthalene melts is used with a metallic bellows system to operate a microswitch, which in turn controls the heater current. Little or no hunting occurs with this system since, provided both liquid and solid states are present at one and the same time in the naphthalene, an increase or decrease in heat applied to the system can only change the ratio of liquid to solid content.

The one shortcoming of the system is that it can be made to operate only at one temperature, namely the melting point of naphthalene (approximately 80°C). Other substances can be used but do not all give the performance achieved by naphthalene.

Despite the excellent performance achieved, it was felt that the difficulties of construction were beyond the average experimenter unless he was unusually well equipped with specialized tools. There are, in addition, patent rights involved.

Resistance thermometers. Resistance thermometers can be used to obtain a very close control of temperature, and allow fully proportional control. Furthermore, it is possible to make the resistors forming the sensor to also act as the heater. This combining of heater and sensor eliminates one major cause of hunting, namely the delay in the heat reaching the sensor due to their separation. Some years ago the author was involved in the design of such a system which, with a double skin system, achieved a temperature control to within 0.001°C, over a wide range of external ambient temperature.

Semiconductor temperature sensors. The variations of the parameters of a semiconductor junction may be used to control temperature. Such a technique is used in certain integrated circuits to control the substrate temperature of a matched transistor pair (e.g. the SGS μA726).

The author has recently described the use of the variation of forward voltage drop in a diode to measure temperature[1], and this method can easily be extended to the control of temperature. It was felt, however, that the system was too complex for crystal oven control.

Thermistor sensors. Thermistors probably provide the most sensitive temperature sensor system for general use, and therefore can be used in relatively simple systems for the control of crystal ovens. Both negative and positive temperature coefficients are now available, and both may be used for the purpose. The positive coefficient thermistor has a sharp change of resistance, but only over a narrow range of temperature, so a different type of thermistor must be used for each temperature chosen. Most commonly available positive coefficient thermistors have a sharp change in the range 100° to 120°C, though some manufacturers produce types suitable for use down to about 50°C.

Because of the high temperatures at which most positive temperature coefficient thermistors operate satisfactorily, it was decided to use the more freely available negative temperature coefficient type of thermistor.

Temperature control circuit

Initially the work on the crystal oven was carried out using the control circuit of Fig. 1. This circuit uses the thermistor in a bridge circuit in order to eliminate the effects of supply voltage variations, at least to a first order. To reduce still further any effect due to supply variations the bridge was supplied from a 4.7-volt zener diode, which was also used to stabilize the supply to the crystal oscillator circuit. The relatively high current at which the zener diode was run, together with the high slope resistance of a 4.7-volt type, resulted in the stabilized supply being close to 5 volts.

The thermistor chosen is one with a resistance at 20°C of 1 MΩ, which falls to 150kΩ at approximately 60°C (the temperature chosen for the operation of the oven). The three fixed resistors making up the remainder of the bridge are therefore of 150kΩ each. No method of adjustment was included since the exact temperature at which the oven operates is not important, provided it is not too near the highest ambient temperature likely to be encountered in use. In addition too high a temperature would be likely to impair reliability. With the components specified the estimated spread of temperature with different samples of thermistor amounts to perhaps ±5°C, hence the decision not to use any adjustment in the bridge. Three samples tried by the author gave controlled temperatures of 57.6°, 59°, and 62°C.

The reason for the choice of a high value thermistor is that with a high ohmic value, the self heating of the thermistor bead with normal supply voltages is reduced to a negligible amount, again reducing the effect of supply voltage variations—a point which is important in the final circuit, where the bridge operates directly from a 12-volt line.

The operation of the Fig. 1 circuit is as follows. At switch-on the thermistor resistance is at around 1 MΩ and hence the base of Tr_2 is at a much lower potential than the base of Tr_1. The whole of the current in this long-tailed pair therefore passes through Tr_1, and as most of this current passes through the base-emitter junction of Tr_3, transistors Tr_3 and Tr_4 are switched full on, and the heater receives the full supply voltage, less only the bottoming voltage of Tr_4.

As the heater warms the oven, the thermistor's resistance drops until it equals that of the other resistors in the bridge. At this point the long-tailed pair is balanced with equal inputs to both bases, and close to this point the complementary Darlington pair Tr_3-Tr_4 ceases to be saturated, reducing the heater voltage. In practice, of course, the heater voltage adjusts itself so that the power input to the heater just equals the heat losses of the oven. The loop gain of this system is not high enough to make the system hunt when used with the oven structure described below, but is high enough to give quite a good performance.

To improve the performance it was decided to increase the loop gain of the circuit. This can be done by (a) increasing the voltage on the bridge and (b) increasing the voltage gain of the amplifier. The control system that resulted is shown in Fig. 2.

The bridge remains as before but the supply is now the full 12 volts. At first it might be thought that the use of the unregulated supply for the sensing bridge would make the controller very sensitive to supply variations, but this is not so, as the bridge operates very close to its balance point with the much increased loop gain. With the bridge at balance no variation occurs at its output whatever the energisation voltage, provided there is no appreciable self heating of the thermistor.

The mode of operation of the Fig. 2 circuit is very similar to that of Fig. 1. The bridge feeds the differential input of the operational amplifier IC_1 with a diode D_1 to prevent excessive inputs when the oven is switched on from cold, and by this means the input level of the operational amplifier is held close to half the supply voltage, the operating condition for which it was designed. Without the diode the operating point of the amplifier might be taken outside the differential range of the amplifier, particularly with respect to reverse bias of one of the input transistors.

The output of the operational amplifier feeds the transistor controlling the heater current, through a 1kΩ limiting resistor to protect the operational amplifier output stage, and through a zener diode to ensure that when the output of the operational amplifier is low the output transistor is cut off although the operational amplifier output may not reach the lower supply rail. The input of the operational amplifier, and the output transistor, both have capacitors connected to severely limit the frequency response of the loop, to prevent high frequency oscillation resulting from stray coupling between output and input, other than through the thermal coupling

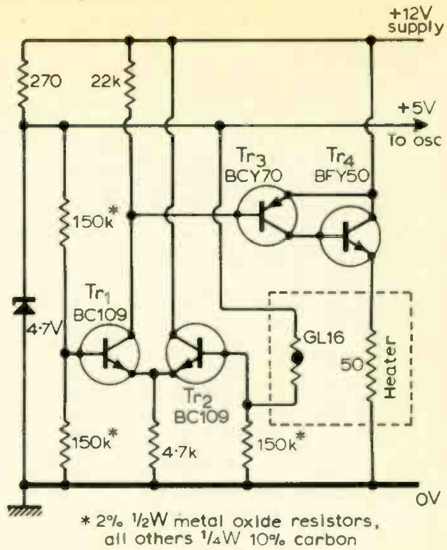


Fig. 1. Initial experimental temperature control circuit for the crystal oven.

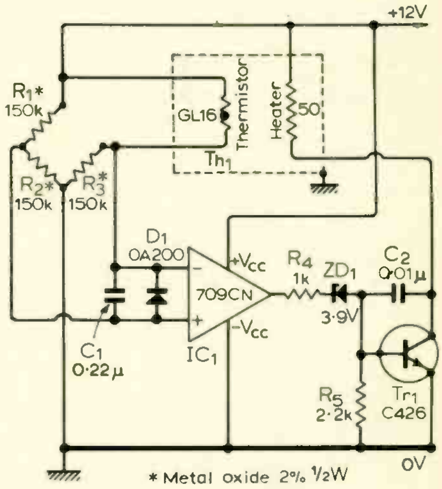


Fig. 2. Temperature control circuit actually used. Improved performance is obtained because of the higher loop gain.

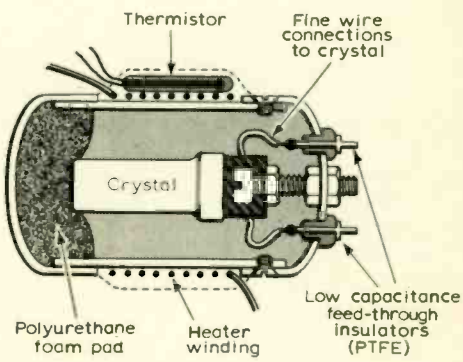


Fig. 3. Cross-sectional diagram of construction of the oven.

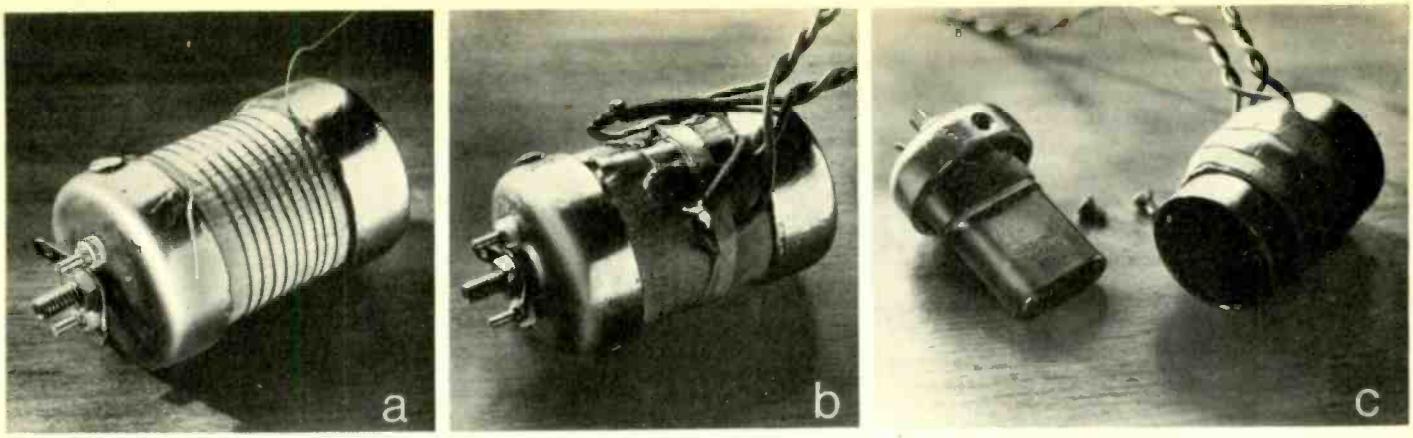


Fig. 4. (a) The oven with the heater winding in place over the insulating paper tape. (b) The heater and thermistor in place, with connecting wires attached. (c) Completed oven, opened to show the crystal in position in its socket.

between heater and thermistor. With this severe limitation of frequency response no screening of heater or thermistor leads is necessary, nor is a screen needed between the heater winding and the thermistor bead. The operational amplifier—type 709CN—needs no further frequency compensation when used in this way. The total voltage loop gain of this controller is approximately 3×10^4 as against some 3×10^3 for the Fig. 1 circuit. There is a further gain of just over 2 times due to the higher bridge energisation voltage in Fig. 2.

At the operating point of the thermistor its resistance changes approximately $-6 k\Omega$ for each degree centigrade, so that with the gains quoted the circuit controls the temperature very closely indeed to the required value, and the performance of the complete crystal oven system depends mainly on the oven construction rather than on the controller. The calculated change of temperature to switch the controller from full-off to full-on is, in fact, only approximately 0.0015°C.

It must by now have become clear to anyone with experience of this type of oven that, with such tight control, it would be almost impossible to avoid hunting, and indeed the system hunts violently, with the output transistor switching between saturation and cut-off.

The system is, however, completely satisfactory, since owing to the construction of the oven with the thermistor in direct contact with the heater, the frequency of the hunting is approximately 1 Hz and the amplitude of the temperature swing is only about 0.03°C peak-peak.

An immediate advantage of this switching mode of operation is a considerable improvement in the overall electrical efficiency, since almost all the power is now dissipated in the oven heater. There is an almost 2-times increase in efficiency over the circuit of Fig. 1.

In normal use the on-off periods of the circuit vary with the demands of the oven, so that at low ambient temperatures the 'off' period is short and the 'on' long, while at high ambient temperatures the 'off' period is long, and the 'on' short. The actual switching frequency does not vary a great deal with ambient temperature.

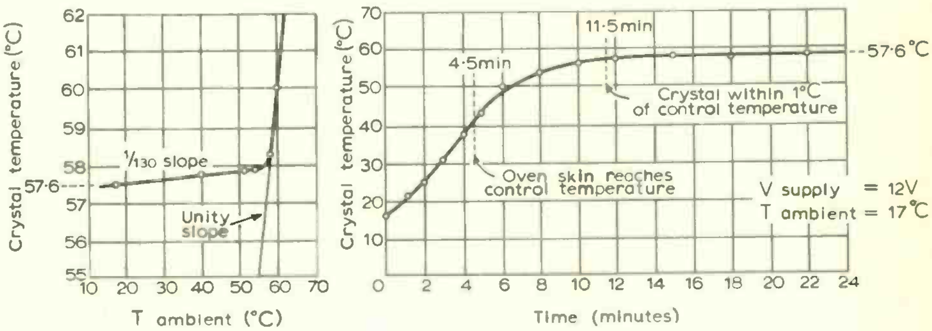


Fig. 5. Warm-up curves for the oven, obtained with a calibrated thermistor.

During the run-up from cold the switching does not, of course, take place—the heater being full on, until the bridge balance temperature is reached, when switching starts abruptly.

Crystal oven construction

Several models of the oven were built before a simple construction of good performance was arrived at. The following points became evident as the development proceeded:

(a) The thermistor must be in intimate contact with the heater element to ensure that the hunting frequency is high and hence the amplitude of the temperature oscillation is low.

(b) The crystal must be totally enclosed within the oven.

(c) The connections to the crystal or crystal socket must not provide a good thermal path to the outside world.

(d) The thermal mass of the oven must be great enough to ensure that all parts of the oven are at almost equal temperatures. The mass must not be too great or the warm-up will be too slow.

(e) The heater element must be in intimate contact with the walls of the oven to ensure that the thermistor, heater, and oven are all at the same temperature.

(f) To achieve the best performance, with minimum power consumption and fastest warm-up, the oven must be well lagged.

The most important aspects of the design are undoubtedly (a), (b), (c), and (e). Early models of the oven were simply

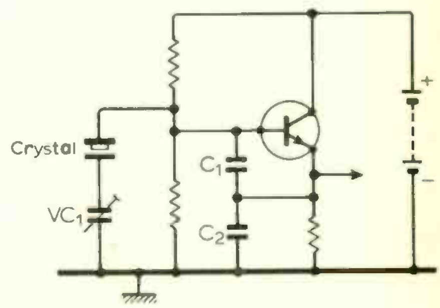


Fig. 6. Basic circuit of the oscillator.

tight fitting covers for the crystal with one end left open for the insertion of the crystal. It was soon found, however, that the heat losses through the pins of the crystal can, via the crystal socket, led to a variation of the heat loss of the system such that the crystal temperature changed at about 1/10th of the rate of ambient temperature change, despite a good control of the oven temperature.

The final model constructed is illustrated in Figs. 3, 4(a), 4(b), and 4(c). This oven has closed ends and the crystal and its holder are fully enclosed, with only fine wires leading from the crystal connecting pins to the feed-through insulators placed in the end wall of the oven, thus greatly increasing the thermal resistance between the crystal and the outside world. The result has been to increase the control factor of the oven from 10 to 130—the control factor being the ratio of change of crystal temperature to ambient temperature, with the oven inside its lagging.

The oven walls are entirely of copper, the body being made of ¾-inch i.d. water pipe. The end caps are formed from standard 'Yorkshire' fittings, made specifically to cap-off such pipes. The fittings are modified by shortening them to the dimensions shown. One of the end caps is sweated onto the body using normal soldering techniques. The other cap is secured to the body by two screws as shown. The author's model was finished by fully tinning all surfaces of the body. An earthing tag is fixed to the screw securing the crystal socket to the end cap.

The heating element is wound onto the tubular oven wall, over a layer of adhesive paper tape applied first for insulation. The winding is then varnished to secure the turns in place. The thermistor, which is a miniature glass encased type, is placed directly on top of this winding. It may be secured by any suitable adhesive, or another small piece of adhesive tape, and a further coat of varnish applied to lock the device in position. Next the leads of the thermistor are sleeved to avoid shorts to the oven body. The winding and thermistor are covered with a further layer of paper tape, and the ends of the heater winding and the thermistor leads are soldered to 7/.0076 twisted pairs of p.v.c. insulated wire, as shown in Fig. 4(b). The whole is then again covered with paper tape, and varnished.

The completed oven is shown in Fig. 4(c) with the end cap removed to show the mounting of the crystal and its socket.

The design should be easily adaptable to other forms of crystal such as those in B7G encapsulation, but the resistance of the heater winding should be inversely proportional to the surface area of the finished oven body. Such changes in turn may mean, with large ovens having low values of winding resistance, that a different output stage with greater current gain and current carrying capacity may be needed following the operational amplifier.

The wound heating element may be replaced with four or five ½-watt metal oxide resistors arranged round the tubular body of the oven, provided the thermistor is in close contact with one of the resistors and the body of the oven. The resistors must be evenly spaced and also in good contact with the oven body. Five such resistors of 10Ω value in series may be used. Suitable resistors are Radiospares '½ watt oxide', Electrosil TR.5, and Welwyn MR.5. The resistors and thermistor should be given several coats of varnish to ensure the best thermal contact, after they have been secured to the oven body with a narrow band of paper tape. Fuller details of the materials used in the construction of the oven are included in the appendix.

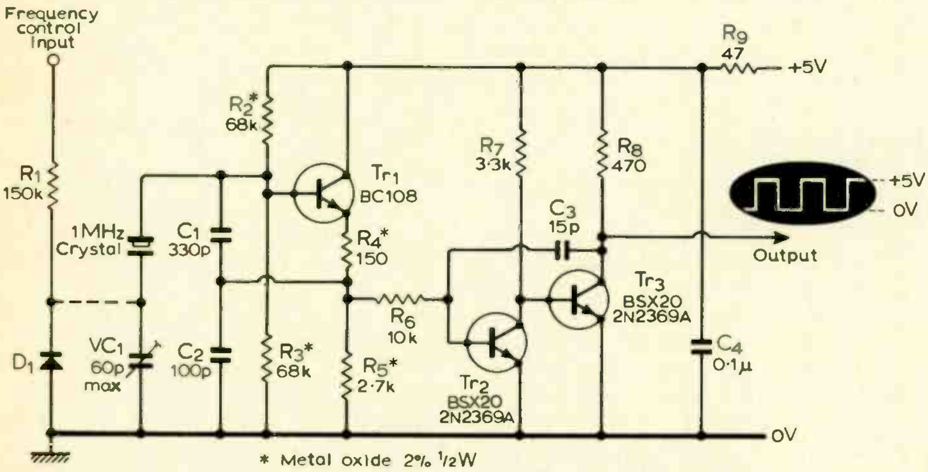


Fig. 7. Complete circuit of the 1MHz oscillator. The final two transistors form a shaping circuit to provide the required square-wave output.

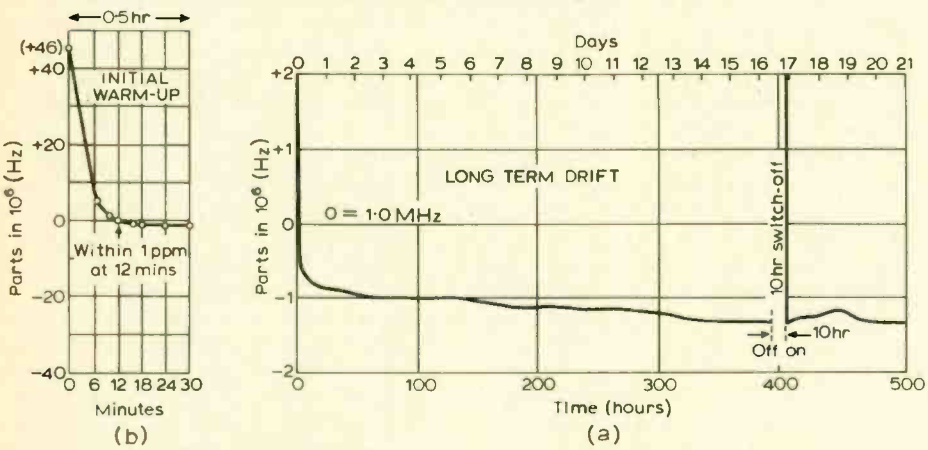


Fig. 8. Results of a 500-hour frequency drift test on the frequency standard (a), showing in detail the initial warm-up phase (b).

The 1MHz oscillator circuit

The basic oscillator circuit is shown in Fig. 6. It is a frequently used circuit for parallel resonant crystals but in its simplest form as shown is not sufficiently stable for the frequency standard of a digital counter-timer. The main problem is the temperature dependence of the transistor parameters, in particular the capacitance of the junctions.

One solution that has been used in a commercial instrument is to swamp the transistor capacitances with large values for C_1, and C_2. In that particular case C_1, and C_2, were each 470pF. This process cannot be taken too far, because of the reduction of the coupling between the crystal and the rest of the circuit.

The author's solution to the problem is to use lower values for C_1 (330pF) and C_2 (100 pF), and then to decrease the loop gain by emitter circuit degeneration. The value used is approximately half the resistance value at which the oscillator just starts, so that oscillation is assured under all circumstances. This method gives good results, and reduces the effects of all the major parameter changes in the active device, as well as those due to supply variations. It is essential in determining the value of this resistor that it should be done with VC_1 set at its minimum value (approximately 2pF with the type quoted in the appendix), since the coupling in the circuit is then at a minimum.

The complete circuit of the oscillator is shown in Fig. 7. The output of the oscillator is applied to a two-stage direct coupled shaping circuit. Positive feedback is applied, via a 15pF capacitor, to ensure sharp transitions at the pulse edges. The current level in the output stage and the drive available from the driver stage ensure an adequate 'fan-out' (when driving t.t.l. or d.t.l. 5-volt logic elements) of up to 15 standard loads. The output waveform is a square wave of approximately 1:1 on-off ratio and 5 volts amplitude.

Fig. 8 shows the results of a 500-hour drift test, including the initial warm up phase. It will be seen that there is close agreement between the initial warm-up curve and the warm-up curve for the oven, as determined with a calibrated thermistor in place of the crystal (Fig. 5), assuming the crystal's temperature coefficient to be −1.1 parts in 10^6. At 400 hours the whole system was switched off to check the effect of this on the crystal stability. After a period of exactly 10 hours the system was switched on again and, as can be seen, there was little if any effect.

All measurements were made against the Droitwich 200-kHz standard frequency transmission, using the author's locked frequency standard[2]. The stability of this transmission is better than 1 part in 10^{10}. Measurements of the relative drift were made over 50 beat periods which, with the typical error of −1 to −1.4 Hz shown on the curve, means a measurement period of some 35-50 seconds. Assuming these figures, a measurement accuracy of 1 part in 10^8 can be claimed with reasonable confidence.

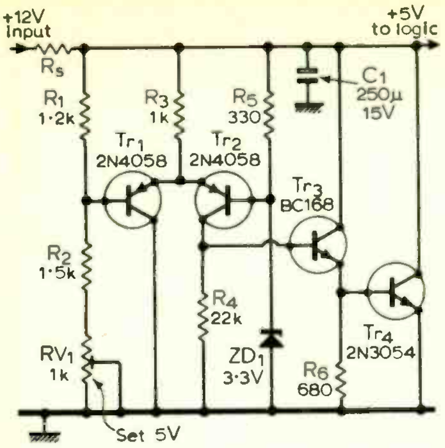


Fig. 9. Circuit of +5V shunt stabilizer for oscillator supply and for d.t.l. or t.t.l. logic of a counter-timer.

Electronic frequency control

The oscillator circuit of Fig. 7 includes a varicap (variable capacitance) diode which may be linked into circuit as shown to enable the oscillator to be pulled onto frequency with a positive control voltage via the 150 kΩ resistor. The intention of adding this diode was to enable the standard to be placed in a phase lock loop, such as that in the author's frequency standard referred to above [2]. The control may, of course, be used with a suitable variable supply to control the frequency, without a phase lock loop, but the stability of the standard will then be considerably degraded by the temperature coefficient of the varicap diode. The diode may be selected from normal diodes for a capacitance at −1.5 V of about 12 pF. The diode used by the author is a selected HS1010, similar to the OA200. The *Q* factor of the diode need not be high. The diode was selected on a bridge, by connecting a 1.5 V battery in series with the diode to produce sufficient reverse bias to prevent forward conduction due to the bridge energization voltage.

Construction of the standard

The prototype was assembled on a single-sided printed circuit board, as shown in the photograph at the beginning of the article. The board carries the crystal in its oven, which is surrounded by approximately ⅛ inch of polystyrene foam and enclosed in a white painted metal case.

The oven controller is that part of the circuit mounted between the TO-66 power transistor, the oven, and the 250 µF capacitor, occupying a space of 1 × 1.5 inches. No heat sink is needed on the TO-5 transistor in series with the oven heater, owing to the switching mode of operation which greatly reduces dissipation in this device.

The oscillator circuit is to the right of the oven, and the remainder of the board is taken up by a high performance shunt regulator, controlling the 5 V supply to the logic elements of the counter-timer and to the oscillator circuit on the board. The potentiometer is the voltage setting control of the stabilizer. A shunt regulator is used since, although there is little to choose, on the grounds of efficiency, between series and shunt regulators at these low voltage and current levels, the shunt regulator is almost completely free from voltage surges at switch-on and at switch-off. An additional advantage of the particular shunt circuit used is that it is a two-terminal device, and needs no additional voltage supplies. The series resistor of this shunt regulator (which may be a lamp for better regulation) is external to the board. The circuit is, to all intents, a high power zener diode with a very low slope impedance. The circuit is included in the appendix.

REFERENCES

1. "Surface Temperature Thermometer" by L. Nelson-Jones. *Wireless World.* April 1969, pp.180-183.
2. "Portable 1MHz Frequency Standard", by L. Nelson-Jones. *Wireless World*, February 1968, pp.666-671. Reprint available from Trade Counter, Dorset House, Stamford Street, London S.E.1. Reprint No. 3, price 3s including postage.

Appendix

Oven controller

R_1, R_2, R_3 .... 150kΩ, 2%, ¼W metal oxide Radiospares ¼W Oxide, Electrosil TR.5, Welwyn MR.5
R_4 (1kΩ)
R_5 (2.2kΩ) .... ½ or ¼W, 10% carbon
C_1 .... 0.22µF, 20V, Radiospares ceramic disc
C^2 .... 0.01µF, 500V, Radiospares, ceramic tubular
D_1 .... OA200, HS1010, etc. Almost any silicon diode is suitable
ZD_1 .... 3.9V, 250 or 400 mW, zener diode Radiospares, Mullard, Texas, etc.
IC_1 .... National Semiconductors LM709CN, 14-pin dual-in-line package. Athena Semiconductor Marketing Co. Ltd., 140 High Street, Egham, Surrey
Tr_1 .... SGS C426, TO-5 transistor. Basic requirement is for less than $0.5V_{CEsat}$ at I_c=250mA, and h_{FE} greater than 60 at 250mA

Crystal oscillator

Crystal .... STC Style D can. 1MHz (with 30pF), parallel resonance, to drawing ITA 202443 NATO Ref: 5955-99-194-5332. Frequency tolerance ±0.005% from −40° to +85°C. Electroniques, Edinburgh Way, Harlow, Essex, supply a 1-MHz crystal similar to the above type at a much lower price, with a reduced specification on temperature coefficient. This cheaper type was used in the prototype, and is quite adequate in view of the oven performance. The full specification represents approximately 0.4 part/10^6 per °C, as against that used by the author of 1.1 parts/10^6 per °C, with which all the above results were obtained.

R_1 .... 150kΩ R_6 .... 10kΩ
R_2 .... 68kΩ* R_7 .... 3.3kΩ
R_3 .... 68kΩ* R_8 .... 470Ω
R_4 .... 150Ω* R_9 .... 47Ω
R_5 .... 2.7kΩ*
*½W, 2% metal oxide, Radiospares, Electrosil TR.5 or Welwyn MR.5. Other resistors ¼W, 10% carbon.
C_1 (330pF)
C_2 (100pF) .... Radiospares silvered mica 1%
C_3 (15pF) .... polystyrene, ceramic or silvered mica types are suitable, 10% tolerance or better
C_4 (0.1µF) .... Radiospares 20V ceramic discs
D_1 .... OA200 etc. selected for varicap use (see text)
Tr_1 .... BC108, BC168 etc.
$Tr_{2,3}$ 2N2369A, BSX20
VC_1 .... 2-60pF Mullard trimmer CO10AA/60E

Crystal oven

Thermistor .... Radiospares TH-B11 used in prototype. Equivalent to STC GL16.
Heater .... Wound with silk- or cotton-covered 42 s.w.g. cupro-nickel (Eureka) wire (Figure 4(a)), 50Ω total
Body .... ¾ inch i.d. copper pipe
End caps .... Yorkshire stop end, Cu61/¾in
Paper tape .... Masking tape (Sellotape, Scotchtape etc)

5-volt stabilizer

R_1 .... 1.2kΩ* R_4 .... 22kΩ
R_2 .... 1.5kΩ* R_5 .... 330Ω
R_3 .... 1kΩ R_6 .... 680Ω
*½W, 2%, metal oxide; rest ¼W, 10% carbon
C_1 (250µF) .... 15V electrolytic
RV_1 (1kΩ) .... wirewound potentiometer (Radiospares, preset)
$Tr_{1,2}$ .... Texas 2N4058 high gain p-n-p
Tr_3 .... BC108, BC168 high gain n-p-n
Tr_4 .... 2N3054, TO-66 n-p-n silicon power
ZD_1 (3.3V) .... 250 or 400mW 5% (at 5mA) zener diode
Rs .... series resistor (wire wound) dropping resistor. Minimum value approximately 15Ω with 12V supply. Limit is set by heat-sink area of power transistor and current gains, but the former is likely to be the greatest limitation. The dissipation in Tr_3 also should not be ignored. Series resistor chosen for maximum demand current of logic elements +20% +7mA (for oscillator on board).

Warning. Wires should not be soldered direct to the pins of any crystal, unless this is of the wire ended type, in which case a heat shunt should be used. A crystal socket should always be used with types designed to plug in. Failure to observe this precaution will lead to large and unpredictable drift rates for a considerable period after soldering. With glass encapsulated crystals there is the additional risk of glass fracture.

Cecilia—Saint or Temple Prostitute?

An impression of Sonex '70

The journey from central London to the Skyway Hotel at Heathrow proved easy but slow. The idea of simply "dropping in" was therefore not entertainable and the tickets that were readily available beforehand (but which had to be given up at the door) need never have been printed. Entrance as such was free, but the "Official Catalogue" cost 4s.

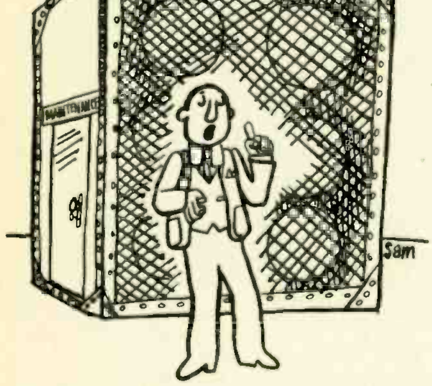
Exhibition rooms were on each side of a long narrow corridor on the ground and first floors. Demonstrations took place in rooms facing out of the hotel, each exhibitor having a room (or two) for this. Discussion of technical points and the inspection of equipment could take place in quiet rooms on the other side of the corridor.

The type and quality of the demonstrations (designed, one presumes, to give sonic evidence of quality) varied considerably. There were three broad categories:

1. Exhibitors with a single component for demonstration in conjunction with other equipment the characteristics of which may or may not be known. Examples in this group include J. E. Sugden (class A amplifiers performing into Quad electrostatic speakers), I.M.F. (transmission line speakers driven by Dynaco amplifiers), and Acos (a ceramic cartridge type 104).

2. Demonstrations of a range of similar items requiring the same ancillary equipment. This was characteristic of loudspeaker manufacturers with a wide range of models (K.E.F., Wharfedale and Richard Allan).

3. Demonstrations involving two or more items of a manufacturer's equipment, where the characteristics of the components could not always meaningfully be separated by the listener. An example here is Cambridge Audio's P100 amplifier driving their transmission line speaker.



"We believe that the general public have realized the deficiencies of bookshelf loudspeakers, and therefore. . . ."

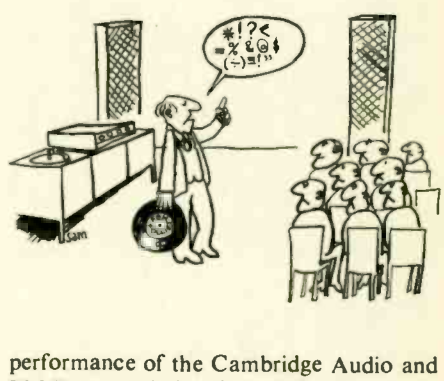
Problem of judgement

Though these categories are badly defined there is an underlying problem to which we drew attention with respect to the Audio Fair. How is the visitor to judge performance when there is more than one unknown factor? For example, if you can (or think you can) hear the difference between class A and class B performance with a given speaker are you likely to be able to differentiate the quality of two very good loudspeakers, one being driven by a class A amplifier and the other by a class B? If you found a given loudspeaker demonstration fatiguing could it be the amplifier's fault? If you came to the exhibition with the intention of selecting a speaker might you not pass over a good specimen whose performance was "poor" because of a weak link earlier in the chain? These are possibilities that point to an obvious lack of sophistication in the demonstration methods. Not that this is a call for proof-by-oscilloscope methods.

Ideally there should be available standard reference equipment—a standard pickup, amplifier, speaker and, possibly, tape recorder—enabling the listener to relax knowing that each item in the chain, save that being demonstrated, was a standard. This standard could be a non-commercial piece of engineering or a generally available unit. Without the emergence of some such standards we think that the success of better equipment could be retarded and the visiting public may well become increasingly perplexed if not exactly dissatisfied.

We have discussed the types of demonstration but not their quality, which ranged from impeccable to banal. The standard for all was set by J. E. Sugden in the demonstration of the A21 and the A51/C51 class A amplifiers. There were no cant phrases or fierce technical terms to be heard in the listening room. The visitor was played a short but excellently selected range of *musically complete* examples, each one introduced simply and without gush. For those with ears to hear all that was revealable was revealed. If you wished to be technically informed you were free to trip across the corridor but the technically innocent needed to endure no embarrassing onslaught. Cecilia, who is surely the patron saint of hi-fi, was paid such homage in very few other rooms. She was frequently buffeted, knocked off her pedestal, mauled and ravished. In K.E.F.'s room the whole range of speakers, including the new Chorale, was gone through with obvious disregard for the music. Enormous contrasts of apparent source size and perspective, tonal balance and coloration, left the listener high and dry. It was quite impossible to come to terms with anything for lack of bearings.

Very interesting is the similarity in



performance of the Cambridge Audio and I.M.F. transmission line speakers.

Cambridge Audio, in characteristic style, employed unselected records taken from private collections of the company's engineers to show up the noise-peak clipping ability of their amplifiers. This was risky as one tends these days to assume that performance deficiencies (especially "coloration") are attributes of the speaker rather than the record. The abnormally low frequency response, and "neutral" sound of the C.A. R50W speakers are characteristics of the transmission line principle. They have been constructed as tall narrow structures to take up little floor space and to disperse the sound over a wide angle. The bass is supplied by a K.E.F. B139 driver in a damped tapered pipe which crosses over to a B110 driver at 400Hz also in a pipe. The two tweeters are one Celestion and one S.T.C. unit.

I.M.F. demonstrated the "Monitor" and the "Studio" speakers—both built on transmission line principles. The claim for these speakers is that they produce a "plane sound source" (whatever this means). The image produced is very forward. Demonstration was from a prepared tape which contained incomplete musical examples, interrupted by a variety of assertions. Had the tape been shorter, the musical examples complete, and the commentary less ornate this could have been a valuable "lesson".

The transmission line principle results in such low electrical efficiency that for very high acoustic output there is the problem of cone break-up. In the mid-range this will have very tiring effects and the only solution likely (in the absence of even stiffer cone materials than at present available) is the use of say four small-cone driver units acting as one unit. This involves the expense of four magnet structures. The bass performance (flat to subsonic frequencies) must be achieved by feeding into the room at relatively high pressure, otherwise how can there be any large movement of air at low frequencies? Anyhow transmission line bass has a characteristic all its own—one person's description is "toothpaste bass".

Improved stereophony

The American company Acoustic Research, now having their products distributed in this country by Bell & Howell, provided a demonstration of 4-channel stereophony. To those who attend a fair number of live concerts the improvement over two channel stereo in getting closer to the real thing must have been immediately obvious. It is just as one would expect from the physics of sound propagation. However, having the information channelled into four speakers from four microphone sources does involve compromise. You cannot walk about in the sound field as you can in a concert hall and get the right effect—moving close to the rear speakers reversed the sound field because they were true sound sources and not the media for reverberation alone.

Moving on from the 4-channel stereo to the Lowther demonstration room afforded a very valuable lesson. Donald Chave produced a completely convincing "auditorium sound" using four speakers and two channels. Instead of single speakers to left and right, two were used in each channel. One speaker of each pair had a forward presentation; the other (an Acousta) delivered the sound as from a greater distance. The effect was immediately acceptable as a true solid sound source that was independent of listener position and did not require precise speaker siting. In our opinion this was nearer the true sound than anything previously heard at any time. A similar experimental system was described recently in *Hi-Fi News**. Lowther hope to bring out, later this year, a simple enclosure combining a forward and a rearward sound source. The rearward sound source need only supply frequencies down to about 200Hz to give the full spatial effect.

How can the exhibition be summed up? As a deliberate break away from the Olympia Audio Fair, Sonex '70 seemed, on balance, to be the same thing less the post-radiogram unit-audio lines. The rooms were small, identical in size, and had solid walls. Sound from other demonstrations did penetrate to about the same extent as at Olympia—but there were several unnecessarily loud demon-

strations going on. The idea of a demonstration room and a technical-talk room for each exhibitor is excellent: in the one room let complete musical examples be heard at reasonable volume; in the other let inspection of component layout and arguments between the pundits proceed unhindered. Never again let a Schubert song compete with a discussion of complementary symmetry. No more ever-open doors (Decca, Celestion, Sinclair Shure etc. etc.) with organ and string quartet competing in the corridor and streams of visitors pushing to get near enough to the speakers to hear clearly above the clatter from outside.

A professional standard must soon emerge along with the above outlined conditions for real musical appreciation. The engineer (as engineer) *must* stay in the second room and not commit sacrilege. If standard items of equipment could be agreed upon, judgments would be sounder and both visitors and manufacturers would benefit.

We entered the mine and found gold, some silver and a lot of base metal. A little alchemy—not involving any philosopher's stone—could yield riches indeed.

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*"Bi-amplification" by Peter Bouwer. *Hi-Fi News*, April, 1970, p.518.

Books Received

Weather Radar for Pilots, by Captain G. E. Manning, is a specially commissioned handbook, published for the Board of Trade Directorate of Flight Safety. It describes the use of radar in the avoidance of turbulence associated with thunderstorms. Airborne weather radar provides the pilot with a 'picture' of turbulence-producing clouds in his path, and indicates the areas of intense activity which he should avoid. Detailed information from many sources is brought together to guide pilots in using weather radar. The nature of atmospheric turbulence and the use of radar for ground mapping purposes is described. Guidance is also given for safe flight in occasionally unavoidable turbulence. Pp.102. Price 13s (13s 8d by post). H.M.S.O., 49 High Holborn, London W.C.1.

BBC Handbook 1970. As might be expected, most of the space in this annual publication by the B.B.C. is devoted to programme news and past and future policies. In his foreword, Lord Hill (chairman) deals with the effect of the changes in network radio and the B.B.C's financial problem. There are, however, 44 pages under the "engineering" section, full of useful reference material. Half of these pages contain local area maps giving TV transmitter locations and coverage, both v.h.f. and u.h.f. In the case of u.h.f. locations, these also include co-sited I.T.A. transmitters. Another set of maps gives similar data for v.h.f. radio stations. Next come tables showing the location, frequency/wavelength, power of and areas served by, all long- and medium-wave stations. The maps and tables are supported by a short article giving information on the B.B.C. engineering services and another offering advice on how to get good reception in the radio and television bands. Readers may be surprised to learn that the B.B.C. currently operates 281 studios and 469 transmitters in the U.K. Pp. 303. Price 10s. BBC Publications, London W1A 1AR.

Computer Weekly Yearbook 1970, edited by Malcolm Butler, is a "guide to computer services, peripherals, suppliers, bureaux and consultants." The main contents (which follow a short appraisal of the computer and data processing service industry in the U.K.) fall into four sections. A 'Selected Review' gives information on equipment and techniques, and 'Services Guide' provides an alphabetical list of organizations offering services to the data processing industry. The third main section concerns 'Mainframe, Ancillary and Peripheral Equipment and Supplies'. Finally there is an 'Alphabetical list of names and addresses'. Pp.196. Price 40s. I.P.C. Electrical-Electronic Press Ltd, Dorset House, Stamford Street, London S.E.1.

Trader Year Book 1970. The 41st edition of this legal, technical and buying guide for the radio, television and domestic electrical industries, is available price 40s from I.P.C. Electrical-Electronic Press Ltd, Dorset House, Stamford Street, London S.E.1.

Which Type of Microcircuit?

An impression of a recent London microelectronics conference

No printed conference papers and a completely "off the record" approach certainly encouraged the speakers and delegates to speak their minds, in the early sessions at least, at the recent conference "Use of Microelectronics" held at the Royal Garden Hotel, London. The conference was sponsored by the journals *Microelectronics* and *Electronic Equipment News*. Some extremely forthright statements were made as users and semiconductor manufacturers crossed swords.

Manufacturers extolled the virtues of their products and bipolar battled with m.o.s, custom design took on "off the shelf" standard ranges, hybrids challenged monolithics and equipment manufacturers took on the lot in an effort to find the best solutions to their problems.

Consider the problems of an equipment manufacturer about to embark on a new digital design. Which technology should he use? He might decide on m.o.s. circuitry, but which type of m.o.s. is best suited to his needs? (One man's m.o.s.t. is another man's least!) High threshold, low threshold, silicon gate, the nitride process or complementary silicon gate? With m.o.s. technology he can enjoy low power dissipation per gate which allows more gates per chip, fewer wire bonds, less packages per system, fewer inter-package connections with the extra reliability that this affords. Cost can be low at around the fourpence per gate mark.

But what about the reliability of the m.o.s. circuit itself? Early problems with the stability of the gate threshold, mainly due to contamination of the region below the gate, have largely been solved by improved processing methods, but no one knows much about the long term reliability of the m.o.s. circuit. Try getting some literature on the subject—you will find it difficult.

If m.o.s. is to be used is the equipment manufacturer going to employ a standard range of microcircuits or is he going to plump for custom design? With the former, a recommended approach is to use m.s.i. blocks "individualized" by a programme contained in an m.o.s. read-only memory, the bit-pattern in the memory being specified by the equipment manufacturer.

If the equipment manufacturer decides that the product he is designing will enjoy a large number of sales, or if— in the case of low volume equipment—a particular need cannot be met by standard circuits and cost is of secondary consideration, he may decide that the large capital outlay required for a custom designed m.o.s. microcircuit is justified. In which case he has to choose between designing the circuit himself, according to rules laid down by the semiconductor manufacturer, or he can let the semiconductor manufacturer perform this task. In either case he has to make arrangements for a second source of supply.

It could be that m.o.s. is not fast enough for the equipment in mind, although m.o.s. manufacturers are quick to point out that circuit speed is not system speed. Using clever circuit "quirks" system speed can be made quite fast. Shift registers up to 25MHz and logic between 6 and 8MHz are on the cards.

However, if this is not fast enough the equipment manufacturer will have to put up with the higher power dissipation of bipolar circuits and face another set of problems. Cost will be higher and custom design more difficult. In fact many bipolar custom design houses want to take the job of design right out of the hands of the equipment manufacturer; as one put it, "we must have the last shout".

A third choice open to the equipment manufacturer is the hybrid microcircuit (thick or thin film). He can have combinations of transistors, operational amplifiers, normal or m.s.i. logic circuits, power transistors, passive components in film or standard form laid down on a single substrate. Custom design costs are less than for custom monolithic circuits and the process, from initiation to production, is quicker.

One speaker said that before very long 50% of all run-of-the-mill circuitry will be made in hybrid form". His mention of three-transistor amplifiers practically brought laughter from the 1000-plus transistors-per-chip digital men. Another speaker said that 50% of all semiconductor memories made will employ some kind of printed film interconnection system ("zero resistance hybrids").

We feel that both speakers understated the case for hybrid microcircuits and are convinced that hybrid techniques are going to be used more and more right across the board from three-transistor amplifiers to complex multi-chip digital, or digital/analogue, systems. Evidence of this was seen at the recent Paris Components Show (see last month's issue).

There are a number of problems to be solved. Should the monolithic chips be encapsulated separately or should they be fixed to the substrate in their "naked" form? If the latter course is adopted should beam lead or wire bonding chip-to-substrate connections be employed?

As one speaker pointed out, beam lead chips are bound to be more expensive because of the general adoption of the wire bonding techniques in normal packages. (TO-18, TO-5, dual-in-line, etc.) Beam lead chips are made only for hybrids so any surplus cannot be used for normal components and therefore they cannot enjoy the price advantage of large scale production.

A solution to this problem was suggested by a speaker who said that normal wire bonded chips could be supplied mounted on a "spider", the legs of the spider being bent down for connection to the hybrid substrate.

The bonding of the chip connections is also a problem in multi-chip hybrid assemblies. Even if the bonding machine was so good as to make only one faulty bond in a hundred, complex circuits could be expected to have more than one fault per substrate. Expensive fault chasing and repair would have to be applied to every substrate.

Another difficulty—how much should be placed on a single substrate? Such hybrids would not be repairable after encapsulation and therefore would make very expensive throw-away items indeed.

In spite of these difficulties hybrid techniques will be employed more and more in the future. Looking into the crystal ball we feel that as the speed of m.o.s. circuits increases and as the manufacturing processes for m.o.s. microcircuits is simpler and cheaper per function (lending itself more readily to custom design) m.o.s. will gradually oust bipolar monolithic circuits in many areas and that the thing for the future will be m.o.s. monolithic circuitry used in conjunction with film interconnections and film passive components.

Electronic Building Bricks

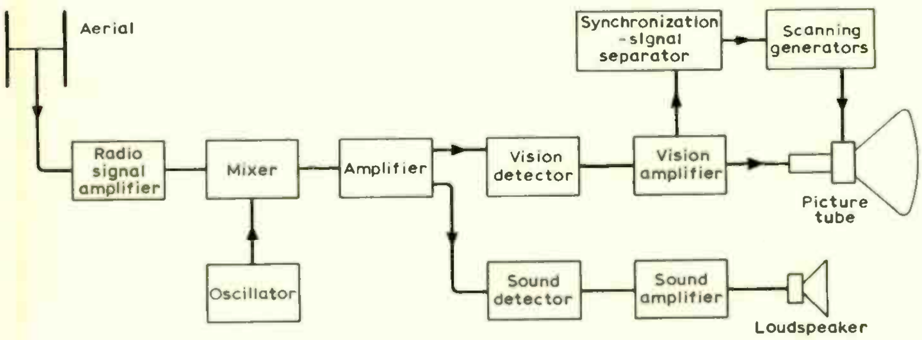
1. What is electronics?

by James Franklin

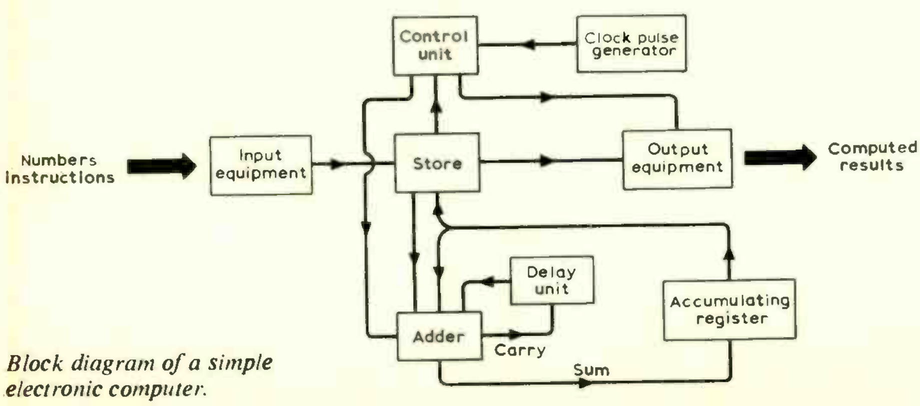
Every time you watch television, listen to the radio, travel in an aeroplane, or shudder at your bank statement or your electricity bill you are experiencing in a fairly direct way the impact of electronics on your life. Every time you use a manufactured commodity, such as sugar, petrol, detergent, or some mass-produced item such as a motor car or a pair of shoes, there is a good chance that electronics has figured somewhere in its production. Yet, probably, you are hardly aware of all this.

The contradiction, that electronic technology is all-pervading and yet unnoticed, is explained by the fact that it is largely concerned with operations on an invisible, intangible commodity—information. When electronically processed information is eventually made visible—say, on a television screen or a computer print-out—it is, of course, in a different form, suitable for human perception. This series of articles explains how electronic techniques are used to transmit and process information before it is made perceptible.

In practice this means that the information is represented by electrical quantities and that various *operations* are performed on them—coding, storage, magnification, attenuation, comparison, counting, integration and so on. Most of these operations—as concepts—will be already understood by the intelligent non-technical reader, at least intuitively if not in precise detail, so the approach will be to emphasize this operational aspect: what the electronic devices *do* rather than what they are. Any non-technical person who tries to get some idea of what electronics is about simply by examining pieces of electronic equipment will end by being completely baffled and demoralized: the construction gives hardly any clue to the function. It is better to forget the "hardware", at least to begin with, and concentrate on the functions that it performs.



Block diagram of a black-and-white television set.



Block diagram of a simple electronic computer.

In fact this approach does accord with the mental processes of electronics engineers, who, before they get down to detail, think of the systems they are designing as groups of functions and draw what they call block diagrams. Two examples are shown here—a television set and an electronic computer. As can be seen, each block in these diagrams has written in it the operation it performs. (Don't worry about the meanings of the labels at this stage.) The lines connecting the blocks represent paths for information and indicate that the separate functions are acting on each other through this information.

Such functional blocks, and the electrical representations of information, are what we have called "electronic building bricks" in the title. It is important to get this clear straight away, and not assume automatically that the "building bricks" are the transistors, resistors, capacitors, switches, dials and other devices that make up the electronic hardware.

Before attempting a cut-and-dried answer to the question "what is electronics?" it might be as well to remind ourselves that from the human, organizational point of view electronics is both a science and an engineering activity. The scientist studies electronic phenomena for his own interest and for what they tell him about the nature of the universe: the engineer makes use of the discoveries of the scientist in order to serve human ends. This is an over-simplification because the activities of the scientist and the engineer do tend to merge and become interdependent. For example the stimulus to invent new things that arises from the business of engineering sometimes results in the discovery of new physical phenomena.

In this series of articles we are largely concerned with the engineering side—the uses to which electronics may be put—but in order to do so we must know a little about the basic phenomena. Fortunately this does not demand a rigorous study of the physics of electronics. The non-technical reader would be surprised to find how much electronic equipment is designed and made to work without the designer having thought very deeply about basic principles. Amateur experimenters tend to jump straight in and get things working by trial-and-error—and why not! Professional engineers, although they have probably studied the fundamentals at one time, design largely from practical formulae, data and other "packaged" information in text-books and manufacturers' literature—and from experience of what has been found successful in the past. Thus a practical understanding of "electronic building bricks" can be obtained with only a nodding acquaintanceship with the physics of electronics.

We shall make our nods to the basic phenomena as the series goes along. For example, electronics is so called because it is concerned with the use of *electrons*, so we shall consider the electron a little, and discuss electron movements and flow rates. Meanwhile our answer to the question "what is electronics?" is, at this stage: the use of electrons to represent and process information for human purposes.

Class Distinction in Audio Amplifiers

A discussion of design problems and how to overcome them

by J. L. Linsley Hood[1]

Since the publication of "Simple Class A Amplifier" the author has received numerous letters asking whether it would be feasible to increase the power output to 15W, or even 20W, to provide a greater reserve for use with inefficient loudspeaker systems.

Whilst it would be possible, the problems associated with increased heat dissipation and the provision of suitable power supplies makes this unattractive. In view of the low average power required for normal listening, the question inevitably arose whether it would be practicable to design an output stage which would operate in class A with an inherently low level of high order distortion up to a watt or two, but progress further into class B operation if and when higher powers were momentarily demanded.

There are, unfortunately, a number of snags with the class B operation of transistor output stages, to which the answers are not fully known.

It was pointed out some years ago, by Bailey[2] and others, that the use of quasi complementary symmetry in such output stages led to an increase in high-order harmonic distortion, associated with the non-linearities in the crossover characteristics at low volume levels, and although the level of total harmonic distortion at maximum power output could be quite low, the distortion content at typical listening levels could be many times greater than this, and would also be of an audibly objectionable type.

A number of schemes have been proposed to overcome this problem, including the use of full complementary symmetry [2,3,4], and various methods of ensuring that there are an equivalent number of forward biased junctions in each limb have been described[5,6], including the ingenious semi-complementary triples arrangement used in the "Quad" amplifier[7].

However, in the author's experience, some class B transistor amplifiers—including those employing full symmetry, which is

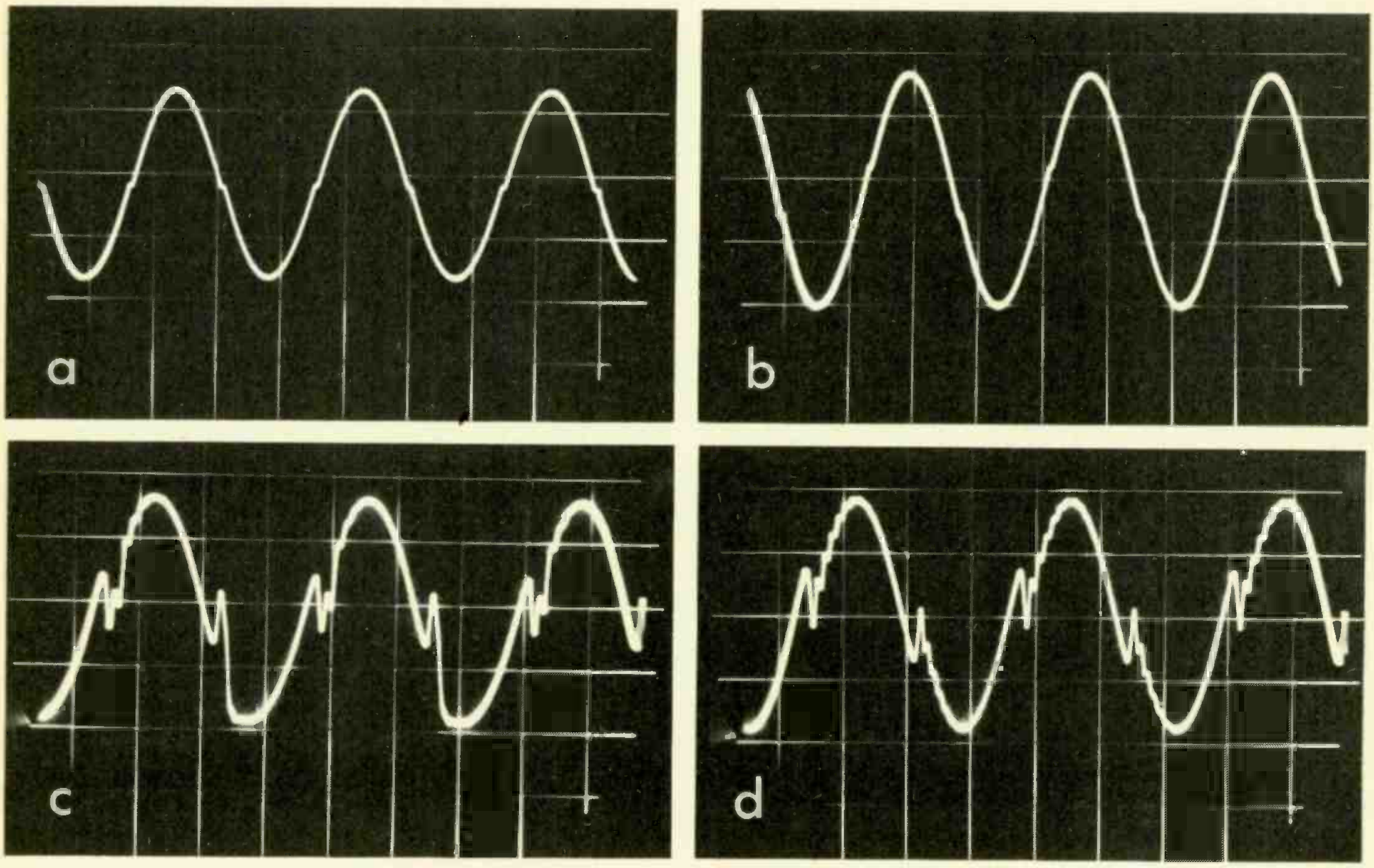


Fig. 1. Crossover distortion in a class B stage employing transistors with an f_T of about 2MHz. (a) Low frequency sine wave at 10mA. (b) High frequency sine wave showing the effect of hole storage on the crossover discontinuity under light load conditions. (c) Influence of hole storage and n-p-n/p-n-p asymmetry under high current conditions at 200kHz. (d) Improvement of conditions in (c) by reducing source impedance.

presumed to eliminate the major fundamental snags of this type of operation—having an impeccable performance on paper, did not have the tonal quality which had been expected. Since harmonic distortion at both high and low power levels had been found to be well below the level at which audible effects might reasonably be expected in some of the designs tested, it seemed more probable that the audible ill-effects were due either to transient instabilities associated with loudspeaker loads—perhaps related to changes in the reactance of the base-emitter junction at the current cut-off point—or to high-frequency crossover-type distortion arising from hole-storage effects. Hole-storage depends on the presence of holes produced when current flows in a semiconductor—even though the current is due to majority carriers (electron flow). The greater the current the greater the number of holes and the worse the problems of hole storage.

Hole-storage phenomena

The expected result of hole storage in the base region of a transistor, following the attempted termination of a high emitter collector current, is that the transistor remains in a conducting state after the forward base bias has been removed. This has the effect, amongst other things, that the normal crossover discontinuity shown in Fig. 1 (a) becomes displaced from the mid-point of the transfer waveform as the frequency is increased, as shown in Fig. 1 (b).

These waveforms were generated in a simple complementary pair emitter-follower circuit, without additional negative feedback, driving a resistive load. (In order to assist its display the crossover effect was deliberately exaggerated by the use of an inadequate quiescent current.) Provided that the peak currents flowing through the transistors are small, this effect is innocuous. However, if the peak currents are increased, by reducing the load resistance, the crossover waveform rapidly deteriorates as shown in Fig. 1 (c), and increasing the forward bias to give a more suitable quiescent current has little effect in removing this prominent notch, until the forward bias is almost equivalent to that of class A operation.

It is known from experience that these effects can be minimized by the use of transistors with good high-frequency characteristics and low-impedance base-emitter return paths. A low-impedance driver stage will also be effective provided that it does not become cut off (as in the case of the Darlington pair) when the input signal reverses polarity.

The effect of reducing the driver circuit impedance from 2000Ω to 100Ω is shown in Fig. 1 (d).

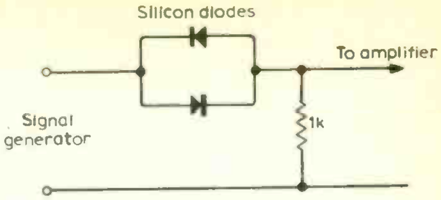
The lack of effective symmetry between the upper n-p-n device and the lower p-n-p is also shown in Fig. 1 (c). This effective asymmetry is reduced if the source impedance is reduced.

It was noted that this effect did not become apparent, even under high emitter current conditions, until the operating frequency approached $0.05 f_T$. At $0.1 f_T$, the problem was severe and this argues that the occurrence of high transient currents—which may arise with certain loudspeaker systems—and high driver stage output impedances, is most undesirable unless the highest frequency components of the waveform are low in relation to the transition frequency of the output transistors. With the availability of power transistors having transition frequencies of the order of 4MHz (such as the MJ480/490 series) it is unlikely that hole-storage phenomena will be troublesome at the rates-of-change of signal voltage likely to be encountered in audio amplifier practice so long as the driver stage does not leave the output transistor base open-circuited on cut-off. However, the use of a driver output, or base circuit, impedance not in excess of a few hundred ohms appears prudent. With earlier designs using germanium diffused junction power output transistors, which usually have very poor h.f. performance, this problem could be important, and Dinsdale has referred to a "subjective audible improvement" resulting from the replacement of low transition frequency output transistors with types having better h.f. characteristics.

Transient instabilities on loudspeaker loads

Phase-angle measurements made with a variable frequency sine wave input, from a high impedance source, reveal that even a simple single-unit loudspeaker can present quite complex characteristics. The reactance—which is normally inductive—changes rapidly, and sometimes even becomes capacitive, at frequencies in proximity to cone and structure resonances.

Fig. 2. Circuit for generating the test waveform shown in Fig. 3.



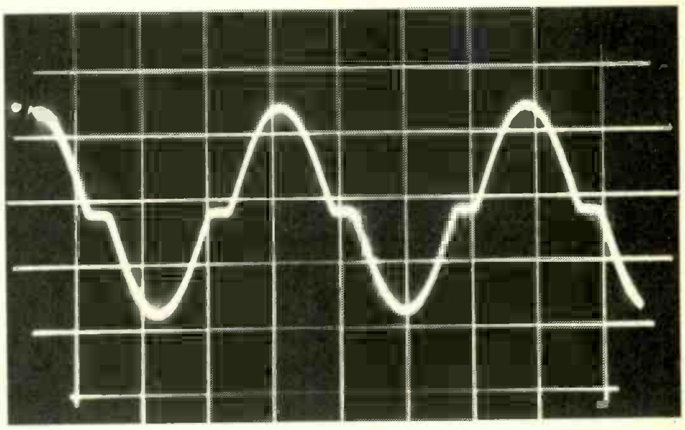


Fig. 3. Test waveform for providing arrested transient input.

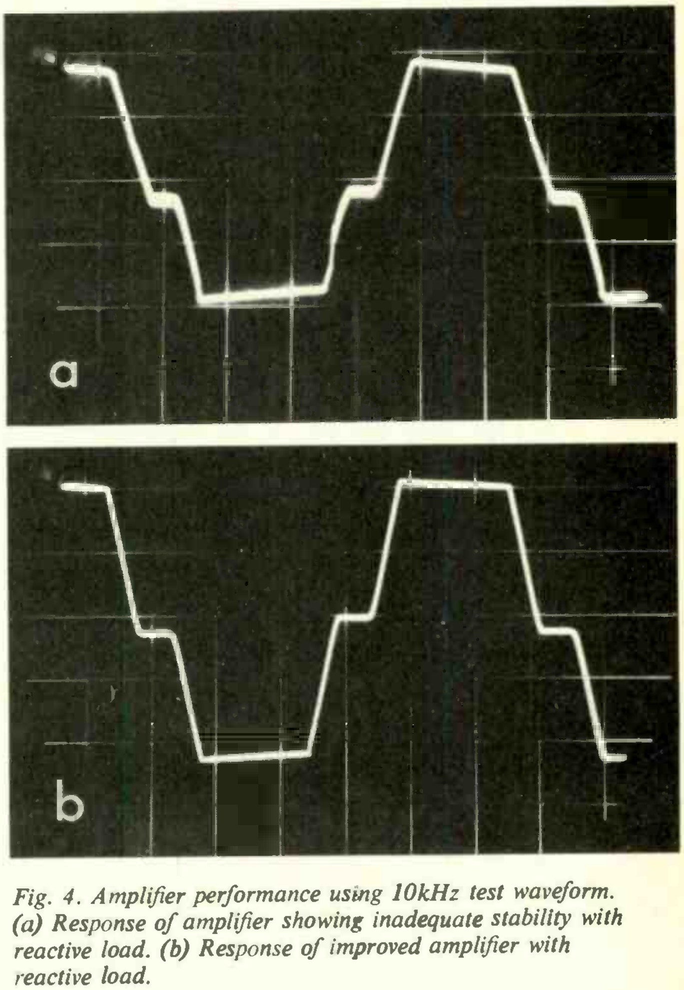


Fig. 4. Amplifier performance using 10kHz test waveform. (a) Response of amplifier showing inadequate stability with reactive load. (b) Response of improved amplifier with reactive load.

In general, the characteristics of most of the common designs of transistor power amplifiers are such that instability problems do not arise with inductive loads, and the inclusion of a small choke, of a few microphenries inductance, in the speaker output lead is a well known technique for avoiding instabilities under adverse load conditions. However, capacitive loads can frequently impair the stability margins of the feedback loop, and it is in this respect that the reactive characteristics of the loudspeaker load are most significant. Since it was suspected that the region of the output waveform where this might arise most readily was that at which the output transistors were being driven from the conducting to the cut-off state, an input waveform which provided a transient of controllable steepness (by varying the input amplitude), but arrested at the mid-point, was provided by the circuit of Fig. 2.

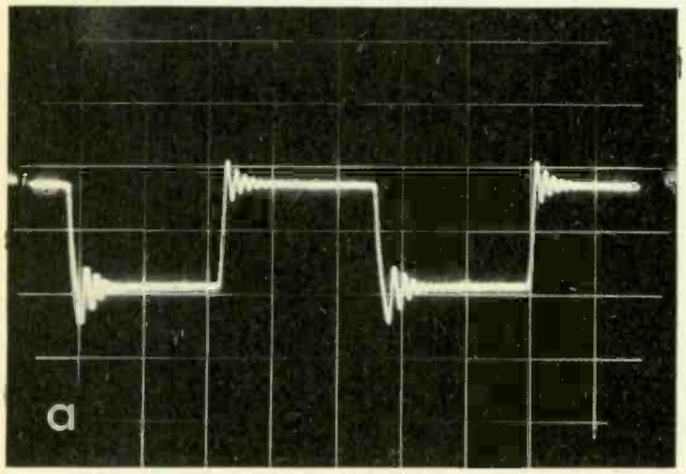
The waveform generated by this device is shown in Fig. 3 and the result of introducing such a waveform into an amplifier of poor stability margins, coupled to a resistive load shunted by an appropriate value of capacitance is shown in Fig. 4(a). (The broadening of the oscilloscope trace in the horizontal regions at the mid-point of the waveform was due to inadequately recorded h.s. oscillation.)

The output waveform obtainable from a design with better stability margins and improved bandwidth is shown in Fig. 4(b). In both cases the magnitude of the input signal was adjusted so that clipping occurred on both negative- and positive-going peaks.

Since the h.f. instability shown in Fig. 4(a)—which did not occur in the absence of a large input signal, and which required a particular range of shunt capacitance to provoke it at all—also occurred on parts of the waveform preceding the arrested transient, it was concluded that the change in reactance of the base-emitter junction at cut-off or switch-on, was not a major cause of the transient induced instability observed in this particular design.

Square-wave performance and tonal quality

In view of the fact that a loudspeaker system can present a reactive load, of a type which is found in certain circumstances to cause signal induced instability, and since this instability could be provoked by a square-wave input into an amplifier with a suitable reactive load, a series of tests and comparative listening trials was conducted to determine whether there was any audible relationship between the two. In the event, it was found, beyond doubt, that an amplifier system which did not show any sign of instability over the range of load shunt capacitances up to, say, 0.33 μF had a better tonal quality on even a simple loudspeaker system than one in which some shunt capacitor value could cause h.f. oscillation. Moreover, in a more complex loudspeaker system, with a crossover network and high-frequency capacitively coupled "tweeter", it was possible to hear the difference between systems which would, in the lab., with some *RC* load combination, give a square-wave response such as that of Fig. 5(a) and those which had a response like that shown in Fig. 5(b). No positive distinction could be drawn in listening trials between a system giving a waveform such as Fig. 5(b) and one in which a square-wave input could produce a single overshoot "spike".



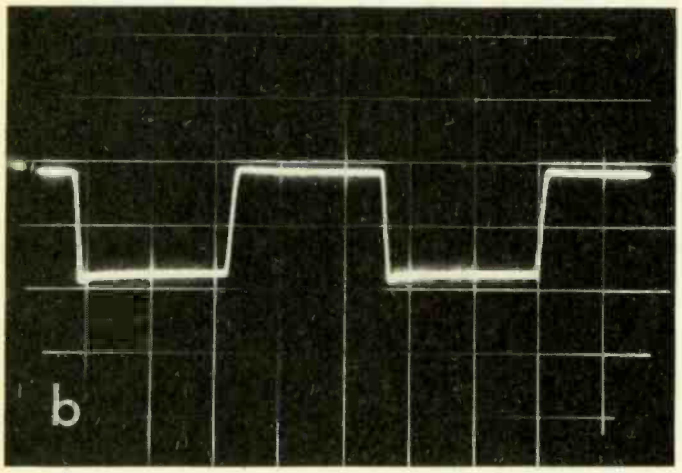


Fig. 5. Amplifier response driving a reactive load (15 Ω, 0.47μF) with a 10kHz square wave. (a) The ringing gives evidence of instability. (b) No transient ring indicates better stability.

Since the frequency of the "ring" waveform in Fig. 5(a) is well beyond the upper limits of the audible spectrum, it is clear that it is not this of itself which produces the undesired sound quality, but rather that this type of behaviour is symptomatic of a different and more objectionable effect when the amplifier is used with a loudspeaker load.

The conclusions which have been drawn from this series of experiments are these: (1) that it is desirable to employ output power transistors in which the transition frequency is at least ten times higher than the highest signal frequency component which is passed to the amplifier from preceding stages; (2) that it is preferable to drive the output transistors from a source which has a low impedance over the whole signal voltage swing, or at least to provide a reasonably low-resistance base-emitter current path; and (3) that the phase/frequency characteristics of the feedback loop should be such that a square-wave output devoid of overshoots is obtained when the amplifier is bench tested with a wide range of shunt capacitance values in an *RC* dummy load. This latter requirement probably implies either a fairly limited number of stages within the feedback loop or a relatively restricted h.f. bandwidth.

When these requirements had been met, and when the harmonic distortion levels over the range 40mW up to the maximum rated power output were of a suitably low level, there was no audible difference, in the most careful listening trials, between several different designs. However, it is difficult in class B systems to obtain the desired low level of harmonic distortion at low signal levels without the use of substantial amounts of negative feedback, and this leads to a worsening of the amplifier response to signals containing transients.

The use of a class AB system, if the problems in maintaining the correct forward bias level can be solved satisfactorily, should facilitate the attainment of these desired standards, particularly if the h.f. negative-feedback loop can be made fairly simple.

Next month full details will be given of a 15-20W class AB amplifier with the following characteristics:—

Power output: 15W into 15 Ω, or 18W into 8 Ω. (20W with modified output circuit component values.)

Bandwidth: 10Hz − 100kHz ± 0.5dB at 2V output; 20Hz − 50kHz ± 1.0dB at maximum power output.

Output impedance: 0.03 Ω (at 1kHz).

Total harmonic distortion: 0.02% at 15W/15 Ω or 18W/8 Ω; less than 0.02% at all power levels below maximum output.

Intermodulation distortion: Less than 0.1% at 10W (12.3V r.m.s. into 15 Ω) and 70Hz, and at 1V r.m.s. at 10kHz.

Square-wave transfer distortion: Less than 0.2% at 10kHz.

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Root Hog or Die

Frequency in two dimensions

by Thomas Roddam

The title expresses a rather stronger attachment to the root analysis method of studying circuits than I feel myself. This is probably because it is used for certain classes of problem which I have normally managed to dodge. I had intended to quote rather more of a folk-song, but by chance I discovered that "root hog, or die" crops up in a number of the songs of the bull-whackers on the Santa Fe and Oregon trails and seems to have originated in the hill country near the Finger Lakes, where they used to dig for ginseng.

Back in March we examined the natural behaviour of a circuit made up of inductance, capacitance and resistance. The object was to find out what sort of waveform a circuit will produce if given the chance. This is obviously the sensible waveform to apply to such circuits. The political philosopher will recognize this as the Maoist doctrine of the revolutionary swimming among the peasants like a fish in the lake. We, however, cannot always use the characteristic frequency, which I suppose amounts to dropping a herring, or a Maoist, in the Round Pond.

The essential result, using the same symbols as before, is

$$m_1 = -\frac{R}{2L}+j\left[\frac{1}{LC}-\left(\frac{R}{2L}\right)^2\right]^{\frac{1}{2}}$$

$$m_2 = -\frac{R}{2L}-j\left[\frac{1}{LC}-\left(\frac{R}{2L}\right)^2\right]^{\frac{1}{2}}$$

For the particular case where $L/C > R^2/4$ we wrote the overall waveform as $\epsilon^{-\alpha t}\cos \omega t$, in which

$$\alpha = R/2L$$

$$\omega = \left[\frac{1}{LC}-\left(\frac{R}{2L}\right)^2\right]^{\frac{1}{2}}$$

Usually ω is the term we call the frequency, and α is the decrement factor, which also has units ($\sec^{-1}$).

Suppose that we write

$$s_1 = -\alpha+j\omega$$

$$s_2 = -\alpha+j\omega$$

We are dealing with

$$\exp(\alpha+j\omega)+\exp(\alpha-j\omega) = \exp s_1+\exp s_2$$

Now we concentrate our attention on the single *thing s*. This is a complex number, and can be represented as a point in a plane. Because we happen to have two of these *things* here, we show them both in Fig. 1. Here we see the two points s_1 and s_2, expressed both as points in the complex plane and as vectors. Because the two complex frequencies were obtained by finding the roots of the current or voltage equation, this is a plot of the roots. Each of these is the solution of a very simple equation: $s = s_1$ or $s = s_2$. Using the first of these,

$$(s-s_1) = 0$$

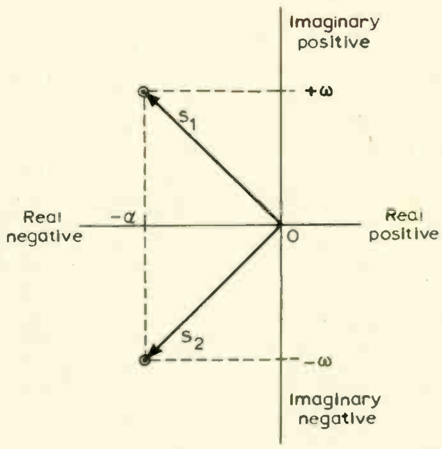


Fig. 1. Frequencies in the complex plane.

This particular kind of root is called a zero. We also encounter the form $1/(s-s_1) = 0$. We should get this, for example, if we worked with the admittance of a series *LCR* circuit instead of the impedance. The root at s_1 is now called a pole.

Concentrating on the one root, we can find some interesting and important features. Let us consider the root shown in Fig. 2. We are free to move this about. If we move it sideways, we shall be keeping ω constant, and altering the value of α. Now α is the decrement term. It tells us how quickly the ringing dies away. It has, as we have seen, the dimensions of "per second" and the nearer the point s is brought to the value $-\alpha = 0$ the smaller the decay per second, the longer the time taken for the ringing to die away.

Moving up and down, by changing ω and keeping α constant, varies the ringing frequency, but each train lasts for the same time, because the time is fixed by α.

Along the line *OD* we have quite a different condition. We are varying both α and ω, while keeping α/ω constant. This ratio has zero dimensions, and gives us a line of constant "decay per cycle". For various reasons it is not expressed in quite this form. I have marked in the point $\omega_0 = (\alpha^2+\omega^2)^{\frac{1}{2}}$, which for the *LCR* circuit is, in fact,

$$\omega_0 = (1/LC)^{\frac{1}{2}}$$

The decrement factor, ζ, is defined as

$$\zeta = \alpha/\omega_0$$

This is expressed in more familiar terms for the *LCR* circuit by writing $\alpha = R/2L$, so that

$$\zeta = R/2\omega_0 L$$
$$= 1/2Q_0$$

where Q_0 is the well-known $\omega_0 L/R$, commonly called Q.

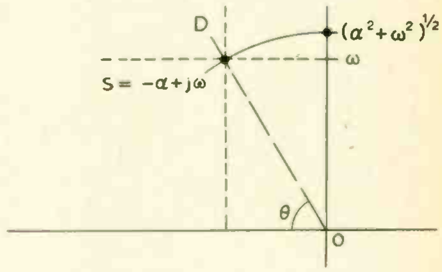


Fig. 2. Features of a root.

Frequency in two dimensions—cont.

I began with the *LCR* circuit because it has roots which are out in the open spaces of the diagram. Let us consider now the simpler case of a resistance and inductance in series. The impedance can be written down immediately as

$$Z = R+j\omega L$$
$$= L(R/L+j\omega)$$

The "frequency" obtained by solving the differential equation

$$L\frac{dI}{dt} = V$$

and so on, which we went through in the February issue, is described by the term $\exp[-t/(L/R)]$. It gives us quite simply a form $\exp(-\alpha t)$ where $\alpha = R/L$, and no j

term at all. Figure 3 shows this root, on the negative part of the real axis. It is a very dull looking diagram indeed. The equation for Z, the impedance, is, as you see, very simple and is rather convenient for showing how,

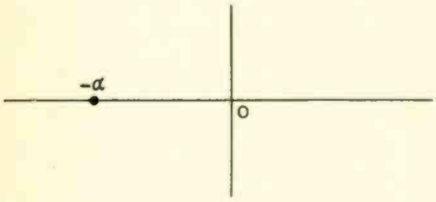


Fig. 3. Root for an LR circuit.

in most circuits, we can avoid working through the differential equation. If we substitute p, or s, or λ, for $j\omega$ we arrive at the expression

$$Z = R + pL$$

and if $Z = 0$

$$p = R/L$$

Which symbol you use depends to some extent on the way you were brought up. There are, indeed, some subtle differences in definitions, but these are so subtle that if you need to understand them you would not be tackling that sort of problem unless you could understand them. This substitution makes writing down the equation, though not necessarily finding the roots, fairly easy. For the series LCR circuit,

$$Z = R + j\omega L + 1/j\omega C$$

$$= \frac{1 - \omega^2 LC + j\omega CR}{j\omega C}$$

$$= \frac{1}{pC}(1 + pCR + p^2 LC)$$

and if $Z = 0$

$$p^2 LC + pCR + 1 = 0$$

giving as we know,

$$p = \frac{-CR \pm \sqrt{C^2R^2 - 4LC}}{2LC}$$

There is also a slightly embarrassing term, which gives us an alternative solution, $p \rightarrow \infty$. It does not really matter which way

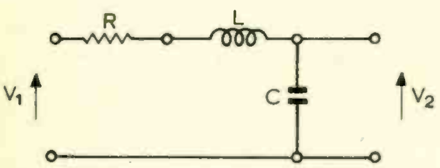


Fig. 4. A way of studying the LCR circuit.

p goes off to infinity. A way of dodging this is to consider the circuit of Fig. 4. In this the current will be

$$I = V_1/Z.$$

The voltage across the capacitance will be

$$V_2 = I/j\omega C$$

$$= V_1 \cdot \frac{j\omega C}{1 - \omega^2 LC + j\omega CR} \cdot \frac{1}{j\omega C}$$

so that

$$\frac{V_1}{V_2} = 1 + pCR + p^2 LC$$

By this conjuring trick I have got rid of a root which looked like being a nuisance. It will appear later that this term would, in some ways, have looked after itself, but we do not want to carry it around at this stage.

We have an equation for V_1/V_2, which we can write as

$$\frac{V_1}{V_2} = \frac{1}{p_1 p_2}(p - p_1)(p - p_2)$$

where p_1, p_2 are the two roots we have already found. In order to breathe some life into this let us look at one term by itself, and consider the factor $(p - p_1)$. We have seen that p_1 is a term of the form $(-\alpha + j\omega_1)$, in which I am writing ω_1 to show that it is a fixed value obtained from the actual values of L, C and R. The plus sign is arbitrary: if p_1 has the plus sign, p_2 will have the term $-j\omega_1$. The variable is p, or $j\omega$, which can have any value, although we are almost always concerned with the situation in which ω is positive and real. Consider the rather bare Fig. 5. This shows the root p_1

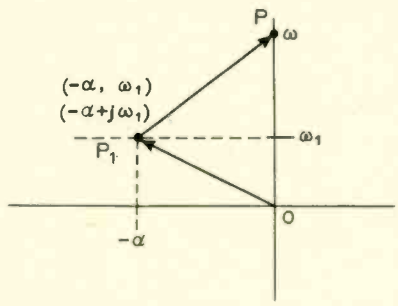


Fig. 5. One root and its effect for sinusoidal excitation.

at P_1 which can be written either as $(-\alpha + j\omega_1)$ or as $(-\alpha, \omega_1)$ depending on whether you think in algebraic terms or trigonometric terms. The point p lies on the vertical axis, at $(O + j\omega)$. We have

$$OP = O + j\omega = p$$

$$OP_1 = -\alpha + j\omega_1 = p_1$$

Now $\quad OP_1 + P_1P = OP$

so that $\quad P_1P = (p - p_1)$

The vector joining P_1 to P represents the term $(p - p_1)$. For the LCR circuit, however, we have a pair of roots, and these are plotted in Fig. 6. Since

$$P_1P = (p - p_1) \text{ and}$$

$$P_2P = (p - p_2)$$

we take the product, $P_1P \times P_2P$ to give us, apart from the constant, the ratio V_1/V_2. The constant, $1/p_1p_2$, can be found from the diagram, because it is simply $1/OP_1 \cdot OP_2$.

Before going on any further with the meaning of Fig. 6 let us look at Fig. 7. Here we have

$$\frac{V_1}{V_2} = 1 + j\omega\frac{L}{R} = \frac{L}{R}\left(\frac{R}{L} + j\omega\right)$$

$$= \frac{L}{R}(p - p_1), \quad \text{where } p_1 = -R/L$$

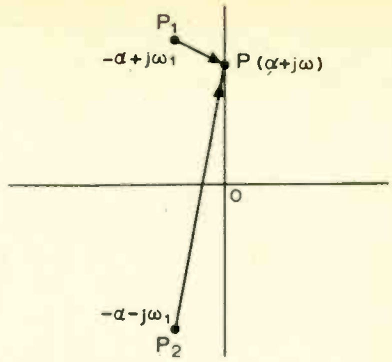


Fig. 6. A pair of roots.

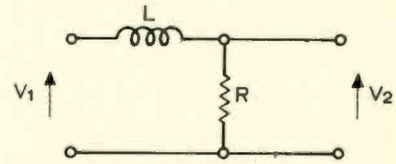


Fig. 7. The simple LR circuit, which has only one root.

This has only a single root, at the point $(-R/L, O)$, on the negative real axis. The reader is left to draw the root diagram for himself. The situation with the LCR circuit when $R^2 > 4L/C$ is rather similar. This highly damped condition gives us, in our equation for the roots,

$$p = -\frac{R}{2L} \pm \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$$

in which the term under the square root sign is positive. We do not get a term in j. However, the term under the square root sign is always less than $R^2/4L^2$, if C is positive, and thus both p_1 and p_2 are negative. If we vary the value of C we get a rather interesting behaviour pattern. When C is very large indeed, the two roots are very near to $-R/L$ and O. These are the two points C_1 and C_2 in Fig. 8. As C is reduced,

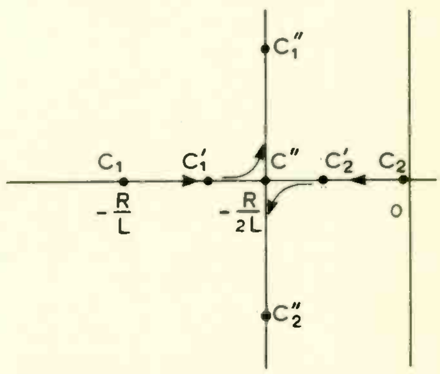


Fig. 8. Locus of roots as C is varied.

the roots move inwards, to points like C_1' and C_2' until when $C = 4L/R^2$ they coalesce at the point C'', $(-R/2L, O)$. It is here that the term under the square root is passing through zero to become negative for smaller values of C. The real part of p now remains constant, and for these smaller values of C we have a j term appearing. The roots head off along the lines $C''C_1''$, and $C''C_2''$, remaining symmetrically spaced. There is no real significance in the arrows showing C_1' moving round to C_1'': when the roots coalesce you can't tell one from t'other. It is the lines $C_1C_1'C_1''$ and $C_2C_2''C_2''$ which are the root loci.

An alternative way of moving the roots about is to vary the value of R while keeping L and C constant. If we begin by taking R very large indeed, the two roots are on the real axis at very nearly

$$\left(-\frac{R}{2L}+\frac{R}{2L}-\delta\right) \rightarrow -\delta$$

where δ is a small quantity, and

$$-R/4L \rightarrow -\infty$$

Reducing R towards the critical damping value brings the roots in towards $-R/2L$ as before. The appearance of the imaginary term, however, gives us roots at $(x \pm jy)$, with

$$x = -R/2L$$

$$y = \left(\frac{1}{LC}-\frac{R^2}{4L^2}\right)^{\frac{1}{2}}$$

Notice that in taking the $(-1)^{\frac{1}{2}}$ outside the y bracket we have had to turn the expression round.

Now $x^2+y^2 = 1/LC = \text{const.}$

This is the equation of a circle. The roots turn off the real axis in the paths shown in Fig. 9. When R falls to zero the roots reach

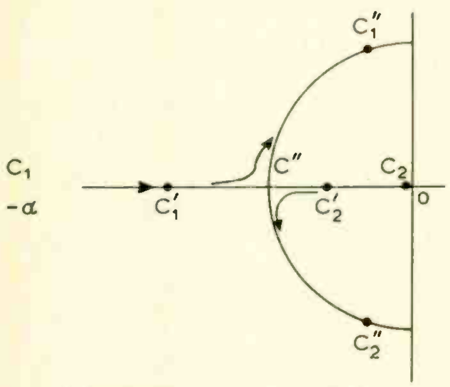


Fig. 9. Locus of roots as R is varied.

the imaginary axis at $\omega = \pm 1/(LC)^{\frac{1}{2}}$. If R becomes negative the roots will penetrate into the right-hand side of the plane, in which the transient "ring" of the circuit grows steadily in amplitude. I do not think I shall have space to follow them there, at least not this month. Very often we try to get this class of system to straddle the imaginary axis, sitting, like the Liberal Party, on the fence until the iron has entered its heart. This is the steady state class-A oscillation condition, in which R is controlled by a thermistor or an a.g.c. circuit. We may, alternatively, let the roots jump from side to side, in the oscillator circuits which use some clipping arrangement for maintaining the steady state.

All this discussion of the way in which the roots associated with a rather simple circuit move about as we change the element values can now be related to the result pictured in Fig. 6. The equation we use has

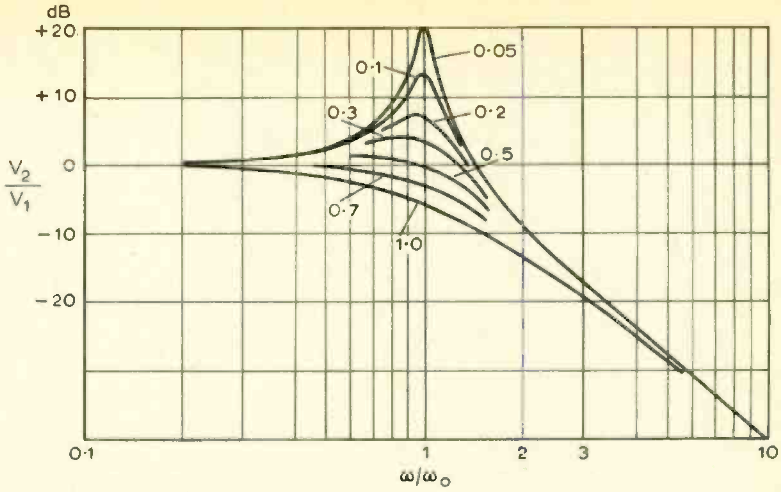


Fig. 10(a). $\frac{V_2}{V_1} = \frac{p_1p_2}{(p-p_1)(p-p_2)}$ *for various values of* $1/2Q_0$

already been given:

$$\frac{V_1}{V_2} = \frac{1}{p_1p_2}(p-p_1)(p-p_2)$$

and $(p-p_1)$ = the length P_1P
$(p-p_2)$ = the length P_2P

When P_1 is very close to the imaginary axis the term $(p-p_1)$ will dominate the behaviour in the region around $\omega = 1/(LC)^{\frac{1}{2}}$. This is the high-$Q$ situation, in which the resonance curve is symmetrical. As the Q is reduced, and P_1 moves to the left, the contribution of the second root at P_2 becomes more important and the response is no longer symmetrical. Indeed, the circuit is slowly transformed from tuned-circuit behaviour to low-pass filter behaviour. This is shown in Fig. 10, which gives a good idea of how, as the roots approach the axis, the response peak becomes the most important characteristic.

Most engineers who are designing equipment professionally are required to design to a specification, and most systems which can be related, sometimes in a rather roundabout way, to the second order network are specified in terms of frequency response. I do not think that, for practical design purposes, the root treatment is the most convenient. In operation, and this is particularly true of video systems and some mechanical systems, the transient response is really what matters, even though it is not such a tidy thing to put into a specification. Figure 11 shows the way in which the output varies with time when a unit step is applied to the input of our LCR circuit.

I am not going to work through the mathematics, but will simply quote the results. The roots, just to remind you, are at

$$-\alpha \pm j\omega_1$$

in which ω_1 is the diminished frequency,

$$\omega_1 = \left(\frac{1}{LC}-\frac{R^2}{4L^2}\right)^{\frac{1}{2}}, \text{ always less than}$$

$$\omega_0 = (1/LC)^{\frac{1}{2}}$$

The time from the switch-on to the first peak is

$$t_p = \pi/\omega$$

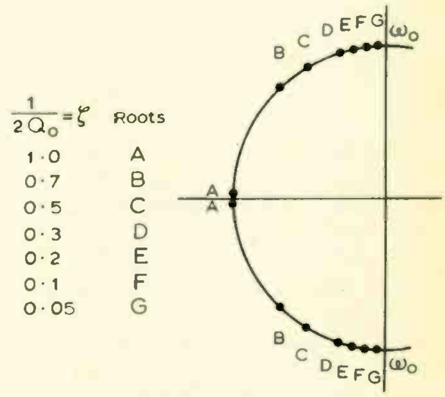


Fig. 10(b). Roots corresponding to responses in 10(a).

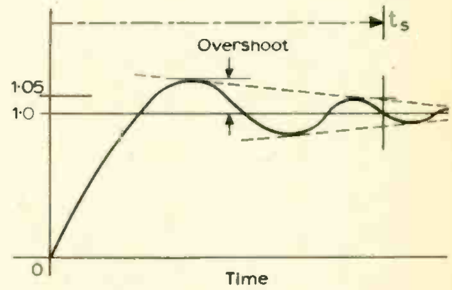


Fig. 11. Response of second order circuit to a step input.

The size of the first peak, that is to say the value reached at t_p, is

$$\exp -(\zeta\pi/(1-\zeta^2)^{\frac{1}{2}})$$

This depends only on

$$\zeta = R/2\omega_0 L = \alpha/\omega_0$$

In the special case of $\zeta = 0$ this has a value of 2, for $\zeta = 0{\cdot}7$, 1·04 and for $\zeta = 0$, 1·00.

When the system has a substantial ring the mechanical people look for this ring to decay to 5%, for the amplitude to lie between 0·95 and 1·05. This will occur after a time t_s, where

$$t_s = 3/\zeta\omega_0 = 6L/R = 3/\alpha$$

All this analysis of the LCR circuit is really only of value because it relates a new technique to a well-known way of behaving.

The technique itself is useful when the system is too flexible for the simple algebraic treatment to be economical. The root locus technique, introduced by Evans for servomechanism analysis, really does use the roots. A servo system is simply a feedback amplifier, except that very often the feedback network has unity gain. For such a system the equation

$$\mu_f = \mu/(1+\mu\beta)$$

reduces to

$$\mu_f = \mu/(1+\mu)$$

Here μ is the forward open-loop gain and μ_f the gain when the feedback loop is connected. The problems all arise because μ is frequency-dependent and can be written, in general, as

$$\mu = \frac{m(p)}{n(p)}$$

where $m(p)$ and $n(p)$ are polynomials in frequency. Typically, if there is one capacitive coupling and one stray capacitance,

$$\mu = \mu_m\left(\frac{j\omega\tau_1}{(1+j\omega\tau_1)(1+j\omega\tau_2)}\right)$$

showing a 6dB/octave tail off at low and high frequencies.

If we take a rather simpler system, which only rolls off at high frequencies,

$$\mu = \mu_m\left(\frac{1}{1+j\omega\tau}\right)$$

or

$$\mu = \mu_m\left(\frac{1}{1+p\tau}\right)$$

with a root at $p = -1/\tau$.

Now connect the feedback:

$$\mu_f = \frac{\mu_m}{1+p\tau}\bigg/\left(1+\frac{\mu_m}{1+p\tau}\right) = \frac{\mu_m}{(1+\mu_m)+p\tau}$$

The root is now at $p = -\tau/(1+\mu_m)$ and by altering μ_m we can move this root about. We are only moving it along the negative real axis, which is pretty dull, but still, it moves.

Two stages of this general kind give us

$$\mu = \mu_m/(1+p\tau_1)(1+p\tau_2)$$

and

$$\mu_f = \mu/(1+\mu)$$

$$= \frac{\mu_m}{\mu_m+(1+p\tau_1)(1+p\tau_2)}$$

We now look for the roots of

$$(1+p\tau_1)(1+p\tau_2)+\mu_m = 0$$

Expanding

$$\tau_1\tau_2p^2+(\tau_1+\tau_2)p+(1+\mu_m) = 0$$

Now, of course, there are two roots. For $\mu_m = 0$ they are at $p = -\tau_1, -\tau_2$. As μ_m is increased they begin to move towards the common value

$$\frac{-(\tau_1+\tau_2)}{2\tau_1\tau_2}$$

and when

$$4\tau_1\tau_2(1+\mu_m) > (\tau_1+\tau_2)^2$$

they acquire an imaginary component. These roots move in much the same way as the roots in Fig. 8 except that here we are varying the gain of an amplifier. The roots stay safely in the left-hand half of the plane, so that the system is always stable.

I am going to cheat a little here. As the roots are moving independently, I am going to start them off together. In the example of two roots this means that I lose the region where they are approaching each other along the real axis. With three roots the equation is then

$$p^3\tau^3+3p^2\tau^2+3p\tau+(1+\mu_m) = 0.$$

We are interested in the way the roots behave as we change μ_m because we fear, indeed in this example we know, that if μ_m is chosen incorrectly the system will be unstable. For the special case of $\mu_m = 0$ the roots all lie at $p = -1/\tau$, safely in the left-hand side of the plane, where transients die quietly away. The cubic equation has one real root and two roots which may be real or may be a complex conjugate pair, $\alpha \pm j\beta$. It is soluble by formula, but as a guide to the tricks which are employed for more complicated systems we can work rather differently. The first thing is to see what Routh's criterion can tell us. We tabulate the coefficients, like this:

$$\begin{array}{ll} \tau^3 & 3\tau \\ 3\tau^2 & 1+\mu_m \\ \dfrac{9\tau^3-\tau^3(1+\mu_m)}{3\tau^2} & \end{array}$$

The last term is $(a_1a_2-a_0a_3)/a_1$, where the original equation was

$$a_0p_3+a_1p^2+a_2p+a_3 = 0.$$

If all the terms in the left-hand column have the same sign the system is stable. Now τ^3 and $3\tau^2$ are positive, so that

$$9\tau^3-\tau^3(1+\mu_m) \text{ must be positive too.}$$

For stability, $\mu_m < 8$, or, to put it another way, if $\mu_m = 8$ there must be a root on the imaginary axis. As $p = 0$ is not a root, there must be a complex conjugate pair, $p = \pm j\omega$. The equation is now

$$\tau^3p^3+3\tau^2p^2+3\tau p+9 = 0$$

and the roots give us

$$(p-p_0)(p^2-p_1{}^2) = 0$$

$$p^3-p_0p^2-p_1{}^2p+p_0p_1{}^2 = 0$$

compared with

$$p^3+(3/\tau)p^2+(3/\tau^2)p+9/\tau^3$$

Thus

$$p_0 = -3/\tau$$

$$p_1 = \sqrt{-3/\tau} = \pm j\sqrt{3/\tau}.$$

This information enables us to sketch in the root locus of Fig. 12, which shows how the 3 roots diverge from the starting point at $\mu_m = 0$. It can be seen that even with μ_m less than 8 the roots are getting rather near the axis, and we would expect a substantial overshoot. We need to follow the roots in detail. At this point I must quote from the preface to Bode, "Network Analysis and Feedback Amplifiers":

"Invincible fatigue set in before these chapters could be written."

Actually, space, not fatigue, is the problem. It seems more important to leave the construction of the locus patterns until, say, Christmas, and to remind the reader of the

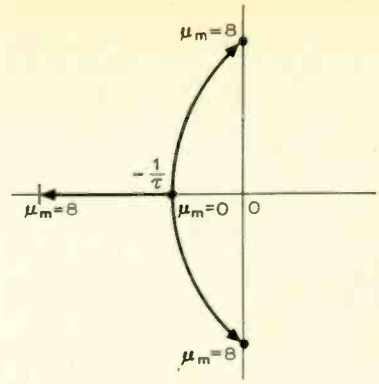


Fig. 12. Movement of three roots.

physical realities. All this talk about roots is fine for the mathematicians, but what does it mean to the man who is slaving over a hot oscilloscope all day? A root is simply a normal frequency of the system, what comes naturally if you give it some energy to play with. The fact that the frequency defined in this way is not just the ω of $\sin \omega t$, but is the complex number $(\alpha+j\omega)$ is the reminder that transients will either die away, in a passive circuit, or grow, in an unstable feedback system. If they grow, they go on growing, theoretically, for ever. Practically, the system equations are changed by one mechanism or another. Pure sine waves are special and, as every oscillator designer knows, cost extra.

I began this article with words sung on the trails to the Far West: the appropriate ending would seem to be: "There's a long long trail awinding. . . ."

Conferences and Exhibitions

Further details are obtainable from the addresses in parentheses

LONDON

June 1-4 New Horticultural Hall
Inventions & New Products Exhibition
(Business Conferences & Exhibitions, Mercury House, Waterloo Rd, London S.E.1.)

June 9-11 Savoy Place
Electrical Interference in Instrumentation
(I.E.E., Savoy Pl., London W.C.2.)

June 12 & 13 Waldorf Hotel
Professional Recording Equipment
(J. N. Borwick, Association of Professional Recording Studios, 47 Wattendon Road, Kenley, Surrey)

UXBRIDGE

June 30-July 2 Brunel University
Mobile Radiocommunication Systems
(Soc. of Electronic and Radio Technicians, Faraday House, 8-10 Charing Cross Road, London W.C.2.)

OVERSEAS

June 2-5 Boulder
Precision Electromagnetic Measurements
(National Bureau of Standards, Boulder, Colorado)

June 8-10 San Francisco
International Conference on Communications
(I.E.E.E., Suite 2210, 701 Welch Road, Palo Alto, California 94304)

June 18 & 19 Minneapolis
Solid State Sensors
(R. S. Dyck, Fairchild Semiconductor, 4001 Miranda Ave., Palo Alto, California 94304)

Active Filters

11. More on the parallel-T network

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

Variable tuning with constant bandwidth

Since the balanced parallel-tee network has the short-circuit output currents of the phase-lag and phase-advance branches, I_1 and I_3, always at a constant 180° phase difference, it follows that balance (zero transmission) may be obtained at a new frequency by varying only the relative amplitudes of I_1 and I_3. This principle is employed in the circuit shown in Fig. 1(a), in which varying the fraction x applied to the phase-lag branch gives $\omega_0 \propto \sqrt{x}$ and $q \propto \omega_0$, i.e. constant bandwidth. With the input at V_1 tuned-circuit response is obtained, Fig. 1(b). Using only simple tran-

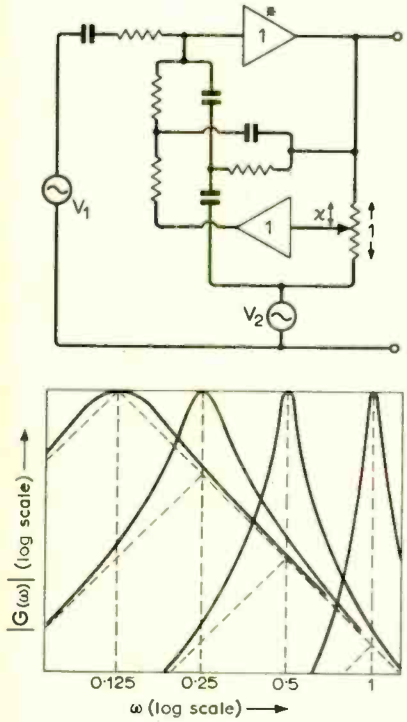


Fig. 1. Use of a potentiometer to give variable tuning with constant bandwidth.

sistor amplifiers the useful tuning range may be restricted to some 3 or 4 : 1. (Because of the increasing reactance of the capacitance of the input arm as frequency is reduced, there is a tendency with amplifiers of only moderate internal gain and input impedance for the peak gain to fall off as x is reduced.)

With the input at V_2 the response is a constant-bandwidth variable-frequency symmetrical notch response, with -3dB points the same as for the corresponding tuned-circuit response. The same principle of variable tuning may be applied to circuits in the "virtual-earth" arrangement.

Third order systems

From any of the low-pass or high-pass configurations described an output may be taken from the junction of the two components in the damping branch (via a buffer amplifier if necessary). This will give a response $V_{out}' = V_{out}/(1+pT)$ for the low-pass connection, Fig. 2(a), or $V_{out}' = V_{out}\, pT/(1+pT)$ for the high-pass, Fig. 2(b). In

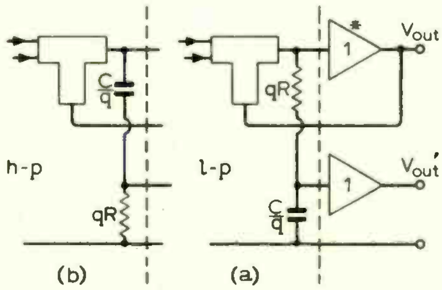


Fig. 2. Use of damping branch to give 3rd-order response.

this way, for example, the additional simple lag (or lead) circuit that is required for odd-order Butterworth responses can be provided with the saving of a CR network.

Using a parallel-tee network with $T_1 = T_2 = T$ necessarily means that the time constant of the additional lag (or lead) is T also. This restriction can be removed by using a parallel-tee network in which component values are chosen to make $T_1 = T/y$, $T_2 = yT$ (so that $T = \sqrt{T_1 T_2}$). Then

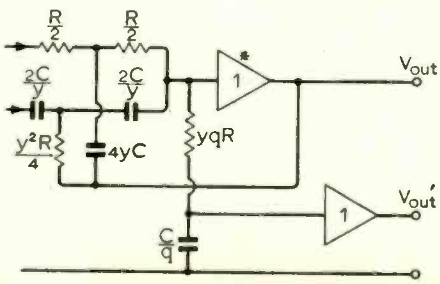


Fig. 3. Network in which $T_1 \neq T_2$.

$V_{out}' = V_{out}/(1+pyT)$ for the low-pass connection shown in Fig. 3, or $V_{out}' = V_{out}\, pyT/(1+pyT)$ for high-pass. It is easily shown however that the residual loss due to finite gain is now given by

$$\frac{1}{q_r} = \frac{2}{A}\left(y+\frac{1}{y}\right) \qquad (1)$$

and it is necessary to check that any required value of y does not impair the performance unacceptably (e.g. if $y>q$ the performance will be worse than that obtained from the lag-lead circuits described in Part 6).

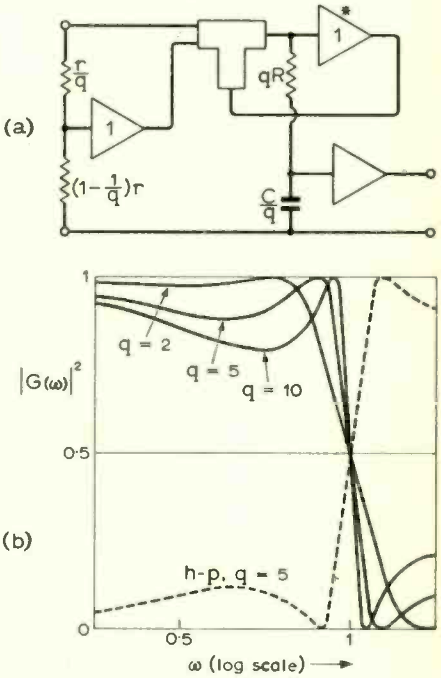


Fig. 4. 3rd-order responses obtainable from active parallel-T system. Note linear power scale.

A third order low-pass system, Fig. 4(a), with a special characteristic is defined by the transfer function

$$G(p) = \frac{1-(1-1/q)\,p^2T^2}{1+pT/q+p^2T^2}\cdot\frac{1}{1+pT} \qquad (2)$$

The frequency response is given by

$$|G(\omega)| = \left\{1+\frac{[(1-1/q)-\omega^2T^2]^2\omega^2T^2}{[1-(1-1/q)\,\omega^2T^2]}\right\}^{-\frac{1}{2}} \qquad (3)$$

which shows that $|G(\omega)| = 1$ at a frequency $\omega_1 = (1-1/q)^{\frac{1}{2}}/T$, as well as at $\omega = 0$, and that, as well as at $\omega = \infty$, $|G(\omega)| = 0$ at the notch frequency $\omega_\infty = 1/(1-1/q)^{\frac{1}{2}}T$. If it is required to build a filter to separate two signals so that one is passed without attenuation and the other rejected, this particular response will do this with the minimum value of q. If the signal to be rejected is the higher of the two frequencies a low-pass filter is used, and tuned so that ω_∞ is at this signal frequency and ω_1 is at the frequency of the signal to be transmitted. These requirements are satisfied by

$$T = 1/\sqrt{\omega_1\omega_\infty} \qquad (4)$$

$$\frac{1}{q} = 1-\frac{\omega_1}{\omega_\infty} \qquad (5)$$

For the opposite requirement the corres-

* Royal Radar Establishment.

ponding high-pass response is used and the positions of ω_1 and ω_∞ are interchanged. It will be noted that the low-pass and high-pass responses cross over at the half power points, and that they are complementary on a power basis (V^2), Fig. 4(b).

Analysis of the parallel-T network

Consider I_1 and I_3, the short-circuit output currents of the tees, Fig. 5. In the absence of C_2 the resistors R' and R'' form a potential divider, and the voltage at their junction would be $V_1R'/(R'+R'')$. When C_2 is present this voltage falls at higher frequencies, being modified by a factor which is the transfer function for a CR lag network, $1/(1+pT_2)$, where T_2 is the time constant of a network consisting of C_2, R', and R'', all in parallel, as equn. (2), Part 10. Consequently I_1, which is the current through R', is given by

$$I_1 = \frac{V_1}{R'+R''} \times \frac{1}{1+pT_2} \qquad (6)$$

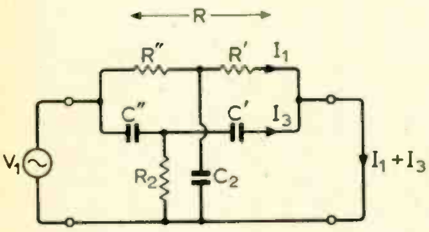


Fig. 5. General parallel-T network.

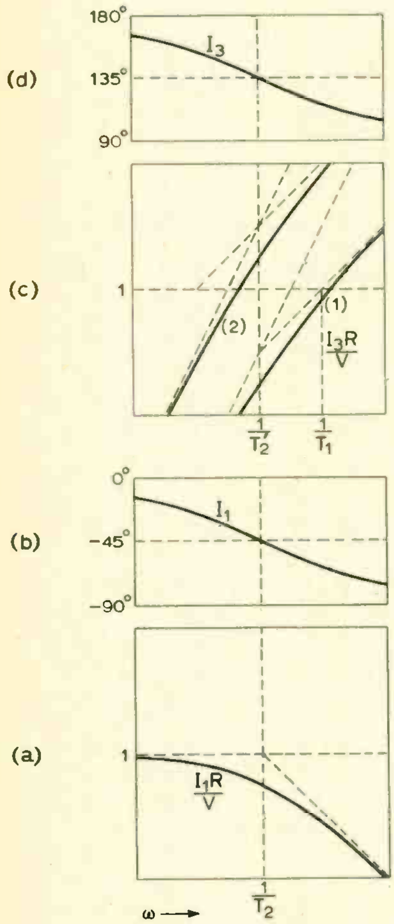


Fig. 6. Phase and amplitude plots of the short-circuit output currents of the two tees for constant input voltage.

$$= \frac{V_1}{R(1+pT_2)}, \text{ if } R'+R'' = R. \qquad (7)$$

For constant V_1, therefore, the amplitude and phase of I_1 vary with frequency as shown in Figs. 6(a) and (b).

Similarly in the absence of R_2 the capacitors C' and C'' form a potential divider, and the voltage at their junction would be $V_1C''/(C'+C'')$. When R_2 is present the voltage falls of at lower frequencies, being modified by a factor which is the transfer function of a CR lead network, $pT_2'/(1+pT_2')$, where T_2' is the constant of a network consisting of R_2, C', and C'', all in parallel, equn. (3), Part 10. Consequently I_3, the current through C', is given by

$$I_3 = \frac{V_1C''}{C'+C''} \times \frac{pC'pT_2'}{1+pT_2'} \qquad (8)$$

which, by substitution from equn. (4), Part 10, becomes

$$I_3 = \frac{V_1}{R} \times \frac{p^2T_1T_2}{1+pT_2'} \qquad (9)$$

For constant V_1, therefore, the amplitude and phase of I_3 would vary with frequency as shown in Figs. 6(c) and (d), curves (1) and (2) corresponding to $T_1 < T_2'$ and $T_1 > T_2'$ respectively. It will be noted that although the amplitude changes with change of T_1 the phase is unaffected.

By making the substitution $p = j\omega$, the frequency-dependent factors of the expressions for I_1 and I_3 become

$$\frac{1}{1+j\omega T_2} \text{ and } \frac{(j\omega)^2T_1T_2'}{1+j\omega T_2'}$$

When $T_2 = T_2'$ these two factors differ only in the numerators, and the j^2 in the second compared with no j in the first means that then I_3 has a constant 180° phase advance on I_1 (i.e. at all frequencies). In other words: when $T_2 = T_2'$ the corner frequencies for the amplitude curves in Figs. 6(a) and (c) are the same, and the two phase curves, Figs. 6(b) and (d), which are the same shape, lie directly one above the other and 180° apart. Consequently, where the amplitudes of I_1 and I_3 are equal, and a look at the amplitude curves shows that there must always be such a frequency, the net output current is zero.

Thus the condition for a null is

$$T_2 = T_2', \qquad (10)$$

and, if this is satisfied, the frequency of the null, ω_0, is given by equating $|I_1|$ and $|I_3|$, obtained from equns. (7) and (8) by substituting $p = j\omega$,

$$\omega_0 = 1/\sqrt{(T_1T_2)}. \qquad (11)$$

When the network has the commonly used component values which make $T_1 = T_2 = T$,

$$I_1 = \frac{V_1}{R} \times \frac{1}{1+pT} \qquad (12)$$

and
$$I_3 = \frac{V_1}{R} \times \frac{p^2T^2}{1+pT} \qquad (13)$$

Whence $\omega_0 = 1/T \qquad (14)$

and at the null frequency I_1 is 45° lagging with respect to V_1 and I_3 135° leading. The phase and amplitude plots are shown in Fig. 7.

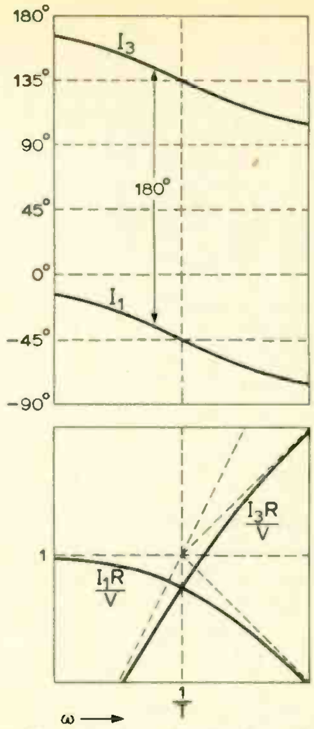


Fig. 7. Phase and amplitude plots when $T_2' = T_2$.

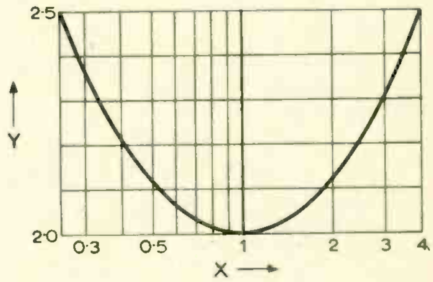


Fig. 8. Plot of equn. (19).

To find the open-circuit output voltage, the short-circuit output current may be multiplied by the output impedance (the impedance seen by looking in at the output terminals with the input shorted). For the symmetrical network shown in Fig. 2, Part 10, this is easily found and is

$$Z_{out} = \frac{R(1+pT)}{1+4pT+p_2T_2}. \qquad (15)$$

Consequently the open-circuit output voltage, $(I_1+I_2)Z_{out}$, is obtained by substituting from equns. (12) and (13) as

$$\frac{V_0}{V_1} = \frac{1+p^2T^2}{1+4pT+p^2T^2}. \qquad (16)$$

For the general case, Fig. 1, Part 10,

$$Z_{out} = \frac{R(1+pT_2)}{1+p(T_1/b'+T_2/b)+p^2T_1T_2} \qquad (17)$$

where $b = R'/(R'+R'')$ and $b' = C'/(C'+C'')$. The transfer function may then be found as above, using equns. (7) and (8), and the Q factor obtained,

$$\frac{1}{q_0} = \frac{1}{\sqrt{(bb')}}\left\{\left(\frac{bT_1}{b'T_2}\right)^{\frac{1}{2}} + \left(\frac{b'T_2}{bT_1}\right)^{\frac{1}{2}}\right\}. \qquad (18)$$

Dependence of q_0 on the ratio T_1/T_2

With an adequate margin of loop gain, the value of q is not much affected by small changes to the value of q_0. Advantage may be taken of this when selecting components to satisfy a design value for T. The expression for q_0, equn. (18), can be written $1/q_0 = Y/\sqrt{bb'}$, where Y is of the form

$$Y = X^{\frac{1}{2}} + 1/X^{\frac{1}{2}} \qquad (19)$$

Maximum value of q_0 (for any particular values of b and b') is obtained when Y has minimum value, which is $Y = 2$ when $X = 1$. But Fig. 8 shows that there can be appreciable latitude in the value of X without much increase in Y and, hence, decrease in q_0. Little is lost provided that X is kept within the bounds, say,

$$\tfrac{1}{2} < X < 2 \qquad (20)$$

(when $b = b'$, $X = T_1/T_2$).

The eight-component parallel-T network

For experimental purposes it is worth noting that a parallel-tee network may be built using eight components, arranged as in Fig. 9, made up of two pairs of matched resistors and two pairs of matched capacitors, and that it will automatically satisfy the necessary condition for balance. This is evidently so, since both T_2 and T_2' are now formed by a parallel combination of resistors R' and R'' with a parallel combination of capacitors C' and C'', i.e.

$$T_2 = T_2' = \frac{R'R''\,(C'+C'')}{R'+R''} \qquad (21)$$

T_1, defined in the same manner as for equn. (4), Part 10, is now given by

$$T_1 = \frac{C'C''\,(R'+R'')}{C'+C''} \qquad (22)$$

and, therefore

$$T = \sqrt{T_1T_2} = \sqrt{C'R'C''R''} \qquad (23)$$

which gives the possibility of meeting a design value of T by manipulation of the values of four independent variables. It is, however, necessary to check that the resulting value of q_0 is satisfactory. A quick answer can be obtained by putting $k_1 = R'/R''$ and $k_2 = C''/C'$, and substituting in the equation

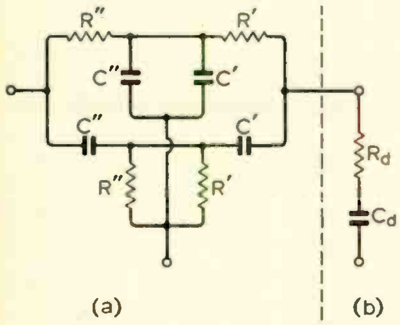
$$\frac{1}{q_0} = \frac{2+k_1+k_2}{\sqrt{k_1k_2}} \qquad (24)$$

For the best result the components should be positioned to make both k_1 and $k_2 > 1$.

The values of the components in the corresponding damping branch are shown in Fig. 9(b).

A particular case of the eight component parallel-tee network, Fig. 10, uses four equal resistors and four equal capacitors, i.e. $R' = R'' = R$ and $C' = C'' = C$, giving $T = CR$ and $q_0 = \frac{1}{4}$. To reduce the effect of scatter in the values of the components, they should be grouped in pairs of most nearly equal values and disposed as in Fig. 9(a).

The advantage of the eight component network is that simple bridge methods may be used to select, or make up, matched pairs of components. This takes care of the most important requirement that T_2 should equal T_2'. However if the absolute values are too much in error, some adjustment may be needed to $T\,(=\sqrt{T_1T_2})$. Small adjustments can be made to T, without affecting the balance $T_2 = T_2'$, by making equal incremental adjustments to both components of any pair of components.



$$T = \sqrt{C'R'C''R''}$$

$$R_d = q\sqrt{R'R''}\left(\sqrt{\frac{C'}{C''}}+\sqrt{\frac{C''}{C'}}\right)$$

$$C_d = \frac{\sqrt{C'C''}}{q}\cdot\frac{1}{\left(\sqrt{\frac{R'}{R''}}+\sqrt{\frac{R''}{R'}}\right)}$$

Fig. 9. Balanced parallel-T network constructed from matched pairs of components.

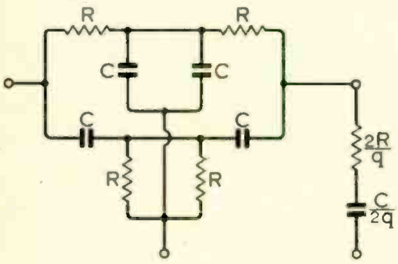


Fig. 10. Particular case of Fig. 9.

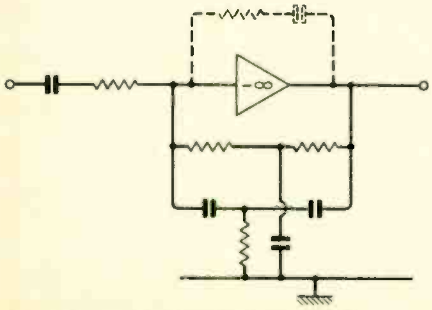


Fig. 11. Parallel-T selective amplifier.

The parallel-T filter considered as a 3rd-order loop

The filter shown in solid lines in Fig. 11 gives, when the circuit values are correct, tuned-circuit response with infinite Q. If it is redrawn as in Fig. 12, it can be seen that there is a loop containing a modified integrator and a simple lag. The frequency-dependent part of the transfer function of the modified integrator (output voltage/input current) is of the form $(1+pT_2)/p^2T_2^2$, and for the simple lag the corresponding relevant function (short-circuit output current/input voltage) is $1/(1+pT_1)$. In terms of the standard diagram, Fig. 13, therefore,

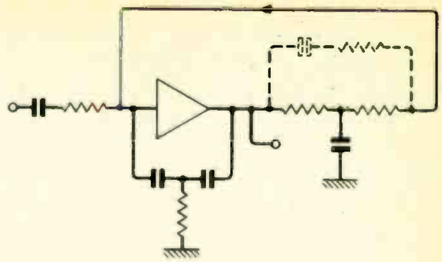


Fig. 12. Circuit of Fig. 11 re-drawn.

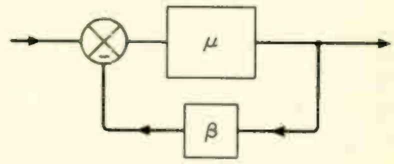


Fig. 13. Standard diagram of feedback loop.

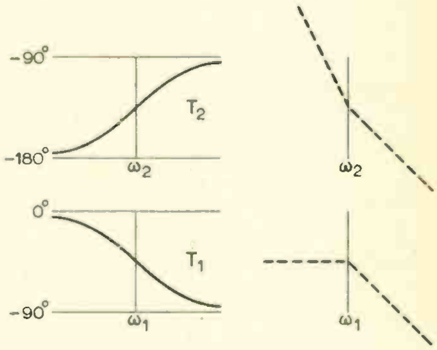


Fig. 14. Phase and asymptotic gain diagrams for the two portions of the loop.

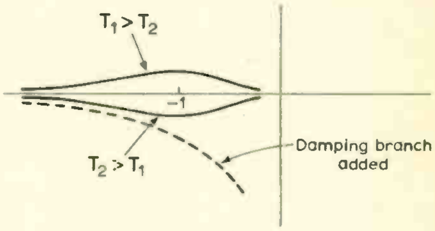


Fig. 15. Nyquist diagrams or loci of $\mu\beta$.

$$\mu\beta = k_1k_2\,\frac{1+pT_2}{p^2T_2^2}\cdot\frac{1}{1+pT_1} \qquad (25)$$

When $T_1 = T_2 = T$, this reduces to k_1k_2/p^2T^2, the same form as for two integrators in cascade, corresponding to a constant phase shift of 180°. As may be seen from the phase diagrams, Fig. 14, when $T_1 > T_2$, $\omega_1 < \omega_2$ and the phase shift at frequencies between 0 and ∞ is greater than 180°: the system is therefore unstable. When $T_2 > T_1$, $\omega_2 < \omega_1$ and the phase shift at frequencies between 0 and ∞ is less than 180°. The Nyquist plot therefore passes the $-1, j0$ point on the safe side, Fig. 15, and the system is stable. The damping branch when connected introduces phase advance, making the loop stable even when $T_1 = T_2$ and the shape of the Nyquist plot becomes approximately as shown in the diagram.

Modern Direct Voltage Calibration System

A look at a precision commercial measuring equipment

by H. Stern, B.Sc.

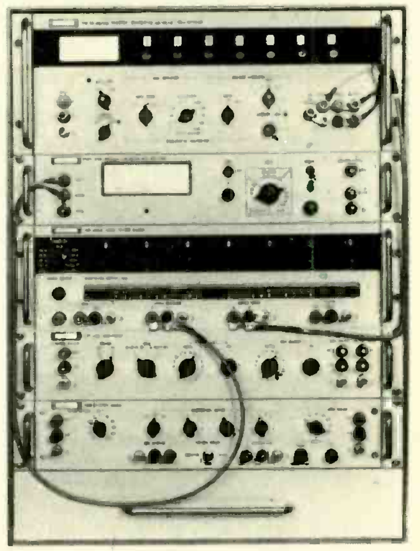
Today we have available transportable instruments readable to a precision previously only attainable in the standards room. This improved accuracy brings with it the necessity of checking the instruments concerned regularly to maintain the claimed performance. The classical methods of checking voltmeters are, of course, still available, but to secure the highest accuracy considerable skill and time are necessary. In consequence, new techniques, which have been derived from the classical ones and which allow rapid re-calibration by persons other than a standards engineer, are being developed. One such approach is described in this article.

Voltage calibrator

The heart of any voltmeter calibration system is a stable voltage source—a voltage calibrator. Basically this is a very stable and accurately calibrated variable power unit. To cover the range of most voltage measurements it needs to go up to 1100V. It must be easily varied over its range and ideally should incorporate means of protecting both itself and the voltmeter on test from inadvertent damage.

A typical high grade voltage calibrator will have a calibration accuracy $\pm 0.002\%$ plus a small "floor" of between 10μV and 40μV. The stability of the unit, with regard to mains and load variations, must be of a higher order than this accuracy. The basic voltage control circuit (Fig. 1), constitutes a series regulator controlling the output from an unregulated d.c. supply. The error amplifier in combination with the series pass element (the section in the shaded portion) can be regarded as an operational amplifier, the gain of which is determined by R_a and R_b; the junction of R_a and R_b is the summing junction. E_{ref} is the input voltage to the amplifier so that the output E_{out} will be $(E_{ref} R_a)/R_b$[1,2]. Thus these three elements determine the output voltage from the calibrator and on them depends the stability of the output. In practice E_{ref} is constant while R_a and R_b can be varied. R_a determines the precise value of E_{out} while R_b determines the range.

The accuracy and stability of the reference voltage is vital to the performance of the calibrator. A zener diode is used as the reference element and is housed in a proportionally controlled oven. The zener controlled voltage is fed via the range resistor to the summing junction.



Complete calibration system.

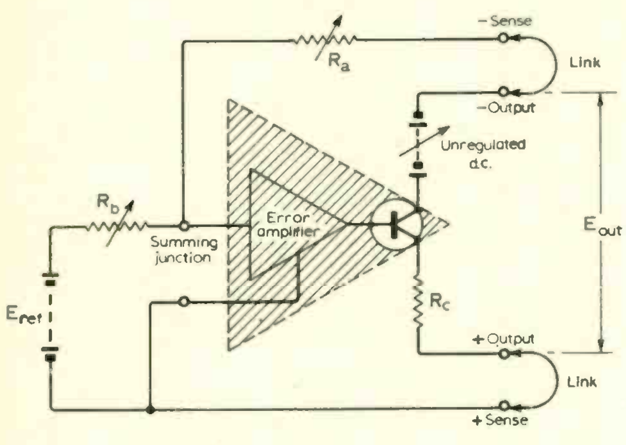


Fig. 1 (left). Voltage control block diagram —voltage calibrator.

R_a consists of sets of resistors, one set per decade, in cascade, so that the total value is determined by the settings of all the decades. Fig. 2 shows, in simplified form, one decade. All resistors in the decade have the same value and the value of resistance selected by S_{1a} is changed on alternate settings only. S_{1b} brings R_1 into circuit on the odd settings of the decade. This reduces the number of resistors required per decade and the number of adjustments needed when setting up. The final value can be set by means of a small variable resistor (typically 0.1% of the total value of the

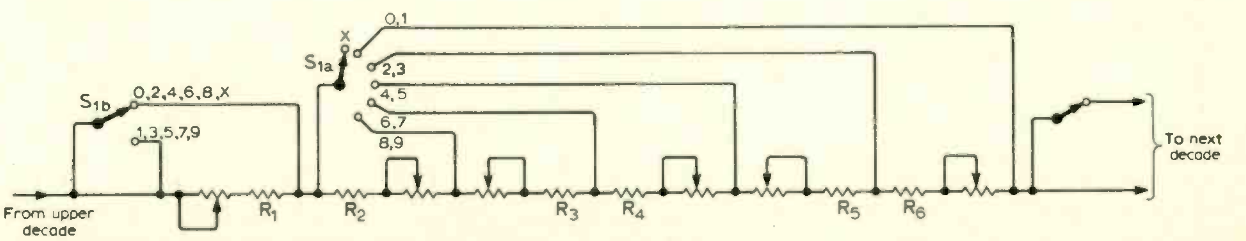


Fig. 2. Typical decade—voltage control feedback resistor.

particular section), in series with the major fixed resistor. Since the variable component is such a small proportion of the whole, the effect of its stability is negligible as a component of the instrument performance specification.

Pre-regulator: When a series regulator is used at low output settings a large portion of the power supplied from the raw d.c. supply must be dissipated in the series element. The efficiency of the device is then low, and heat, affecting both reliability and drift, is generated in this element. This can be eliminated by use of a pre-regulator (Fig. 3).

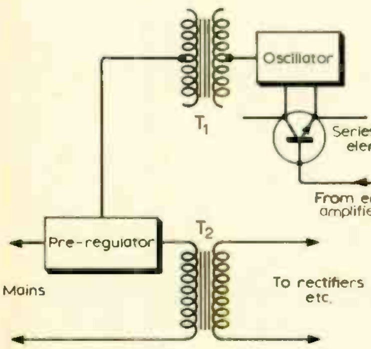


Fig. 3. Pre-regulator.

An oscillator shunts the series pass element and provides a control voltage varying with the voltage across the pass element. This control voltage is coupled via T_1 to the pre-regulator, in series with the mains transformer T_2. The pre-regulator switches off the supply to T_2 for a portion of the mains cycle depending on the voltage across the pass element; the greater this voltage the lower the duty cycle of the supply to T_2. Thus the energy supplied to T_2 and hence the raw d.c. supply voltage is reduced as the voltage across the series pass element tends to rise.

Remote sensing: One possible source of error is the voltage drop in the leads to the voltmeter on test. Even small loads and short leads may have appreciable effect when working at this high accuracy. For example, the drop in leads with a resistance of 30 milliohms at 1mA will be 30μV which may be equal to the calibrator accuracy when working on the 1V setting.

The problem is easily avoided by using a four wire system, removing the links shown in Fig. 1 and transferring their junction to the voltmeter on test.

Protection: A high voltage unit capable of such high accuracy needs protection against damage to itself and to the meter on test. Three different protective devices are employed: a variable current limiter, a current trip and a variable voltage trip.

The current limiter sets the maximum current drawn by the load so as to protect the voltmeter on test. Should the pre-set level be exceeded the calibrator acts as a constant current device and a panel warning light is illuminated. Should the limiter, for any reason, fail to operate and a severe overload, likely to damage the calibrator, occur, the current trip automatically switches the calibrator to a stand-by condition.

The load current is sensed by R_c in the positive output lead (Fig. 1) and the resultant voltage fed to the current limiter (Fig. 4). VR_1 is the current limiter adjustment, setting the base-emitter voltage of Tr_1, which is normally non-conducting. When over-current conditions occur, Tr_1 is rendered conducting by the voltage sensed across R_c and causes Tr_2 and Tr_3 to conduct. Tr_3 causes Tr_4 to draw current from the error amplifier bypassing part of the sampling resistor chain current. This causes a drop in the calibrator output voltage limiting the output current. Simultaneously the output from Tr_3 switches on the warning lamp circuit.

The current trip also uses R_c to sense the output current. In the case of severe current overload, this voltage switches over a monostable circuit which operates a relay de-energising the high voltage transformer. After removing the overload the calibrator may be restored to normal operation.

The purpose of the voltage trip is to protect the voltmeter on test from excessive voltage. Should a pre-set voltage be exceeded the high voltage is removed in a similar way to the current trip

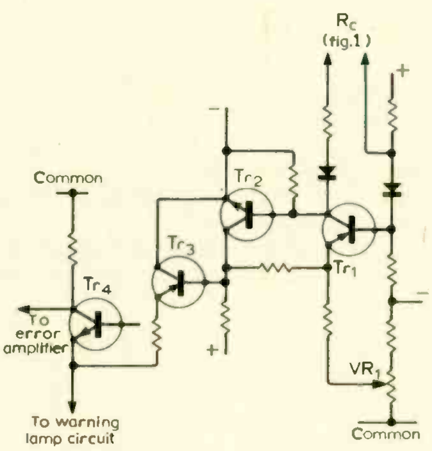


Fig. 4. Simplified current limit circuit.

operation. The variable control on the voltage trip circuit is provided by controlling a reference bias on a transistor which is normally non-conducting. If the main output rises sufficiently high the transistor conducts to operate the trip circuitry.

Checking calibration: However stable a calibrator may be it is essential that its calibration should be checked regularly The unit should be, as far as possible, self-checking and any equipment needed to check it should be readily available. The particular calibrator under discussion can be checked using a null detector (preferably with high input resistance), a standard cell and a stable voltmeter with adequate resolution.

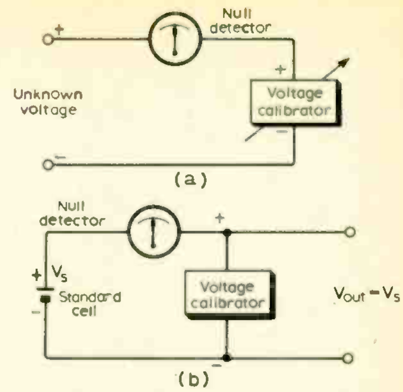


Fig. 5. Voltage calibrator and null detector used as (a) high resolution differential voltmeter (b) power standard cell.

It has already been noted that the sample decade (Fig. 2) has a '10' position, that is to say a 10% over-range. To distinguish this from the normal 10 using the 1 on the next decade up, it will, in the following, be designated X. This over-range facility means that there are two ways to arrive at most voltages, e.g. 20 = 10 + X, 30 = 20 + X, etc. The division accuracy is therefore checked by setting up each voltage in two ways, monitoring them using the voltmeter mentioned above and then adjusting one to equal the other by means of the pre-set controls. Only the even values are adjusted, since the design of the resistor chain implies that adjusting these resistors automatically sets the odd values.

There remains the necessity of checking the absolute accuracy of the calibrator. A standard cell and a high resistance null detector are connected as show in Fig. 5(b). The calibrator on its lowest range (10V) is set to the nominal standard cell e.m.f. and the reference circuit on the calibrator adjusted to give a null indication against the standard cell. Then, using a voltmeter as previously, the upper ranges may, in turn, be checked against the over-range voltages on the next lowest range, e.g. 11V on the 100V range against 11V on the 10V range, and the appropriate range divider adjusted.

This procedure allows the accuracy of the calibrator to be referred back to a standard cell which can be certified by the appropriate national laboratory (e.g. N.P.L.) while the equipment, apart from the cell, stays in the user's laboratory.

Null detector

Many measurements involve nulling a known voltage or resistor against an unknown. For this purpose an electronic null detector is of great value since it can combine high sensitivity with high input resistance.

The null detector consists basically of high sensitivity transistor voltmeter with a centre zero.

Apart from being used independently, it may be connected to the calibrator to form a high resolution differential voltmeter

(Fig. 5a). An extension on this arrangement is the "power standard cell" (Fig. 5b) wherein a voltage equal to that of the standard cell, but of low source resistance is obtained. This is achieved by nulling the output of the calibrator against the standard cell and then using the calibrator output as the voltage source. Variations in the calibrator voltage are continuously monitored by the null detector. The high input resistance of the null detector protects the standard cell.

Reference Divider

The calibrator described may be used on its own; this divider complements it and serves as an aid to checking the calibrator output. A simplified circuit diagram is shown in Fig. 6. The upper portion is a simple voltage divider while the lower, associated with the standard cell voltage, is a Kelvin-Varley divider. The output from this K-V divider is fed to a standard cell in series with a high resistance null detector. The ratios are such that, when a nominal voltage is fed directly into any higher tap, the voltage across the 'standard cell' portion should be equal to that cell e.m.f. as set up on the K-V divider and can be compared with the cell e.m.f.

Normally, the input is fed in via the over-voltage circuit, the two adjustment rheostats and the input voltage switch. The input voltage can then be nulled against the standard cell either by means of the two adjustment rheostats or at the source. In either case a slightly higher voltage than the nominal input voltage at the divider will be required to compensate for the drop in the rheostats and the protection circuit.

The unit can now be used as a voltmeter calibrator; a suitable voltage is fed in and the output from this and lower taps used to check the cardinal points on the voltmeter. If the meter draws current when connected to a lower tap, the standardisation procedure must be performed with the voltmeter in circuit, to allow for the voltage drop in the intermediate section of the divider.

The divider may also be used to check power supply or voltage calibrator output voltages. The input voltage is fed to the 'output' connections to avoid voltage drop in the rheostats and protection circuit. Care must be taken to avoid overloading the divider in these circumstances. The power unit output is adjusted by nulling against the standard cell.

This procedure forms part of the more detailed calibration for the voltage calibrator mentioned earlier. Its advantage is that all ranges on the calibrator are checked directly against the standard cell and a greater accuracy may be achieved. Moreover, the checks can be performed at a variety of voltages including the full scale value on any range of the calibrator.

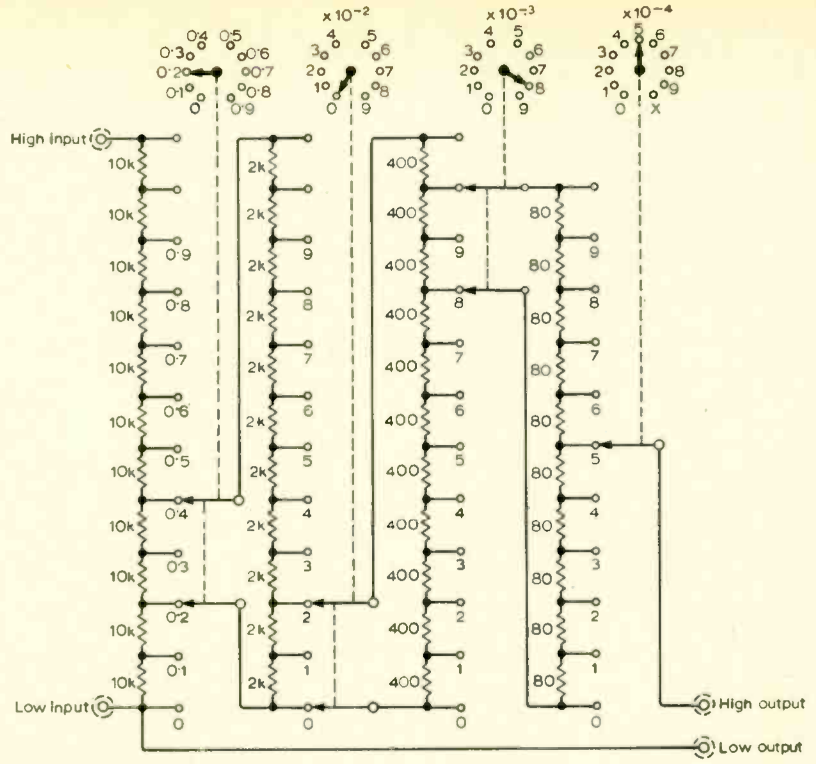


Fig. 7. Kelvin-Varley divider—basic configuration.

Resistive ratio standard Kelvin-Varley divider

This unit serves a variety of purposes, including that of providing a standard against which to check the reference divider. Because ratios are unitless quantities they may be set up and checked without recourse to certification by outside bodies. This makes a ratio device a very useful tool in the standards laboratory.

The most widely used types of ratio standard are the universal ratio set and the Kelvin-Varley divider. When used for resistance measurements with conventional galvanometers the former is more responsive at low values of resistance, while the K-V divider has advantages at high values. However, if a high input resistance null detector is employed the K-V divider can be used over a wider range than the universal resistance set and, because of its higher resistance (between 10 and 100kΩ compared with 2kΩ for the U.R.S.), can handle higher voltages (1kV compared with about 50V). It is also less complex and therefore less expensive.

Fig. 7 shows the basic K-V divider. Each decade, except for the lowest, consists of eleven equal resistors and the total resistance looking back into successive decades is equal to the value of two of the resistors in the preceding decade. Thus, the first decade contains eleven 10kΩ resistors and the next decade has a total

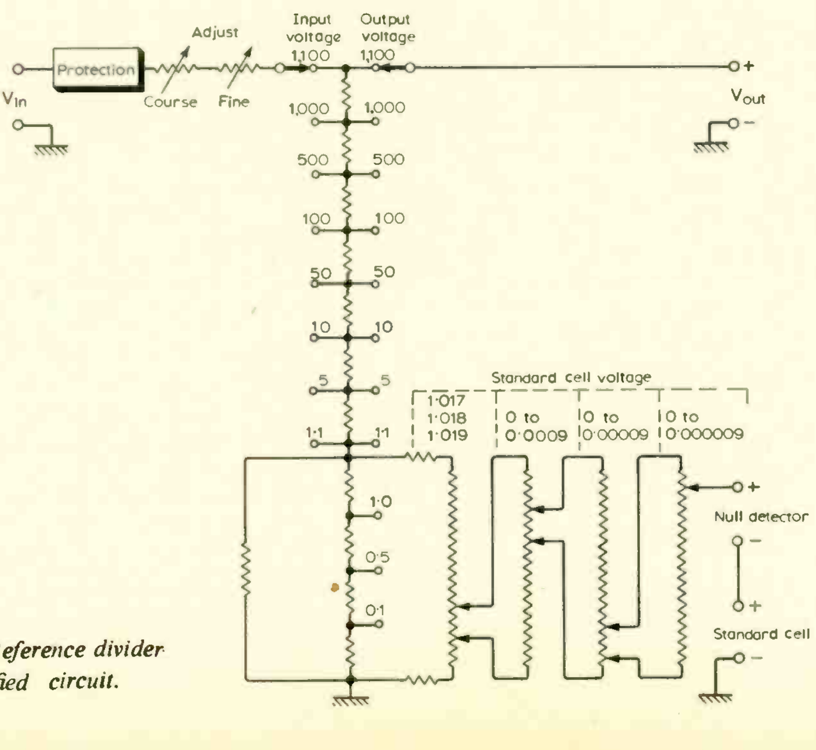


Fig. 6. Reference divider —simplified circuit.

resistance of 20k Ω. (At first sight it appears to be 22k Ω—but read on.)

A pair of switches shunts each decade across two adjacent resistors in the previous decade, so halving their effective value. Thus the resistance between the high and low input terminals in Fig. 7 is 100k Ω. Similarly, the next decade has a total resistance of 20k Ω instead of 22k Ω because of the shunting effect of the third decade. And so on down the chain. The last decade contains only ten resistors. The load on the output should have a high resistance compared with this decade if errors are not to occur. The input resistance of the divider will then be constant at all settings.

Although only four decades are illustrated, it is possible to cascade a large number if desired. The divider used in the system under discussion has seven decades.

If the simple circuit of Fig. 7 was used for a seven decade unit the value of each resistor in the last decade would be 0.64 Ω. This is inconveniently low, since wiring and switch resistance can have a serious effect on accuracy. Using a higher set of values in the top decade would result in an excessive value there. The problem is overcome by using higher values for the resistors in lower decades and then shunting the whole decade with a resistor to bring the total resistance, looking back into it, down to the correct value. For example, 1k Ω resistors are used in the three lowest decades and each decade is shunted by a 2.5k Ω resistor to bring its total resistance down to 2k Ω.

There remains the problem of checking and re-setting the division accuracy of the divider. The most important resistors are those in the highest decades and each

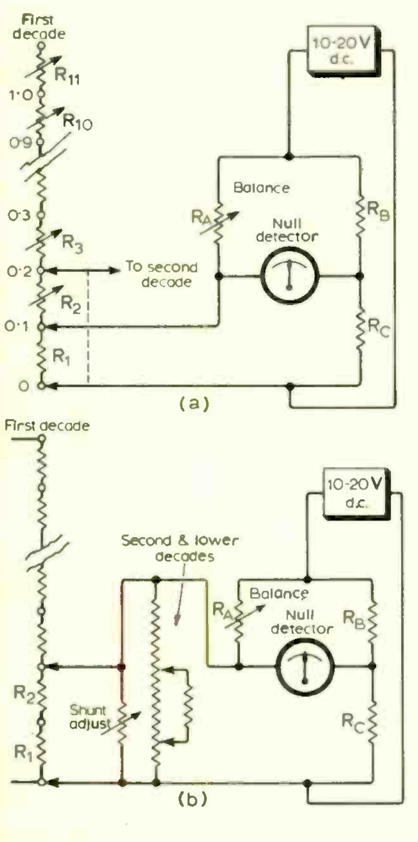


Fig. 8. Linearizing Kelvin-Varley divider.

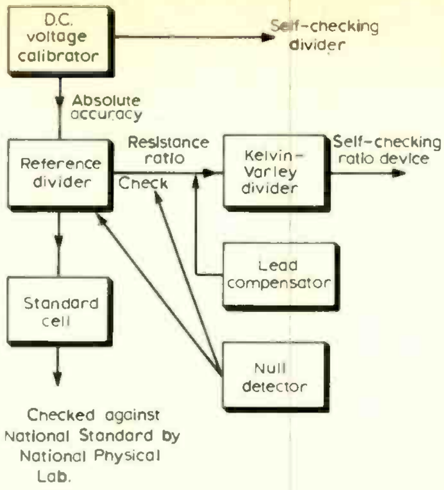


Fig. 9. Tracing measurement to the national standard of voltage.

resistor in the top three decades may be adjusted by means of a small rheostat in series with it. The value of the rheostat is sufficiently small for any instabilities not to affect the overall performance.

To set up the divider we adjust the appropriate resistors in each of the three principal decades to equality with one another and adjust the shunt resistors on the second to fourth decades to render the resistance of the appropriate decade equal to two of the resistors in the preceding decade. Adjustment of individual resistors in the four lowest decades is not needed since the effects of normal variations in their values is insignificant. This procedure is facilitated by turning the appropriate section of the divider into a Wheatstone bridge (Fig. 8a). R_1 is the lowest resistor in the decade under test, R_A and R_C are extra resistors used only for this purpose. The bridge is balanced using R_A, then R_1 is replaced by R_2, the next resistor in the decade, and the bridge re-balanced by adjusting R_2. The process is repeated up the decade, adjusting R_3 to R_{11} in turn. The result is that each resistor in the chain has been adjusted to equality with R_1. Similarly with the next two decades. To adjust the shunt resistors the circuit is slightly re-arranged (Fig. 8b) and, without altering the bridge balance control, the shunt resistor for the appropriate decade is adjusted so that the parallel combination of R_1 and R_2, and subsequent decades is made equal in value to R_1.

The K-V divider has several applications; e.g. by dividing down an unknown voltage the unknown may be compared with a standard cell as with the reference divider, but without the unknown voltage needing to correspond to a cardinal point. In conjunction with a standard resistance, the K-V divider may be built into a bridge, the divider forming two arms, to allow accurate resistance measurements to be performed.

Particularly important is its use to check the division accuracy of the reference divider. The reference divider and the K-V divider are connected into a bridge circuit, each forming two arms of the bridge. Both dividers are set to the same nominal ratio and the appropriate adjustments made on the reference divider to balance the bridge. One other item which facilitates this process is a lead compensator.

The complete system

The units described together form a complete calibration system which, apart from the standard cell, can be checked and adjusted in-house to give accurate voltage and resistance ratio measurements traceable to the national standards. Fig. 9 illustrates the route through which the voltage standard's output can be traced to the standard cell which, in turn, can be checked by the national laboratory against their standards. Although the system reduces considerably the skill needed care must be taken to avoid errors due to thermal e.m.fs, (for example by using special interconnecting leads) and large ambient temperature variations. Last, but not least, care needs to be taken with earth connections,[3] so as to avoid anomalies due to common mode interference.

Acknowledgment

I am grateful to Fluke International Corporation for permission to publish this article.

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New Books

Principles of Pulse Code Modulation, by K. W. Cattermole, aims "to give a clear exposition of the principles and properties that are essential to a full understanding of the mechanism and quantitative appraisal of the performance of p.c.m." Mathematical complexity has been avoided and both physical explanation and links with the general theory of signal presentation are given. The discussion of quantizing includes, besides the elementary theory, spectral distribution, optimization, prediction and the effect of irregularities. The section on coding exhibits the diversity of mechanisms. The author was recently appointed Professor of Telecommunication Systems at the University of Essex, in 1968. Pp. 447 including index. 182 illustrations. Price 95s in U.K. Iliffe Books, Butterworth & Co., 88 Kingsway, London, W.C.2.

20 Solid State Projects for the Home, by R. M. Marston, includes circuits for motor speed control, photographic timing, and metal detection. Besides silicon planar bipolar transistors the circuits employ s.c.rs, triacs, i.cs. and unijunction and field effect transistors. Helpful constructional comments are made and detailed component lists given. Pp.105 and 54 illustrations. Price 25s for hard back and 18s for soft. Iliffe Books, Butterworth & Co., 88 Kingsway, London, W.C.2.

Circuit Ideas

Generating fast complementary pulses

The circuit of Fig. 1 provides equal amplitude positive and negative pulses. The control voltage has no critical level. The zener diode provides a path for the current created by generators Tr_3 and Tr_4. Poles a and b of the so formed unearthed source can be earthed by Tr_1 and Tr_2, provided that the absolute value of the potential at the emitters of Tr_3 and Tr_4 is greater than the zener voltage. When the input voltage is negative Tr_2 is saturated and b is earthed. When the control voltage reverses polarity Tr_1 saturates and a is earthed. With the collector currents of Tr_3 and Tr_4 made equal (by adjusting VR_1) the only current flowing through the saturated transistor is the current taken from the output. With a 5.6V zener diode and an offset of under 1mV for Tr_1 and Tr_2 the output pulses are equal to within 0.02%. Greater accuracy can be attained using a higher voltage zener and with transistors having a smaller offset voltage. Fig. 2 shows the rise and fall time of the pulses at the outputs when the input voltage is $\pm$ 4V.

A. IVANOV,
Sofia,
Bulgaria.

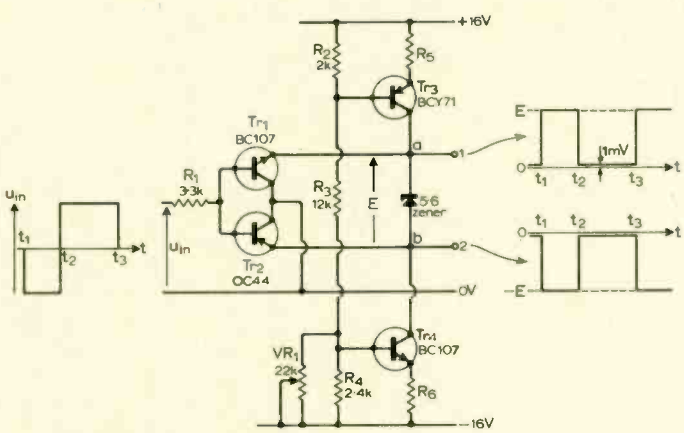


Fig. 1. Circuit of complementary pulse generator.

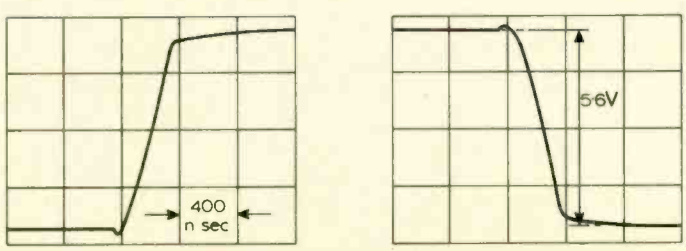
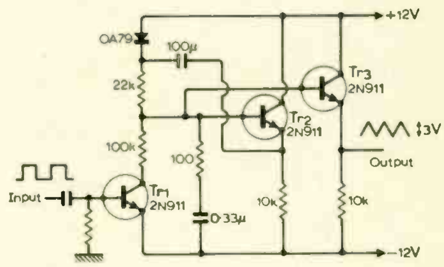


Fig. 2. Rise and fall times of the circuit.

Triangular waveform generator

Tr_1 is a switching transistor which, during the time it is cut off due to the gating waveform going negative, allows the current to flow into $C(0.33\mu F)$ from the positive rail through the diode and 22kΩ. The collector load of 100kΩ adds to the resistance of the cut-off stage. The voltage rise across the capacitor is linearized in the conventional bootstrap manner by means of the emitter follower TR_2 and the 'floating battery' of 100μF. The diode is reverse biased due to this. When the gating waveform goes positive Tr_1 saturates, allowing the charged capacitor to discharge through it. Here again, the collector load of Tr_1 (100kΩ) allows Tr_1 to saturate easily. The rate of discharge of C through Tr_1, when made equal to the charge rate, generates the triangular waveform. The output from the capacitor is picked off by another emitter follower Tr_3 for the purpose of providing a low output impedance to the load. The p-p amplitude of the waveform is limited due to the same drawback confronting the usual bootstrap circuit—a time is required for the recovery process of the 'floating battery', when recurrent charging and discharging take place. Here a p-p amplitude of 3.0V was obtained. The component values of the circuit given provide a frequency of 50Hz. With suitable changes in value of C and adequate fast measures to recharge the 'floating battery' the operation can be extended to higher audio frequencies as well. Transistors used were 2N911.

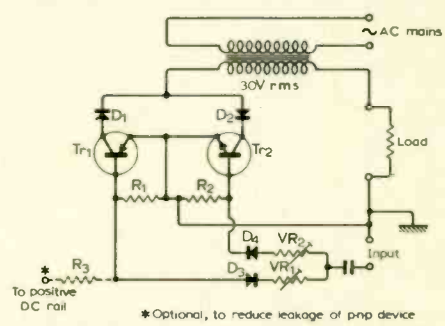


Generator circuit with charge time equal to flyback time.

S. NAGARAJAN,
Hyderabad,
India.

'Proportional' output stage for temperature control

The main feature of the circuit is the high on/off power ratio obtained, typically 80dB. It is basically a power phase-sensitive detector, and may be driven from the amplified output of an a.c. Wheatstone bridge, which is energized from the same supply as the output stage. The circuit shown delivers 30W into 30Ω and is highly stable under all conditions provided that the heat sink for the power transistors has a thermal resistance not greater than about 3°C/W. Output power is typically about 0.3μW in the off state.



Control circuit with low power dissipation when off.

M. GLUYAS and B. W. JAMES,
University of Salford,
Lancs.

Electric Field Probe

High-impedance paper leads avoid field disturbance

by J. Thickpenny

Recently an active probe has been developed by Green[1] using high-impedance leads in the frequency range 150 kHz–30 MHz to measure the near ($<\lambda$) electromagnetic field. The r.f. signal is amplified and rectified inside a hollow dipole and the resulting d.c. voltage, which is proportional to the electric field intensity, is transmitted via high impedance leads (distributed resistance 25 kΩ/ft) to a remote d.c. voltmeter. An impedance of this magnitude is necessary since metallic leads would perturb the field being measured. The leads used by Green were 30 ft long and 0·03 in. in diameter and comprised carbon fused into polytetrafluoroethylene (p.t.f.e.). This type of lead proved to be very efficient and field measurements have been made to within 1 dB. However, to date, this carbon/p.t.f.e. lead is unavailable on the British market so a similar probe was constructed with leads made out of high impedance paper (Teledeltos pen recording paper). This paper-lead probe was very sensitive to small field changes and exhibited a cross field rejection >40 dB when tested in a capacitive field. Also measurements recorded in an arbitrary electromagnetic field were repeatable (±1 dB) for any lead position as long as the first foot is approximately perpendicular to the probe length.

The probe was constructed as shown in Fig. 1. The r.f. amplifier, balanced rectifier and the two 9-V batteries were positioned inside a brass tube (balanced dipole). The rectifier output was connected to the two paper leads approximately ⅛ in. from the Tufnol bush. Adequate contact was made by wrapping the paper around the two protruding 20 s.w.g. output wires located in the Tufnol bush with plasticine and then covering with at least six turns of 35 s.w.g. wire.

Apart from the probe end, where the paper was tapered, the width of the paper was approximately 1·25 in. and two lengths of 15 ft had a d.c. resistance >0·75 MΩ. Small croc. clips were used to connect the paper leads to a high impedance digital voltmeter (>25 MΩ). When taking measurements greater lead flexibility was obtained by folding the paper lengthwise into a "V" shape. The a.c.–d.c. response of the r.f. amplifier, rectifier, leads etc. (not including dipole), is shown in Fig. 2.

TABLE 1

Results	D.V.M. reading
Probe in vertical position and batteries disconnected	1·7 mV
Mean of ten readings taken in horizontal plane (E_H)	8·5 mV
Vertical measurement (E_V)	1·077 V
Therefore cross field rejection	>40 dB

Polarization tests in capacitive field

The probe was positioned between the plates of a capacitor which comprised two 90×110 cm pieces of metal situated 130 cm apart, Fig. 3.

Due to the probe size relative to the plate dimensions no attempt was made to calibrate the probe. However, the cross field polarization can be determined from this simple arrangement since, although plate fringing will distort the ideal linear vertical voltage distribution, the horizontal component at the centre will remain effectively zero.

The results are given in Table 1 and show a considerable improvement when compared with a dipole of the same physical length using metallic leads—15 dB being the measured cross field rejection.

Measurements in an arbitrary electromagnetic field

Due to space required at 7·7 MHz it was not possible to test the probe in a standard field. However, the effects of the paper leads, etc., can be shown by taking measurements

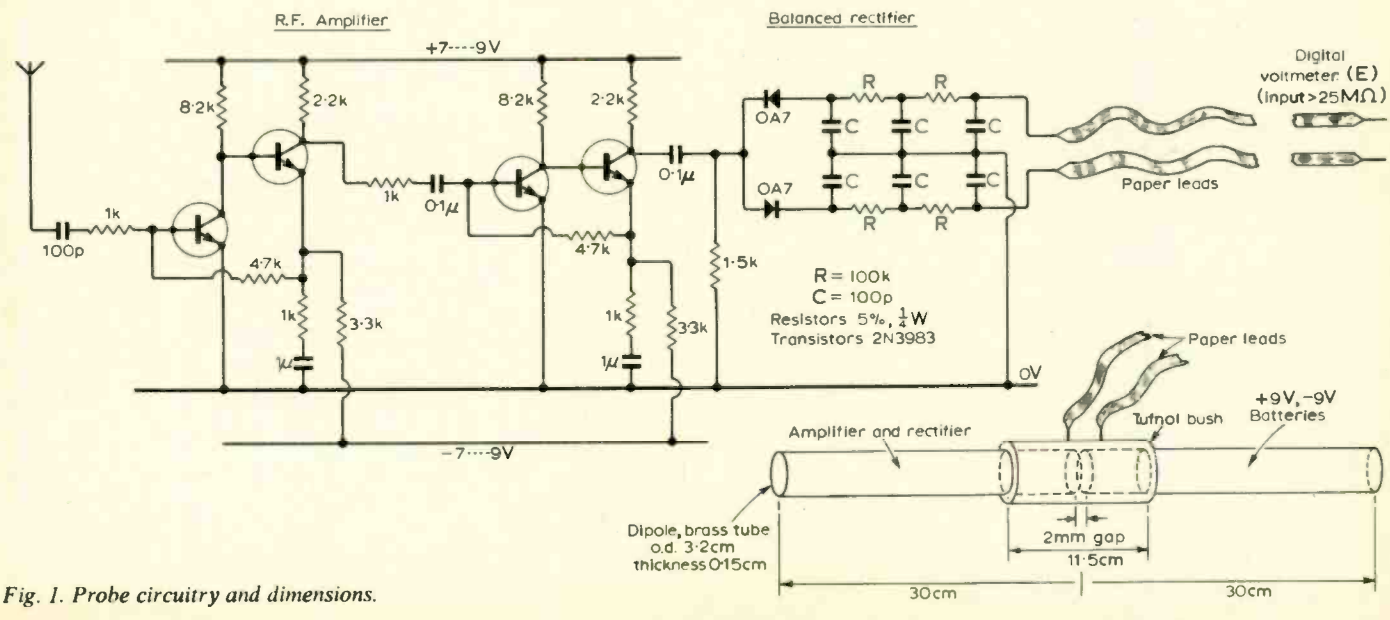


Fig. 1. Probe circuitry and dimensions.

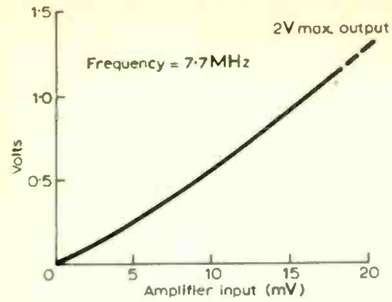


Fig. 2. A.c./d.c. response of electronic circuits.

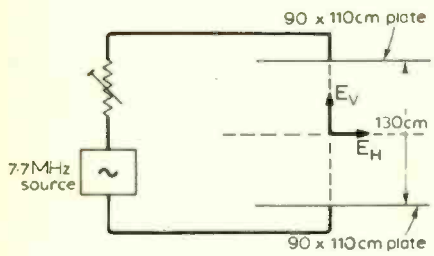


Fig. 3. Diagram of capacitor.

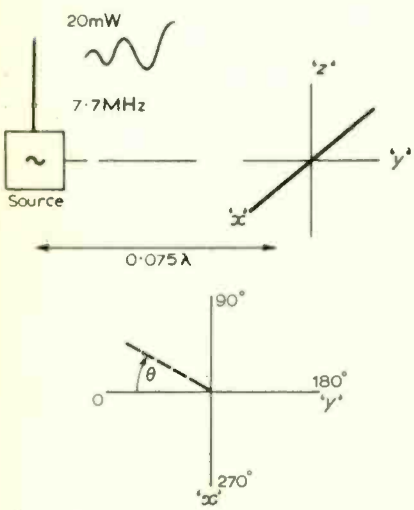


Fig. 4. Diagram showing probe location.

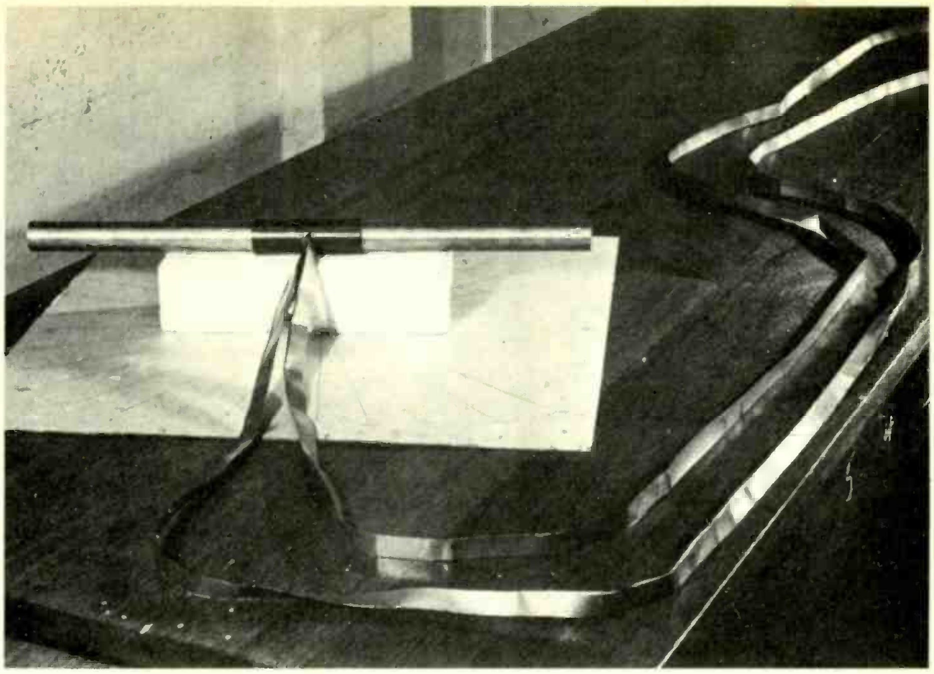


Fig. 5. The probe with its "paper" leads (θ = 270°). The assistance given by J. Bruce in constructing the probe is gratefully acknowledged.

in one plane 0·075 λ from an electric source and rotated by 360° as shown in Fig. 4.

The paper leads for the first foot were positioned parallel to the angle of rotation θ plus 90°, and at θ = 270° (photograph) they point towards the source before turning back around the probe in the "y" direction (digital voltmeter situated approximately 10 ft in "y" direction and 2 ft below the xy plane. The selected measurement plane was convenient since there was a max/min voltage ratio of about 6. The results in Table 2 from one measurement run give an estimation of the repeatability. At any one position a complete rearrangement of the paper leads only produced voltage variations of ±10%. (This is a random error which can be minimized by making many measurement runs.)

The results show that it is possible to make sensible near-electric-field measurements using paper high impedance leads to transmit a d.c. voltage from the probe to a remote indicator. It has been suggested that silver paint would produce a better paper-to-wire connection but experiments made with a thermal-setting silver paint weakened the paper to breaking point under the slightest pressure.

Measurement runs have also been made at 1000 MHz in the aperture of a 11-dB pyramidal horn by strapping the paper leads (0·25 in. wide; 100 kΩ per 6 in.) directly on to a backward diode. The electric field distributions have not yet been thoroughly compared with the theoretical distributions but the repeatability was of the same order as that experienced at 7·7 MHz. At 1000 MHz and above, due to the theoretical difficulties involved in calculating the electric field, especially around the horn aperture rim, a better assessment of the paper leads could probably be determined by comparing the field distributions with those obtained from another measurement system, e.g., the modulated scattering technique.[2]

A further possible use for this type of paper would be to supply the d.c. power for a telemetric probe (probe which re-radiates a signal on the same receiving dipole), where at frequencies above 500 MHz the size of the batteries is a limitation on the size of the probe.

TABLE 2
Results of one measurement run

θ°	E (V)	θ°	E (V)
0	0·295	180	0·263
10	0·442	190	0·391
20	0·625	200	0·572
30	0·775	210	0·695
40	0·909	220	0·856
50	1·004	230	0·979
60	1·108	240	1·059
70	1·162	250	1·125
80	1·187	260	1·155
90	1·188	270	1·146
100	1·162	280	1·054
110	1·075	290	0·973
120	0·972	300	0·862
130	0·835	310	0·741
140	0·659	320	0·567
150	0·428	330	0·388
160	0·271	340	0·245
165	0·216	345	0·212
170	0·180	350	0·204
175	0·183	355	0·225

Noise voltage with batteries disconnected ≈ 2 mV

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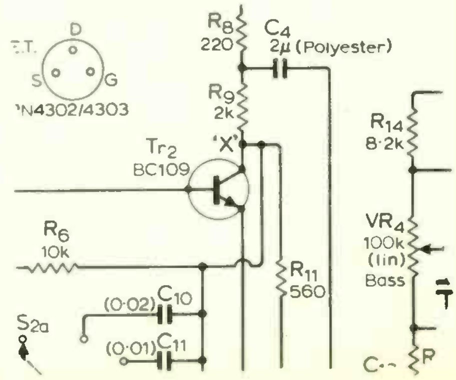
2. Richmond, J. H.: "A Modulated Scattering Technique for Measurement of Field Distribution," *I.R.E. Transaction M.T.T.*, July 1955.

Correction

"Simple Audio Pre-amplifier" (May 1970): Readers may have noticed a contradiction between the text at the beginning of p.209 and the circuit diagram of Fig.4. The junction of C_{10} and R_6 should go to the collector of Tr_2 not to the emitter. The correct connections are shown below.



Metal Glaze Resistors

How metal glaze resistors are made and how they compare with other types

*by K. L. Dove**

For many years circuit designers had to rely mainly on wire wound or carbon composition resistors. The former are still in use today when high power dissipation is important. Wire wound resistors are of high stability and can be made to close tolerances. The parameters can be changed by varying the type of wire, the former and encapsulation employed. The main disadvantages of this type of resistor are high-cost, large-size and the difficulty of producing resistors of high ohmic value.

Carbon composition resistors are less expensive because of the method of construction and the cheaper materials employed. They have improved over the years and 5% tolerance is about the best that can be obtained at present although stability during life cannot be expected to be better than about 10%. Throughout the world many hundreds of millions of these resistors have been used annually in the less critical applications. However, for more demanding purposes there is now a complete range of resistors including cracked carbon, metal film, tin oxide, and now thick film metal glaze. Table 1 shows some of the more important attributes of glaze resistors compared with the current limits of Defence Specification DEF5115 for other types of resistor.

The construction of one type of carbon composition resistor is worth noting, as the glaze resistors described here are similarly made. Conducting carbon is dispersed with an insulating filler in a varnish, the ratio of the materials determining the resistance value. This coating is applied to a substrate and cured to form the resistor. In the glaze resistor more stable materials are used; metals and stable metal compounds are employed in place of the carbon, and fused glass replaces the varnish binder, resulting in a component of far superior stability.

*Dubilier Condenser Co. (1925) Ltd.

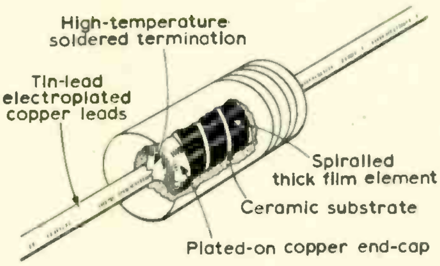


Fig. 1. The construction of a metal glaze resistor.

A considerable amount of development work has been carried out on different glaze materials intended for silk screen printed thick film circuitry. Several papers have shown the excellent performance of the glaze type of resistor although much of this work cannot be fully utilized because other components, such as high value capacitors, are difficult to manufacture using compatible printing techniques. For this reason, glaze resistors are being manufactured by the Dubilier Condenser Co. (1925) Ltd., as discrete components to enable users to benefit from their excellent properties without the high cost of development and tooling required for the production of hybrid thick film circuits.

This article describes these discrete resistors constructed as shown in Fig. 1. The ceramic substrate is coated with a glaze consisting primarily of a glass powder and a metal dispersed in an organic solvent. After drying the glaze is fired at temperatures up to 1150°C for up to half an hour so that the glass will melt and re-flow. After termination of the element ends the glassy resistive coating has a spiral cut in it to increase the resistance to the required value. The wires are then soldered and the assembly moulded in a silicon modified phenolic resin to impart mechanical strength, uniform shape and to enhance the tropical characteristics.

Design

The choice of ceramic substrate is important because it has a major influence on the final properties of the resistor, since during manufacture, the glass is fused to the substrate to form an integral element. The ceramic substrate is usually alumina, but the final choice will depend on the purity, smoothness, inertness, strength, thermal conductivity, cost, resistivity, thermal expansion and consistency. All these, in turn, affect the properties of the finished resistor. For instance the thermal conductivity affects temperature rise. The thermal expansion must be similar to that of the fired glaze in order to prevent cracking and crazing of the glass coating.

The glaze employed is of great importance. The first glazes used as resistive inks were made from noble metals and borosilicate glass. The use of noble metals is undesirable due to cost although glaze inks containing palladium silver have been commercially available for several years. Many other metal compound glazes have

TABLE 1

Type of resistor	Carbon Composition	Cracked Carbon	Metal Oxide	Metal Glaze		Metal	Wire Wound
Pattern	RFG1	RFG3	RFG5	Service Rating	Commercial Rating	RFG7	RFP1
Length mm*	10.7	15.6	7.1	6.7	6.7	17.8	20.7
Diameter mm*	2.7	6.4	2.5	2.5	2.5	8.0	7.1
Watts at 70°C	0.25	0.25	0.25	0.25	0.5	0.25	0.25
Load life stability	15%	2%	3%	0.5%	1%	0.5%	0.05%
Selection tolerances %	5. 10.	2	1,2,5	1,2,5	1,2,5	0.1. 0.5	0.1. 0.5
Temp. coeff. max. ppm/°C	−1200	−1200	250	100	100	50	20
Max. surface temp °C	125	150	180	150	150	150	120
Resistance range	10Ω-22MΩ	10Ω-2MΩ	10Ω-150KΩ	10Ω-150KΩ	10Ω-150KΩ	100Ω-1MΩ	10Ω-510KΩ
Humidity class	H515%	H62%	H61%	H61%	H61%	H60.5%	H60.05%
Max. temp. rise	55°C	80°C	110°C	25°C	50°C	80°C	30°C

*Dimensions to nearest 0.1 mm

been investigated some of which are commercially available for printing thick film circuits. These include titanium, chromium, tin, zirconium, molybdenum, tantalum, indium, tungsten, ruthenium, and thallium, used in combination with oxides, carbides and nitrides.

The claims of various glaze manufacturers differ widely, but the essential properties of any metal used are that it shall not dissolve in glass and it should be chemically stable. The metal particles are divided down to micron sizes, and mixed with glass powder of a similar size and an organic vehicle—various other additives can be used to control the viscosity and thixotrophy of the glaze mix, and to control the flow characteristics both during the application of the ink and during the firing operation. Additives can also be used to control the properties of the finished resistor, and this is one of the advantages of metal glaze resistors, since with continued research and development, the properties which the resistor user looks for will be achieved and continually improved.

The sheet resistance obtained from glazes 0.5 to 1 mil in thickness can now be varied from as low as 10Ω/sq* to $10^6\Omega$/sq and other properties such as temperature coefficient are continually being improved.

The change of sheet resistivity with percentage weight of metal varies considerably with the materials chosen for the glaze ink. As the percentage of glass is increased the resistance increases, and for a pure metal such as silver, the rise in resistance is very rapid. As the glass content increases there is little change in resistance until a point is reached where the silver particles are no longer in close contact and then the resistance rise is extremely rapid. This state of affairs is not satisfactory for the resistor designer since a reasonably linear change of resistance, with conductor concentration over a fairly wide band, is what is really wanted. A change of one resistance decade for a change of about 10% in the conductor concentration and a resistivity running from about 100Ω/sq to $100\text{k}\Omega$/sq is usually satisfactory.

The conductive particles in an ideal glaze mix are embedded in a continuous mixture and should, therefore, possess a very high degree of stability. Very low resistance values can, however, be less stable because of the lack of glass and it is therefore necessary to change to a metal which is a better conductor. Conversely, in order to obtain high values of sheet resistivity, a change in the metal compound may be preferred to a further increase in glass content which is likely to give an intermittent nature to the conducting particles in the fired glaze. Generally, it is best to keep the metal content between 25% and 75% of the total weight of the solids in the glaze. In order to obtain accurate and reproducible results, the firing of the glaze is done in a conveyor furnace as the maximum temperature distribution and firing time play a critical part in the value of sheet resistance, temperature coefficient and other properties of the finished resistor. The atmosphere of the furnace also affects the resistor and certain glazes require air or oxygen to form oxides in the resistor, whilst other glazes must be fired in an inert atmosphere.

After the glaze is fired to the ceramic rod, the terminations are applied and the element then forms a usable resistor. The glaze surface is then spirally cut with a diamond wheel to adjust the resistance value. By using a close pitch and more turns, the resistance value can be increased by up to 150 times the value before the spiralling. Besides increasing the resistance range of the glaze, the spiralling has the added advantage of being able to trim the resistor to a very close tolerance, and resistor tolerances of 2% or even 1% can be obtained with good yields. The temperature coefficient is influenced by the aspect ratio as well as the glaze formulation and care must be taken to ensure that the resistance track is not made too long at the expense of track width as instability can result.

Characteristics

The temperature coefficient usually varies with sheet resistivity, i.e. the metal content and type of metal in the glaze. Pure metals usually exhibit a positive temperature coefficient while semiconductors have negative temperature coefficients. The values for metal glaze resistors may be either positive or negative depending on the ratio of metal-to-metal compound and the glass content, and can generally be controlled within ± 200 p.p.m./°C and some glazes and concentrations yield ± 50 p.p.m.

Because of the method of construction and the extremely high temperature used for firing, metal glaze resistors may be run at very high temperatures and loads. Several papers have been published which indicate that ratings of 10W per square inch of film area are readily available with intermittent loading to 100W at temperatures up to 225°C.

The film in the discrete resistor described here can be rated at 25 to 50W per square inch, but it must be remembered that this is due to the good heat conductivity of the ceramic substrate, the quality of the termination joint to the element and finally dissipation by the wires.

Metal glaze resistors constructed in the manner described meet fully all the requirements of DEF 5115-1 Pattern RFG5 and have superior performance under conditions of overload due to the thick robust film surface and alumina ceramic which dissipates the heat more readily than other substrates. (The thermal conductivity of ceramic is 5 to 10 times that of glass.) Fig. 2 shows the increase in surface temperature with percentage of rated power input which demonstrates how cool this type of resistor will run.

It is a well known fact that an increase in temperature increases the degradation rate of electronic components and the fact that this metal glaze resistor runs cooler than equivalent types, under the same conditions of loading, contributes to the excellent life test data shown in Fig. 3. It can be seen that when the metal glaze resistors are tested at rated wattage and 70°C for 1.5 hours on load 0.5 hour off, in accordance with DEF 5115, that the change of resistance value is well within the limit of ± 3% allowed at 2000 hours of testing. A histogram after 10,000 hours (i.e. 5 times the normal specification limit) shows the percentage change of resistance is still well within the specified limit of ± 3%.

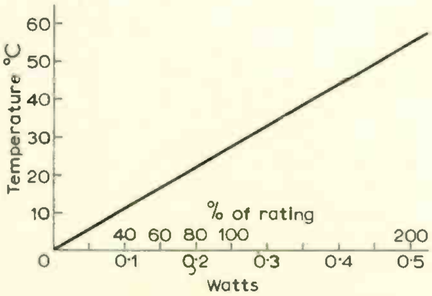


Fig. 2. Typical temperature rise with power dissipation for the RGO7 resistor.

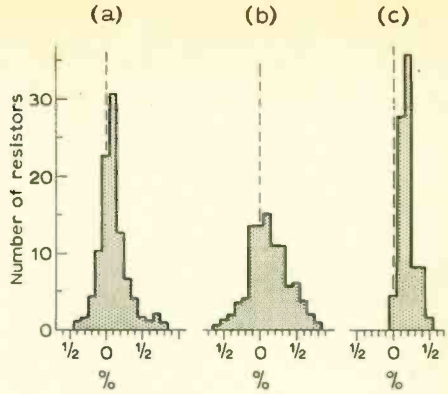


Fig. 3. Typical test results showing the percentage change of resistance for given conditions. (a) Conditions as per DEF5115/RFG5F at rated volts at 70°C for 2000 hours; spec. limit ±3%. (b) Same conditions as (a) but for 10,000 hours. (c) Tropical exposure with light load for 1,344 hrs; spec. limit ±1%.

* Ω/sq the resistance of a square of resistive material of uniform thickness as measured between two edges will be the same whatever the dimensions of the square. As the distance between edges increases the cross-sectioned area of the resistive material also increases; one effect exactly cancels the other.—ED.

47th Edition

The Radio Amateur's Handbook, the 47th (1970) edition by the American Radio Relay League, has new material throughout. The portable/mobile and aerial chapters have been completely rewritten. Semiconductor tables have been much expanded. Among the new construction projects are universal power supplies (for all voltages from 3 to 3000V); solid-state receivers, transmitters and converters. Two new linear amplifiers are described in the transmitting chapter. Pp. 710. American Radio Relay League, Newington, Conn., 0611 U.S.A. Price 48s from The Modern Book Co., 19-21 Praed Street, London W.2.

World of Amateur Radio

Amateurs seek more space facilities

The recent meeting in Brussels of the I.A.R.U. Region 1 v.h.f. working group has been concerned with preparations for next year's I.T.U. world administrative conference on space communications. While amateurs are concerned primarily with retaining their present frequency allocations in the face of increasing pressures from other services, they also want to obtain less restrictive regulations on their space activities. At present international regulations permit the use of artificial satellites in the band 144 to 146MHz only. Official support is being sought for widening both the definition of amateur space communication activities and for the extension of facilities to all u.h.f. bands up to 10GHz. While such proposals already appear to have official backing in the United States, the response from Region 1 countries is considered disappointing.

The American organization A.M.S.A.T. is planning a long-life, multi-channel active transposer-type satellite for Oscar VI (to be known as Oscar B until launch) carrying experimental packages from other groups. The British "Project Trident" group is hoping to build a transposer-type satellite with 144MHz for the up path and 433MHz down.

B.A.T.C.'s 21st Anniversary Convention

In 1949, a young British amateur, Mike Barlow, G3CVO (now a professional television broadcast engineer in Canada), began circulating a duplicated newsheet called "CQ-TV" and so launched the British Amateur Television Club. The following year, Ivan Howard, G2DUS, exhibited an amateur-built camera channel at the R.S.G.B. exhibition and soon after assisted in 430-MHz tests which resulted in the Post Office agreeing to grant amateur TV licences.

Since then many forms of amateur TV activity have continued to appeal to a group which, although never amounting to more than a few per cent of licensed amateurs (there are currently about 180 stations licensed for amateur TV in the U.K.), make up for this by the quality of their efforts. B.A.T.C. membership ranges from young amateur enthusiasts to senior engineers professionally engaged in television. Much of the appeal stems from the chance to pursue independent activities, free from professional direction, and the achievement of making for a few pounds equipment which would cost perhaps £500 to buy.

To mark its 21st anniversary the club is holding a two-day convention on amateur TV at Churchill College, Cambridge, on July 25th & 26th, featuring lectures, films and video tapes, visits to an equipment manufacturer and to amateur stations, an exhibition of amateur equipment, and a convention dinner on the Saturday evening. It is expected that demonstrations of the reception of a number of amateur TV stations will be possible at the College. Residential accommodation will be available from the Friday or Saturday evening until Sunday tea-time. Ladies will be welcome at all events.

For a still relatively small group the programme is an ambitious one. Convention forms available from D. S. Reid, 71A Rose Valley, Brentwood, Essex.

Illegal operation

The Minpostel and the Post Office appear to have stepped up their efforts recently to break up the blatant "pirate" operation which has been going on for a long time around 6.5MHz. Until quite recently this part of the spectrum has appeared at times to have been virtually taken over for "amateur-type" operation by pirates, often posing as part of Army Cadet networks.

Telecommunications Day

Among the special-activity stations expected to commemorate the second World Telecommunications Day (May 17th) are 4U7ITU in Geneva and GB2ITU and GB3ITU in London. The theme of the day is the use of telecommunications for educational purposes and the training of telecommunications specialists. A special c.w. contest on May 16th and a phone contest on May 17th (all h.f. bands) has been sponsored by the Brazilian Ministry of Communications. An I.T.U. Trophy will go for one year to the national society of the country whose top ten contestants score the most points, with a gold, silver and bronze medal to the three highest scoring amateurs.

Mobile rallies

The 1970 mobile rally season is now in full swing, and the following are among the many events planned for June. A tenth anniversary rally at *H.M.S. Mercury*, Petersfield, Hants, on June 14th organized by the Royal Navy Amateur Radio Society and the Portsmouth and Fareham radio clubs. An Anglian rally at the Suffolk Showground, Ipswich, on June 20th-21st. The annual rally of the University College of Swansea amateur radio society at Singleton Park, Swansea, on June 21st. The Longleat Safari rally (Longleat House, near Warminster) on June 28th organized by Bristol R.S.G.B. group.

An Edwardian amateur

A link extending back 54 years to the early amateur radio era of 1906-1914 has been broken with the death, at the age of 82, of Maurice Child. He founded the London Telegraphic Training College at Earls Court and held such callsigns as ECX and, in the early 'twenties, 2DC. The 1-kW spark transmitter at his training school became one of the best-known amateur stations in the pre-1914 period, his licence officially permitting contacts up to ten miles. He had witnessed the early Marconi experiments between Poole and the Isle of Wight. He was associated with many pioneering events, including the radio coach "6ZZ" attached to an L.N.E.R. train in July, 1924, to investigate the feasibility of radio communication with trains.

In Brief: The Morse proficiency transmissions (20 to 40 words per minute) on G3BZU have been restarted on the first Tuesday of each month at 20.00 B.S.T. on 3520kHz. Certificates are issued for correct copy (QRQ Manager, Royal Navy Amateur Radio Society, *H.M.S. Mercury*, Petersfield, Hants.) . . . . JA3XPO is the callsign of the official EXPO 70 station at Osaka, active on all h.f. bands on c.w. and s.s.b. . . . . The address of the QSL Bureau of the Irish Radio Transmitters Society has been changed to: P.O. Box 462, 12 Stella Avenue, Dublin . . . . First station to gain the new five-band "worked all states" award was W1AX (formerly W1JYH) . . . . During 1969, the A.R.R.L. issued 2000 "worked all continents" awards . . . . Rhodesian beacon station, ZE2AZE, is operating on a 24-hour basis on 69.998 MHz . . . . Ever heard of a country called "Market"? The A.R.R.L. has recently added this little known island, located exactly on the boundary between Finland and Sweden, to the official DXCC country list . . . . A portable station operated by the Cambridge University Wireless Society has made the first 1296 MHz contacts between the Isle of Man and England and Wales.

PAT HAWKER, G3VA

Personalities

Data Recognition Ltd, of Reading, has announced the appointment of **David J. B. Carter,** A.M.I.E.E., Grad.I.E.R.E., and **Brian F. Bradford,** A.M.I.E.E., as senior sales executives. Mr. Carter was with Trend Electronics for 2½ years as home sales manager prior to joining Data Recognition. Before that he worked for Elliott Automation as a systems sales engineer and for I.C.I. as an electronics development engineer. David Carter was awarded a Thoroughgood scholarship in 1959 and studied electrical/electronics engineering at Reading Technical

David Carter

College. Mr. Bradford was, until recently, with I.B.M., where he was a systems engineer specializing in document readers. Prior to that, he was a product marketing manager with SGS-Fairchild Semiconductors, which he joined in 1966 after spending seven years with Solartron Ltd. Data Recognition has also appointed **P. J. Pullen,** who joined the engineering service department two years ago, a sales executive. Mr. Pullen, who is 31, was a service engineer with Ohrtronics Ltd and Kode Electronics before joining Data Recognition.

Clive Hollins has joined Brookdeal Electronics Ltd as chief of test at their new factory in Market Street, Bracknell. Much of Mr. Hollins' experience of electronics was gained in the Navy in which he enlisted in 1955 as junior radio electrician's mate (Air). After initial training he moved to the Fleet Air Arm where he worked on airborne radar and radio equipment and, for the last two and a half years of his service, on ground installations at R.N.A.S., Lossiemouth in Scotland. On leaving the Fleet Air Arm in 1968 he was employed by Racal-BCC as an electronics tester and subsequently as test engineer. Mr. Hollins, who is 31, is an amateur radio transmitter (G8BOU) and acts as radio instructor and communications officer to Windsor and Eton Sea Cadets Corps. Brookdeal have also announced the appointment of 29-year-old **Ian Stimpson** as senior product development engineer at the Bracknell factory. Mr. Stimpson gained his early experience of the electronics industry with Ultra Electronics which he joined in 1959 as a student apprentice. During his apprenticeship he took a sandwich course at Southall Technical College, obtaining his Higher National Diploma. From 1964 until his present appointment he had been with Strand Electric, initially as design engineer and later as head of their electronic design section.

Harold Stern, B.Sc., recently joined Techmation Ltd, of Edgware, to co-ordinate and control the company's marketing activities. Mr. Stern, who contributes an article on a modern direct voltage calibration system in this issue, graduated in physics and mathematics from Queen Mary College, London University, in 1953. He has served with several companies, including E.M.I. Electronics, Cawkell Research & Electronics, Honeywell Controls and latterly with Fluke International Corporation where he was sales manager. Techmation have also announced the appointment of **Vic Holmes** as service manager, with full responsibility for customer liaison and the running of the Electronic Service Department. He joined the company in July 1969 having previously worked for Caps Research and Advance Electronics.

Robert Hirst, M.I.E.R.E., has been appointed director of engineering to Audits of Great Britain Ltd, the company which carries out national television audience measurement surveys. Mr. Hirst, aged 35, who has frequently

Robert Hirst

contributed to *Wireless World,* was with Standard Telephones and Cables where he was initially an engineering group leader on design, development and planning of h.f. products and latterly manager of special assignments in the Aviation Division.

Dr. George H. Brown, executive vice-president (patents and licensing) of RCA Corporation, has accepted the invitation of the Royal Television Society to become a fellow. Dr. Brown has been with RCA since 1933 where his early work was on the development of the turnstile aerial for television and v.h.f. sound broadcasting. From 1948 to 1957 Dr. Brown played a leading part in the development of the N.T.S.C. colour television system.

R. M. Denny, M.I.E.R.E., has joined the London executive staff of Rediffusion Ltd with a view to his being appointed, in due course, to the boards of companies in the Rediffusion Group. From 1955 until last month, Mr. Denny, who is 43, served with A.T.V. Network Ltd where he was at one time head of the sound department and since 1967 had been general manager (Elstree). Prior to joining ATV Mr. Denny was with the B.B.C. for nine years and also spent three years in the Royal Navy.

A Ministry Liaison Officer has been appointed by Cambridge Consultants. He is **Wing Commander Alec Cross,** O.B.E., who joined the R.A.F. in 1926 as a technical apprentice, and was commissioned in the Flying Branch in 1939. Since 1949, he has held a number of appointments including Commander of the Underwater Missiles Unit at Gosport, Commander R.A.F. Porton and Commander of the Strategic Bombing Group at Boscombe Down. For two and a half years he did research work with the United States Air Force in Florida. Cambridge Consultants claims to be the largest independent contract R & D company in Britain.

Bernard Ness is joining The Plessey Company Ltd on July 1st as a divisional director within the Components Group. He will assume responsibility for the development of the Garrard operation and other Plessey consumer activities in audio/visual communications. Mr. Ness, who is 45, was formerly with E.M.I., the Rank Organization and R.C.A.

Ronald M. White, has been appointed marketing director of Advance Filmcap Ltd, of Wrexham, the capacitor subsidiary of Advance Electronics. He joined the company just over a year ago from Electrosil where he was a Northern Area sales manager for a number of years. Mr. White previously spent three years with Plessey as a sales engineer having started his engineering career with G.E.C. in Coventry.

Frank Clements, who has been in charge of all engineering and development work at Teleng since he joined the company 15 years ago, has been appointed chief engineer. Mr. Clements, who was for 2½ years a lecturer in electronic experimentation at St. Xavier's College, Bombay, where he graduated, joined Teleng shortly after its formation as Telefusion Engineering Ltd in 1955. The company, which operates from South Ockendon, Essex, specializes in television distribution systems.

The Dubilier Condenser Company has announced the appointment of **Bernard V. Sargent,** A.M.I.E.E., as

Bernard Sargent

marketing manager. Prior to joining Dubilier he held executive appointments with Electrosil, M.E.C. and The Plessey Co.

New Products

F.M./A.M. Demodulator I.C.

Two integrated circuits from Signetics International, the first of their kind, will precisely duplicate the frequency of a signal and can demodulate f.m. and a.m. waveforms without tuned circuits. These new products represent the first of a family of phase-locked-loop linear integrated circuits. Categorized as NE560B and NE561B, the frequency range is from 1Hz to 30MHz and the lock range is adjustable from ±1% to ±15%. These circuits will operate with signals of 100μV to 1V, with best operation at an input of 5mV. Signetics International, Trident House, Station Road, Hayes, Middx.
WW 301 for further details

PAL Delay Line

A miniature solid delay line specially designed for use with PAL systems is available from Impectron. Dimensions are: height 44.2mm, width 49.2mm and depth 7.3mm. Called the MS9P, it has a delay time tolerance of ±3ns at a nominal frequency of 4.433619MHz on the nominal delay time of 63,943μs. Impectron Ltd, Impectron House, 29/31 King Street, London W.3.
WW 302 for further details

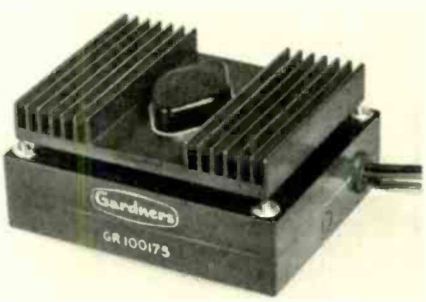
Broadband "Discone" Aerial

A vertically polarized "discone" aerial designed for field communication is available from Microwave International. The unit is mounted on a ground plane of 12 radials. A cylindrical radome encloses the

vertex of the cone for structural strength and waterproofing. It is supplied with a base flange for mounting. The frequency range is 250-1000MHz, radiation pattern omnidirectional, input impedance 50Ω, input power 750W, and weight 4kg. Microwave International (U.K.) Ltd., 33-37 Cowleaze Road, Kingston upon Thames, Surrey.
WW 304 for further details

Inverter Assemblies

The M48 E.H.S. augments the standard range of low-power output inverter modules introduced last year by Gardners Transformers. It offers power ratings up to 30 W stabilized or 50 W unstabilized in a standard mechanical assembly. The assembly incorporates a single power stabilizer which would be fitted in the d.c. output line for



single output inverters or in the input to the inverter where multiple outputs are specified. The whole assembly is encased in resin which is highly conductive thermally and shock absorbent. Input and output connections are by flying leads. Gardners Transformers Limited, Christchurch, Hants.
WW 312 for further details

High-speed Switching Transistor

A silicon transistor, type MM4049, with an extremely high switching speed, is now available from Motorola. Claimed to represent a significant advance in p-n-p current-mode switches, the device has a minimum f_T of 4GHz and a typical C_{ob} of 0.8pF. These values are respectively double and half the values for previous similar switching devices. Other important characteristics of the MM4049 include a maximum leakage current of 10nA (at 10V) and a d.c. current gain of 20 to 80 (at 25mA and 2V). Primarily designed for use as a high-frequency current-mode switch in digital circuit applications such as pulse generators, counters, radar receivers and computers, the device will also be useful as an r.f. amplifier and oscillator due to its extremely high current-gain/bandwidth. Its low collector-base time constant (15ps max.) also enables it to be applied in some u.h.f. linear applications. The device is packaged in a TO-72 can and exhibits a high degree of resistance to neutron radiation. Cost is 93s 11d each for quantities of 100. Motorola Semiconductors Ltd, York House, Empire Way, Wembley, Middx.
WW 311 for further details

Frequency Converter

Most electronic equipment will operate equally well from 50Hz or 60Hz supplies but some devices, such as chart drive motors, or constant voltage transformers,

must be fed with the correct frequency. Other devices cannot tolerate the short-term variations of local mains supply. The frequency converter unit shown here, type FC110/-/-, provides a supply of 110W at the required frequency and is powered by local mains. The unit in the photograph is an export version, accepting either 110V or 220V input at 60Hz, and delivering either 115V or 230V at 50Hz. Variants are available for operation from 50Hz supplies, to deliver 60Hz and to deliver 50Hz with a stability of a few parts in one thousand. It is possible to lock these to an external signal. Other variants provide crystal control of frequency, 50Hz/60Hz interlock to permit synchronization in a mixed Anglo-American system, 400Hz output. The distortion figure for this particular unit is under 10%, but lower distortion levels can be provided. A square wave output can be offered at a slightly lower cost. R. Gilfillan & Co. Ltd, Southdown-view Road, Worthing, Sussex.
WW 305 for further details

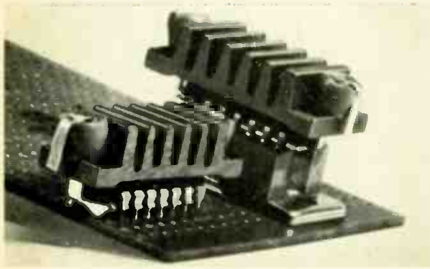
I.C. for TV Sound Systems

The CA3065 from RCA is a 14-lead dual-in-line plastic package incorporating a monolithic integrated circuit which combines a multi-stage i.f. amplifier limiter, an f.m. detector, an attenuator, a zener diode power-supply regulator and an audio amplifier-driver. Drive to the audio output stage of a television receiver is achieved via the audio amplifier-driver which is designed

so that it may be directly coupled with either an n-p-n power transistor or a high-transconductance valve. Replacing the conventional volume control is the "electronic" attenuator in which the bias levels are changed by means of a variable resistor connected between the control terminal and earth. There is no audio signal present at this terminal and therefore hum and noise can be bypassed. The audio drive capability is 6mA pk-pk and the undistorted audio output voltage is 7V pk-pk. Electronic Components Division, RCA Ltd, Sunbury-on-Thames, Middlesex.
WW 309 for further details

Heatsink for i.c. Module

To give extra power handling ability to integrated circuit modules Redpoint has produced heatsinks type DIP14/1 and DIP14/4. The sink is of finned aluminium, and heat resistant silicon rubber springs



ensure good thermal contact between the sink and the module. The DIP14/1 and DIP14/4 are rated at 30°C and 28°C per watt respectively. Redpoint Ltd, Lynton Road, Cheney Manor, Swindon, Wilts.
WW 316 for further details

Op-amp Power Unit

Type 705 dual power supply from Microtest, is a low-cost unit for analogue and digital integrated circuits. The output voltages are independently adjustable from $\pm$12V to $\pm$15V at 100mA. For series connection the output is variable from 24 to 30V. Mains regulation is 0.01% and load regulation better than 0.02%. Ripple and noise amount to less than 250μV peak-to-peak. Current protection takes the form of foldback limiting. Price £18. Microtest Ltd, 28 Walker Lines, Bodmin, Cornwall.
WW 310 for further details

I.Cs for Data Communication Interfaces

Motorola have available a quad d.t.l. line driver (type MC1488L) and quad d.t.l. line receiver (type MC1489L), which have been specifically designed for interfacing data-transmission lines with ancillary equipment. Principal characteristics of the MC1488L driver include a current-limited output of 10mA maximum, an output resistance of 300Ω minimum, a flexible operating supply range, and simple slew-rate control by means of an external capacitor. The MC1489L receiver has an input resistance of 3 to 7 kΩ, an input signal range of $\pm$30V, good input threshold hysteresis, and response control for logic threshold and noise filtering. Up to four lines can be driven (or received), by the two devices, which each contain four integrated circuits.

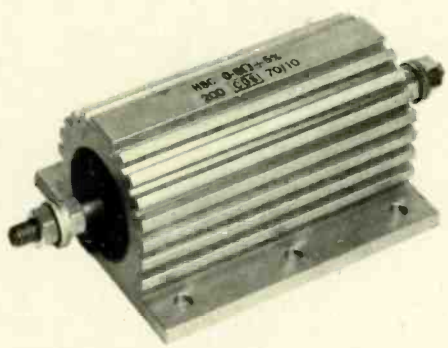
Both the MC1488L and MC1489L are available in four-circuit 14-pin dual-in-line ceramic packages, and have an operating temperature range of 0 to 70°C. Prices for 100 or more are 93s 11d and 83s 6d each respectively. Motorola Semiconductors Ltd, York House, Empire Way, Wembley, Middx.
WW330 for further details

Miniature Wafer Switches

A range of miniature rotary moulded wafer switches is being produced by Lorlin Electronic Co. Only 25mm in diameter each switch is made up of self-spacing wafers with a diecast indexing mechanism. The range of wafers extends from 1-pole 12-way to 6-pole 2-way, and indexing can be 30°, 45° or 90°. Prices range from 6s 9d each for a single wafer switch to 24s each for a six wafer assembly—in quantities of 500. Lorlin Electronic Co. Ltd, Billingshurst, Sussex.
WW306 for further details

200W Heatsink Resistors

C.G.S. have now increased the HS range of aluminium housed, power wirewound resistors to include 100 and 200W sizes. The HSC100 and HSC200 are designed for direct chassis attachment and are



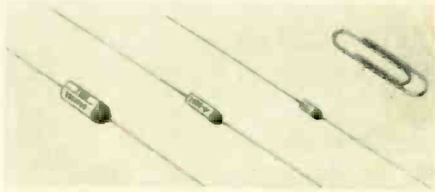
under half the physical size of existing high-wattage vitreous resistors of equivalent power rating. Resistance values are available between 0.1Ω and 50kΩ. The C.G.S. Resistance Co. Ltd, Marsh Lane, Gosport Street, Lymington, Hants.
WW307 for further details

Microwave Aerial Feed

A 2-channel monopulse aerial feed which operates over the range 1,425 to 2,300 MHz is now available from Microwave International. It is suitable for exciting nearly any size of parabolic reflector. Sidelobe levels of less than −22dB have been achieved for both sum and difference channels over the full frequency band thereby minimizing ground reflections. Other main specifications are: impedance 50Ω coaxial, null depth 40dB min., v.s.w.r. 2 max., sum channel axial ratio 2dB max., and sum/difference isolation 35dB max. The unit weighs less than 3.18kg and will handle 50W. Gain is 26-30dB and beamwidth 7-5°. Microwave International (U.K.) Ltd, 33-37 Cowleaze Road, Kinston-upon-Thames, Surrey.
WW303 for further details

Miniature Tantalum Capacitors

A range of miniature tubular sintered-anode tantalum capacitors has been introduced by Sprague. They are designed for operation over the temperature range −55°C to



+85°C without voltage derating, and are protected against electrolyte leakage and lead breakage. Sprague Electric (U.K.) Ltd., Sprague House, 159 High Street, Yiewsley, West Drayton, Middx.
WW 314 for further details

TV Boost Amplifier

A wide-band TV boost amplifier with a 12dB gain and a complementary power unit are introduced by Teleng. The amplifier, type SX5341, is fitted to the aerial mast-head to boost aerial output in areas of low signal strength. It receives its power from the separate power unit, type SX5342, which can be installed in any convenient position where a mains supply is available. The screened transistor amplifier has separate input circuits for u.h.f. and v.h.f. signals, which are then diplexed together by low-loss filter sections. The v.h.f. input circuit incorporates two filter traps covering the 70 to 170MHz band which can be tuned to reduce the effect of interfering signals. The units each measure 136 × 96 × 54 mm. Teleng Ltd, South Ockendon, Essex.
WW 315 for further details

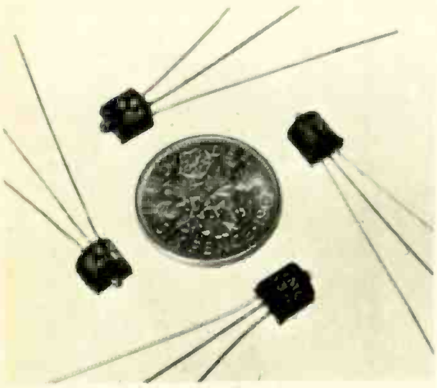
U.H.F. Wired TV Amplifier

A solid-state u.h.f. amplifier, in the TA900 series, by Thorn Bendix, is available with gains of 19dB or 38dB and can be a.c. or d.c. powered. The amplifier module has a bandwidth of 470 – 860MHz and offers a high output with low noise level. Input and output impedances are 75Ω. Operating from 12V d.c., the TA901 has a gain of 19dB $\pm$ 1dB and the TA902 a gain of 38dB $\pm$ 2dB; power requirements are 40mA and 80mA respectively. Of the mains-operated units the TA911 and the TA912 have similar gains but power requirements

are 5W and 7W a.c. respectively. The TA900 series amplifiers provide companions to the existing TA200 and TT100 series, in that together they form a complete system suitable for the distribution of u.h.f. and v.h.f. signals at fundamental frequencies, in blocks of flats and small estates. The d.c. units TA901 and TA902 can be powered from the companion TA200 or TT100 units. Thorn Bendix Ltd, Industrial Electronics Division, Beech Avenue, New Basford, Nottingham NG7 7JJ.
WW 313 for further details

Logic-state Indicator

An electronic device, in custom hybrid form, which gives visual indication of the state of binary logic circuits is announced by Newmarket Transistors. This device uses a gallium phosphide electroluminescent diode attached to a thick film hybrid microcircuit. It has three leads and is encapsulated within maximum



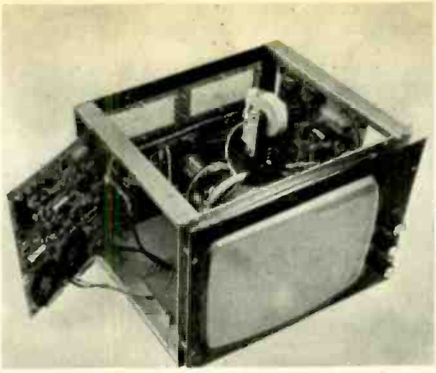
dimensions of 5mm. The circuit contains one transistor, one diode and two resistors and is designed to operate from a 5-V 4-mA supply. It indicates logic states of "0" (0.5V lamp off) and "1" (2.5V lamp on) with input currents of 5μA and 30μA respectively. Newmarket Transistors Ltd, Exning Road, Newmarket, Suffolk.
WW 317 for further details

Moulded Power Resistors

The PM range of wirewound miniature resistors from the C.G.S. Resistance Company, provides low resistance values down to 0.05Ω in four wattage ratings—3.5, 7, 10 and 14W. The units have small, insulated bodies and tolerances down to $\pm$1%. Prices are from 1s 7d each. The C.G.S. Resistance Company Limited, Marsh Lane, Gosport Street, Lymington, Hampshire SO4 9YQ.
WW325 for further details

C.C.TV Monitors

A new range of closed-circuit TV monitors are being produced by Cotron Electronics with most of the components mounted on p.c. boards. This allows for easy servicing by replacing boards, and also enables boards to be sold as separate units for incorporation in custom-built display



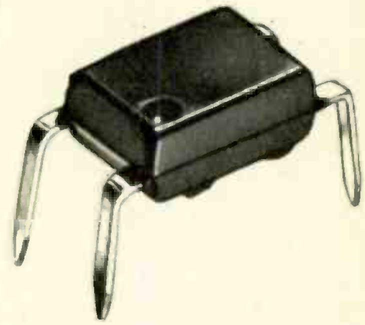
cabinets. A range of c.r.ts from 280 to 610 mm, with 70, 90 or 110° deflection can be accommodated provided the e.h.t. required is 16kV and the neck diameter 28mm. The standard unit is based on a 280-mm c.r.t. It is constructed of aluminium with the two main printed boards hinged on either side of the unit. The front panel is removable and the c.r.t. can be withdrawn through the front. The only front panel controls are 'contrast', 'brightness' and 'on/off'. Two versions are available—for 625-line 50 field/sec and 525-line 60 field/sec. Signal inputs required are 0.5-2V video, composite or non-composite, positive-going, and 10mV-2V synchronizing, negative-going. Frequency response is −3dB at 8MHz (−3dB at 10MHz if required). Geometry and linearity is less than 2% from ideal. Line synchronization incorporates flywheel lock with a hold-in range of $\pm$1kHz, and a black-level clamp is used in the form of a gated d.c. restorer. The monitor in its standard form measures 245 × 315 × 305 mm and weighs 8.5kg. Price £155. Cotron Electronics Ltd, 12 Harecroft Crescent, Sapcote, Leicester.
WW 322 for further details

Waveguide Balanced Mixer

A waveguide balanced microwave mixer which the makers call the Micromode Mixer is available from Micro Metalsmiths, in either brass or aluminium alloys. It is obtainable in the frequency ranges 9-10GHz, v.s.w.r. 2 (max), or 9.2-9.6GHz, v.s.w.r. 1.7 (max). Isolation is 20dB (min). The device measures 49mm across the flanges which are situated at 180° from each other, with the crystals and mixing strip mounted between them. Although basically broad-band, the mixer can be optimized electrically for better v.s.w.r. over restricted bandwidths within the complete waveguide band. Micro Metalsmiths Ltd, Kirby Moorside. York YO6 6DW.
WW 320 for further details

Low-cost I.C. Amplifiers

Motorola Semiconductors have announced a range of low-cost integrated circuits for the consumer-equipment field. Known as MFC units, these plastic-encapsulated devices use smaller chips and contain fewer circuit elements than the professional-equipment range of i.cs. They also have wider pin spacing to make them suitable for the printed-circuit boards used in consumer products. The first two devices in the range to be introduced are a low-power audio amplifier and a wide-band amplifier. Type MFC4000, is a 250-mW a.f. amplifier with a low total harmonic distortion (typically, 0.7% at 50mW output) and is designed for pocket radio receivers. Contained in a four-lead package, it includes six transistors, three diodes and five resistors and requires no output transformer to match to a 16-Ω load. The input sensitivity is 15mV r.m.s. for 50mW output. It requires a 9-V d.c. supply and the quiescent current is 3.5mA. The second unit, type MFC4010, is a high-gain (60dB) wide-band (100Hz to 4MHz, −6dB points) amplifier that could



be used either as a general-purpose a.f. amplifier or as an i.f. amplifier at 465kHz. Typical output noise is 1mV r.m.s. Maximum power supply potential is 18V and typical current drain is 3mA. This i.c. contains three transistors and five resistors. Motorola Semiconductors Ltd, York House, Empire Way, Wembley, Middx.
WW 321 for further details

Mobile Communication Aerial

The ASP629 whip aerial from Antenna Specialists for vehicle mounted v.h.f. communciation systems offers 2.5dB gain relative to a ¼-wave aerial. It consists of a stainless steel whip and matching transformer assembly. The frequency range is 130-174MHz, and interference suppression ratio better than 6dB relative to ¼-wave aerial. The mounting hole required is ¾ in diameter. No access is required to inside of car. The overall length at 170MHz is 1 metre. The price is £3.6.0. Antenna Specialists UK Ltd, 66 Bolsover Street, London W.1.
WW308 for further details

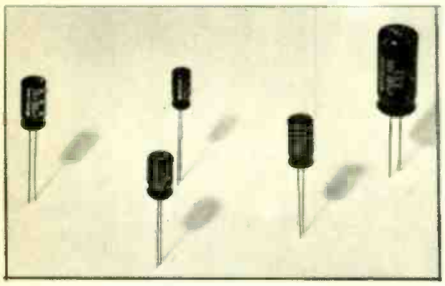
Instant P.C. Boards

What are called Bishop Circuit Zaps are pre-etched, pressure-sensitive, copper component patterns, pads, and conductor paths designed to eliminate most of the conventional processes in prototype circuit development. They comprise 28gm copper on 0.6mm glass epoxy film backed by a pressure-sensitive adhesive. This enables printed wiring boards and test circuits to be made directly from the

component layout in one operation. It can be laid down on a standard epoxy p.c. base board in the same manner as pressure-sensitive drafting aids, and adjusted until the design matches the schematic drawing. Holes are then drilled for inserting terminal stakes which requires the use of a special spring-loaded insertion tool and anvil. Holes for component insertion are drilled in the normal manner. Free samples are obtainable from the supplier: Oswald E. Boll, 4a Commercial Road, Woking, Surrey.
WW 323 for further details

Miniature Electrolytic Capacitors

A new design of miniature electrolytic capacitor is announced by ITT. The capacitors, coded Type EN 12.35 cover voltage ranges from 6.3 to 50V d.c. and capacitances from 0.47 to 1000μF. They



are fitted with insulating sleeves which, together with the single-ended design, allow close arrangement on printed circuit boards. Temperature rating is from −25° to +85°C. ITT Components Group Europe, Capacitor Product Division, Brixham Road, Paignton, Devon.
WW307 for further details

Trimmer Capacitors

Polar announce two new additions to their range of trimmers. The S5801/8 is a vertically mounted printed circuit trimmer with a capacity up to 15pF and the S5801/9 a horizontally mounted version of the same trimmer. Both have a low temperature coefficient and are suitable for u.h.f. applications. Wingrove & Rogers Ltd, 95b High Street, Great Missenden, Buckinghamshire.
WW 318 for further details

Current Source

Keithley Instruments has introduced model 225 current source which provides a predetermined amount of current that will not vary more than ±0.005% of full range, despite a wide variation of operating conditions. It will automatically establish any output terminal voltage necessary to maintain the chosen output current, from 10^{-7} to 10^{-1} A within the compliance voltage range, which may be selected from ±10 to ±100V. If the

voltage necessary to maintain the desired current level exceeds the chosen compliance limit, the 225 automatically changes its operating mode from constant-current to constant-voltage, thereby protecting voltage-sensitive loads. A light on the front panel signals that this has occurred. For making precise dynamic measurements, an external a.c. signal generator can be conveniently used to modulate the current output by means of a transformer-coupled input on the rear panel. Applying a 10 V r.m.s. sinewave at a frequency of 50Hz would produce 40% modulation peak-to-peak, decreasing to 8% modulation at 500Hz. This arrangement of superimposing modulation on a precise d.c. bias can simplify measurement of forward current-voltage characteristics and other parameters of semiconductors. An output current range switch on the front panel selects milli-, micro-, or nano-ampere ranges. Output current value within these ranges is selected by means of three decade switches, which provide a three-digit in-line display of the value selected. A resolution of 0.02% is provided by a vernier trim knob. A polarity selector switch on the front panel eliminates changing leads to reverse output polarity, a feature which makes floating unnecessary in many applications. When desirable the output can be floated up to ±500V off earth. Stable to 0.02%, output current provided is regulated to within 0.005% of full range, from no-load to full-load on the 10^{-1} to 10^{-6} ampere range, ±0.05% on the 10^{-7} ampere range. A noise level less than 0.01% of full range reduces the possibility of extraneous signal generation. Model 225 weighs 3.5kg and measures 140 × 220 × 255mm. Operation is from 105-125 and 210-250V 50-60Hz a.c. mains. Price in America $595. Keithley Instruments Inc. 28775 Aurora Road, Cleveland, Ohio 44139, U.S.A.
WW332 for further details

Differential-input Op. Amp.

Three new chopper-stabilized amplifiers from Burr-Brown combine a differential input with low voltage drift, low input current and long term d.c. level stability. The three versions, 3354/25, 3355/25 and 3356/25 feature respectively, a voltage drift of 0.2 V, 0,5 V and 1 V/degC (max) and input bias currents of 20, 50 and 50pA (max). Other features include high open loop gain and common mode rejection. These are typically 140dB at d.c. and 100dB up to 100Hz and are two parameters which combine to give linear amplification in non-inverting circuits. Output is ±10V d.c. at ±5mA. Minimum full-power response is 100kHz and minimum unity gain bandwidth is 3MHz. Input impedance for common mode signals is typically 10^{13} Ω. U.K. distributors, Fluke International Corporation, Garnett Close, Watford, Herts. WD2 4TT.
WW319 for further details

Instrumentation Recorder

It has been announced that the new Tandberg Series 100 instrumentation tape recorder will be marketed in the U.K. by Farnell Instruments. The recorder features 4 channels of i.r.i.g. standard f.m. recording on ¼in. tape at speeds of 7½, 3¾ and 1⅞in/sec. Signal-to-noise ratio at 7½in/sec is better than 48dB. Although figures for flutter are claimed to be low,

they can be further improved with electronic flutter compensation. Channel 4 has three modes of operation: data only, voice only and data interrupted by voice. A useful built-in feature is a c.r.t. monitor, which displays the deviation of all four channels simultaneously and facilitates selection of the appropriate input range. The instrument weighs 11.3kg and measures 330 × 240 × 270mm. Farnell Instruments Ltd, Sandbeck Way, Wetherby, Yorks, LS22 4DH.
WW331 for further details

Reed Microswitch

Long operating life, high switching frequency and accuracy are features claimed for a new type of microswitch with hermetically sealed reed contacts. Endurance tests, say the makers, have revealed a service life of over 100 × 10^6 switching cycles, a switching frequency of up to 50Hz and a repetitive accuracy of better than 0.01mm. The reed contacts are sealed in a glass capsule filled with inert gas and the switch is housed in a glass fibre reinforced synthetic resin. The unit, designated FBR-Robo 1, weighs 14gm and it can be fastened by screws in any position. Voltage rating is either 50 or 380V a.c. or d.c. and current rating is 0.5A. Switching power rating is 10W

(12VA) and maximum initial contact resistance 200mΩ. R. C. Knight Ltd., 20 Solent Avenue, Lymington, Hants, SO4 9SD.
WW329 for further details

Cable Identity Tester

Information Computer Systems Ltd, have announced a new instrument designed to save time and cost whenever complex cable forms or harnesses are to be checked or assembled. Immediate identification of any single wire in a group of up to 999 wires is claimed, the wire identity being displayed by numbers. Variations of the instrument include models for up to 99 wires, models expansible in 100-wire increments up to 999 wires, and

self-powered versions for use inside aircraft or where mains supplies may not be available. The instrument is not affected by cable capacitance, resistance, or inductance, and no damage can be caused to low-power components which are joined to the wires under test. Information Computer Systems Ltd, Mill Street, Crewe, Cheshire.
WW328 for further details

Noise Generator

Model NS10 has been added to the range of solid state random noise generators from ADM Electronics. Random noise is produced in the band 300kHz–1,000MHz. Over the range 1-50MHz the noise is within ±0.3dB. Operation can be from 9-24V supply and at 9V the excess noise ratio is 43dB. Consumption is less than 40mW. Voltage sensitivity is 0.6dB/V and the source impedance 37Ω. The unit is primarily intended for in-service communications receiver tests and as a primary source for video test equipment. It is available in small quantities for £2. ADM Electronics, P.O. Box 3, Merthyr Tydfil, Glam.
WW324 for further details

D.I.L. Reed Relay

A reed relay mounted in a 14-pin dual-in-line package is announced by ERG. Designed specifically to have fast closure with low bounce, the relay's 5V 9mA operating coil is suitable for low-output i.c. logic. Typical operating time is 300 μs. Dielectric strength is 200V d.c. and insulation resistance (coil to contact) $10^{10}\Omega$. Optional variations are

available. ERG Industrial Corporation Ltd, Luton Road, Dunstable, Beds.
WW327 for further details

Electronic Isolator/Coupler

An electronic device for low-level data handling, where it is required to couple systems working at different voltage levels, is being offered by Cole Electronics. It is the Rafi isolator/coupler providing d.c. separation of circuits which have a level difference of 300V d.c. (in a vacuum encapsulated version, up to 2,000V a.c.). Input is applied to an iron-cored coil with a magneto-resistor placed in the air-gap. The magneto-resistor is connected between base and emitter of a transistor which provides the outputs. When the coil is energized the magnetic field produced in the air-gap causes the resistance of the magneto-resistor to increase. The transistor base will become more positive and the transistor will conduct. The coil, magneto-resistor and transistor are contained in a case with connecting wires brought out through the bottom at 2.5mm spacing. Units are available with 5, 12 or 24V coils. Output current is 50mA (max) and output voltage 3-30V. Rise time can be 0.2-0.5ms and delay time 0.3-0.4ms depending on the configuration of input and output circuits. Cole Electronics Ltd, 7/15 Lansdowne Road, Croydon, Surrey CR9 2HB.
WW333 for further details

U.H.F. Portable Transceiver

GEC-AEI (Electronics) have announced their first u.h.f. portable f.m. transceiver for mobile radio which will be available later this year. It is type RC850/TR-P which operates on up to 10 channels in the 450-470MHz band and is intended to provide a personal communication link instead of the conventional link between base and vehicle. In its portable mode it is provided with re-chargeable batteries, loudspeaker, microphone and aerial, but it can also be slotted into an adaptor in a vehicle when it utilizes the vehicle battery, loudspeaker and aerial. Solid-state circuitry is used throughout and the weight of the transceiver in portable form is about 3.2kg. Space is provided for the addition of selective calling from base to mobile and from mobile to base by coder and decoder modules, either or both of which may be fitted. The signalling system comprises two single sequential tones. A total of 100 different codes can be handled by the decoder; the coder is able to provide nine different call codes. Channel separation can be 25kHz with ±5kHz f.m. deviation or 50 kHz with ±15kHz deviation. Ambient temperature range is −30 to +60°C or −10 to +60°C (two versions). Transmitter power output is 5W and receiver a.f. output 1W with less than 5% distortion. Spurious response better than −80dB relative to wanted signal. Approximate unit dimensions are 210 × 248 × 70mm. GEC-AEI (Electronics) Ltd, Mobile Communications Division Spon Street, Coventry, Warks., CV1 3AZ.
WW334 for further details

Single-film Silvered Mica Capacitors

Sprague Electric have introduced single-film silvered mica capacitors which have lead spacings interchangeable with those of conventional ceramic disc capacitors. They permit substitution of stable mica capacitors for various types of ceramic dielectric capacitors when the characteristics of silvered mica dielectric are required for improved circuit stability without the need for complete revision of printed wiring boards. The new capacitors, type 91M, are available in 45 ratings ranging from 10-680pF at 500V.

Graduated case sizes are offered to ensure minimum size and cost in each rating.

Standard capacitance tolerance is ±5% or ±5pF, whichever is greater. Sprague Electric (U.K.) Ltd. 159 High Street, Yiewsley, West Drayton, Middx.
WW335 for further details

Power Amplifier

An amplifier specially designed for servo-systems or other inductive loads has been announced by Ancom. The encapsulated module, type 40P-1, measures 52 × 29 × 16mm and is internally protected against transient short-circuits and inductive loads, a.c. or d.c. Supply voltage is ±40V. Characteristics include input voltage of ±10V and output of ±36V into 360Ω at

±150mA (max). Open loop gain is 5,000 (R load = 1kΩ) and closed loop gain 50. Input offset voltage is 5mV (max) and the c.m.r.r. 1,000. Maximum operating frequency is 5kHz at full output. Typically the 40P-1 could be used to drive the field coil of a d.c. servo motor where the armature is fed with a constant current and the field coil is driven between ±40V. Ancom Ltd, Devonshire Street, Cheltenham, Glos. GL50 3LT.
WW326 for further details

Literature Received

For further information on any item include the WW number on the reader reply card

ACTIVE DEVICES

We have received a large amount of literature from Fairchild (U.K.) Ltd, Kingmaker House, Station Rd, New Barnet, Herts. concerned with their range of m.s.i. integrated circuits.

"Total capability with m.s.i./l.s.i. building blocks" WW401
"System design with m.s.i. building blocks" WW402
9300 four-bit shift register WW403
9301 one-of-ten decoder WW404
9304 dual full adder WW405
9306 up/down b.c.d. counter WW406
9307 seven segment decoder WW407
9308 dual four-bit latch WW408
9309 dual four input multiplexer WW409
9310 b.c.d. decade counter WW410
9311 one-of-sixteen decoder WW411
9312 eight-input multiplexer WW412
9314 quad latch WW413
9315 one-of-ten decoder/driver WW414
9316 four-bit binary counter WW415
9317 seven segment decoder/driver WW416
9318 eight input priority encoder WW417
9328 dual eight-bit shift register WW418
9601 retriggerable monostable multivibrator WW419
4510 dual four-bit comparator WW420
MμL4027 128-bit read/write random access memory WW421
MμL9034 256-bit read only memory WW422
MμL9035 64-bit read/write memory WW423
Application note 9300 shift register WW424
Applications of the 9301 decoder WW425
Applications of the 9304 dual adder WW426
Applications of the 9311 decoder WW427
Applications of the 9601 one-shot WW428

SGS (United Kingdom) Ltd, Planar House, Walton St, Aylesbury, Bucks, have produced a large catalogue devoted to integrated circuits which costs 21s. Digital and linear circuits are included.

We have received the literature listed below from the Semiconductor Division, Westinghouse Brake and Signal Company Ltd., 82 York Way, King's Cross, London N.1.

"High-power ceramic capsule thyristors" WW429
data sheets for the following capsule thyristors:
Type 342Tx. 540amps WW430
Type 344Tx. 580amps WW431
Type 358Tx. 775amps WW432
Type 362Tx. 805amps WW433
Type 364Tx. 845amps WW434
Type 366Tx. 905amps WW435
"Westinghouse thyristors" WW436
data sheets for thyristors:
Type 71Tx. 250amps WW437
Type 73Tx. 275amps WW438
Type 74Tx. 300amps WW439
Type 80Tx. 325amps WW440
Type 81Tx. 350amps WW441

Sprague Electric Company have produced an 88-page brochure (engineering bulletin 25645) devoted to the 54H/74H series of t.t.l. logic circuits. The three sections in the publication deal with general design characteristics for reliable system design, electrical characteristics detailing test and limiting conditions, and finally, parameter measurement information. The brochure may be obtained from SDS (Portsmouth) Ltd, Gunstore Road, Hilsea Industrial Estate, Portsmouth, Hants. WW442

A short-form catalogue (PG110) published by Pirgo Electronics Inc. describes a range of power transistors capable of handling up to 90A and triacs intended for use up to 250A. The catalogue is available from Sprague Electric (U.K.) Ltd, Sprague House, 159 High Street, Yiewsley, Middlesex WW443

We have received from Technical Publications Department, R.C.A. Ltd., Sunbury-on-Thames, Middlesex, reprints of two papers by R.C.A. engineers.

ST-4150. "MOS dual-gate transistor for u.h.f. applications" WW444
ST-4128. "RF integrated amplifiers in high-power broadband structures" WW445

The second in a series of application notes being produced by Hivac Ltd, Stonefield Way, Ruislip, Middlesex, HA4 0JT, is now available. It describes the use of glow diodes in timing circuits, gives performance curves for tungsten filament lamps and describes a sub-miniature neon lamp WW446

A.E.G. Telefunken, Fachbereich Röhren, Vertrieb, 7900 Ulm, Söflinger StraBe 100, West Germany, have available a 486-page data book covering valves, tubes and photo-electric devices WW447

PASSIVE COMPONENTS

"Liquid Crystals and their Applications" is a title of a book available from the Optosonic Press, Box 883, Ansonia Station, New York, N.Y.10023, U.S.A., at $12 per copy. The book contains a bibliography of over 600 entries and descriptions of 25 patents concerned with liquid crystal applications.

A marine aerial catalogue for the h.f. and v.h.f. bands may be obtained from Antenna Specialists U.K. Ltd, 66 Bolsover Street, London W.1 WW461

Reed relays are the subject of a new catalogue from Electrothermal Engineering Ltd, 270 Neville Road, London E.7 .... WW462

A leaflet (MB/4/69) mentioning some of the company's varied products (insulators, sockets, indicators, variable capacitors, programme boards, etc.) may be obtained from Oxley Developments Co. Ltd, Ulverston, Lancs. WW463

The latest, enlarged, Radiospares Catalogue (April-July '70) is now available. Radiospares, P.O. Box 427, 13-17 Epworth Street, London E.C.2 .... WW464

The following literature is available from Best & Raynor Ltd, 27 Homesdale Road, Bromley, Kent.

Indicator lamp and lampholders by Guest International WW465
Ten-way rotary thumbwheel switches WW466

"Magnadur magnets for d.c. motors" (TP1139) is the title of a 50-page book intended for students, lecturers and designers of small electric motors. It costs 16s 6d by post from Mullard Ltd, Mullard House, Torrington Place, London W.C.1.

A range of indicator lamps, including one with an arrow-shaped head for mimic diagrams, is described in leaflets (LS5 and LS14) from J.H. Associates Ltd, 1 Church Street, Bishops Stortford, Herts WW467

Timers, relays etc., are described in a catalogue from Intertechnique Ltd., Unit 5, Victoria Road, Portslade, Sussex BN4 1XQ WW468

Details of a new logic training aid, which uses discrete components on a printed circuit card and miniature wire-ended bulbs are given in a leaflet from Limrose Electronics, Lymm, Cheshire WW479

Supplementary list IIIF of used scientific equipment for sale may be obtained from V.N. Barrett & Co. Ltd, 1 Mayo Road, Croydon, CR0 2QP, Surrey WW480

A short-form catalogue of oscilloscopes, a counter/timer, digital voltmeter and stroboscopes has been produced by SE Laboratories (Engineering) Ltd, North Feltham Trading Estate, Feltham, Middlesex WW481

Reference, comparison and measurement instruments, bridges, potentiometers and resistive networks are included in the current Guildline Instrument's condensed catalogue (11-69) which may be obtained from Lyons Instruments Ltd, Hoddesdon, Herts WW482

We have received a price list and leaflets describing the Mk.2 Norkit system. This is a logic tutor employing discrete components, r.t.l. and solderless interconnections WW483

A leaflet describing a logic test probe which indicates 0, 1 or open circuit has been produced by Electronic Equipment Manufacturers, Bromham, Chippenham, Wilts WW484

We have received the following literature from Millbank Electronics, The Square, Forest Row, Sussex.

Catalogue 2520. "Turner microphones" WW485
Leaflet 2570. "Turner balladier microphones" WW486
Leaflet. "Amplifiers for professional use" WW487
Leaflet. "Loudspeakers for internal and external use" WW488
Leaflet. "Sound mixers" WW489
Leaflet. "Audio modules" WW490
Leaflet. "Sound system accessories" WW491

Nore Microwave, of Southend-on-Sea, Essex, have published two data sheets.

Solid state noise generators WW492
Noise generator supply WW493

A new catalogue, bulletin 7501, called "Airpax Tachometry" describes equipment for speed measurement, sensing and control. Airpax Electronics, Seminole Division, P.O. Box 8488, Fort Lauderdale, Florida 33310, U.S.A. WW494

A Kelvin bridge ohmeter for measuring low resistance values is the subject of a leaflet from the Croydon Precision Instrument Company, Hampton Rd, Croydon CR9 2RU WW495

GENERAL INFORMATION

The Metrication Board has produced a leaflet "Going Metric—Everyday Units". Metrication Board, 22 Kingsway, London W.C.2.

"Know How, No.7" from Pye Group (Radio and Television) Ltd, P.O. Box 49, St. Andrews Rd, Cambridge, CB4 1DS, is a guide to servicing Pye single-standard monochrome television receivers fitted with the 169 or 569 chassis WW502

Another book in the "Concept series" is available from Tektronix U.K. Ltd, Beaverton House, P.O. Box 69, Harpenden, Herts. It is called "Vertical Amplifier Circuits" and consists of some 460 pages. The cost is 10s per copy including postage.

Communications Receivers

Abridged specifications of some of the equipment on the British market

It being several years since we published a survey of communications receivers we recently sent a questionnaire to some 60 manufacturers and importers. From the replies received we have compiled the following tables showing the main features of over 50 receivers. This information, together with the survey article by Pat Hawker on p. 256 will, we hope, assist readers in the choice of suitable equipment. The list includes only those receivers which are complete in one unit (except for power supplies, in some cases) and which can be continuously tuned. Further details may be obtained by direct application to the appropriate supplier.

Name, Brand and Model	*Type of Circuit*	*Frequency Coverage*	*Receiving Modes*	*Input and Output Impedance*	*Sensitivity and S/N Ratio*	*Number of Valves and/or Semi-conductors*	*Gain Controls*	*Country of Origin*	*Additional Information*
ASTRO COMMUNICATION LABORATORY (U.K.) SR–209B (Standard) from £900 or SR–250B (Ruggedized version) from £1,100	Single, double or triple superheat	2MHz–12GHz using plug-in tuning heads	A.M. F.M. C.W. Pulse	50 Ω (I/P) 600 Ω audio, 93 Ω video (O/P)	0·3μV at 1kHz bandwidth to 60μV at 8MHz A.M. 10dB F.M. 21dB	Typically 75 transistors 20 diodes dependent on modules used	R.F. A.F. Video	U.K.	Image rejection 60dB. Built-in power supply. Signal strength and tuning meters. Modular construction. Battery Pack.
SR–502 from £1,000	Double superhet	10–500kHz 0·5–30 MHz	A.M. F.M. C.W. S.S.B. Search	As for SR–209B	1μV A.M. and F.M. 0·3μV S.S.B. 0·1μV C.W. A.M. 10dB F.M. 20dB	← As for SR-209B	→	U.K.	As for SR-209B. Plus frequency synthesizor with digital readout.
AVELEY ELECTRIC LTD. **Rohde & Schwarz** EK 47 (Price on request)	Double superhet	10kHz–30MHz	A.M. C.W.	50 Ω (I/P) 600 Ω (O/P line) 5 Ω (O/P L.S.)	— 10dB			Germany	B.F.O. "S" meter. Battery/mains supply. Image rej. > 80dB. I.F. rej. > 80dB.
EK 56 (Price on request)	Double superhet	10kHz–30MHz	A.M. F.M. C.W.	As for EK 47	2·6–8μV 20dB			Germany	Aerial E.M.F. meter. Variable I.F. bandwidth. A.G.C. <2dB change from 1μV–100mV aerial E.M.F. Image rej- > 80dB. I.F. rej. > 80dB. Battery/mains supply.

Name, Brand and Model	Type of Circuit	Frequency Coverage	Receiving Modes	Input and Output Impedance	Sensitivity and S/N Ratio	Number of Valves and/or Semi-conductors	Gain Controls	Country of Origin	Additional Information
Aveley Electric Ltd. cont.									
HFH (Price on request)	Double superhet	100kHz–30MHz	A.M.	60 Ω (I/P) 4k Ω (phone) 15 Ω (L/S) 500k Ω (recorder)	0·1µV	13 Valves 10 Transistors		Germany	B.F.O. Crystal cal. 500kHz. Battery/mains supply. Variable I.F. bandwidth. Meter. I.F. rej. > 50dB.
ESUM (Price on request)	Double superhet Triple superhet	25–1,300MHz (plug-in units)	A.M. F.M.	50 Ω (I/P) 4k Ω (phone) 15 Ω (L/S) 250k Ω (recorder)	1µV > 6dB	32 Valves 36 Semiconductors		Germany	Crystal freq. cal. 10MHz. Meter 0–20dB and 0–80dB. Battery/mains supply. Variable I.F. bandwidth. Image rej. > 50dB. I.F. rej. > 90dB. Built-in L.S.
BARNET FACTORS LTD.									
Unica UNR 30 £13 13s.	Superhet	550kHz–30MHz	A.M.	75 Ω (I/P) 8 Ω (O/P)		4 Valves		Japan	Built-in P.U. Built-in L.S.
UR 1A £24	Superhet	550kHz–30MHz	A.M. S.S.B.	75 Ω (I/P) 8 Ω (O/P)				Japan	Built-in P.U. or 12V battery operated. Built-In L.S. "S" meter. Telescopic aerial. Bandspread tuning.
Lafayette HA 600 £45	Superhet	150–400kHz 550kHz–30MHz	A.M. C.W. S.S.B.	50–400 Ω (I/P) 4,8 or 500 Ω (O/P)	1µV 10dB	19 Semiconductors	A.F. R.F.	Japan	Built-In P.U. or 12V battery operated. "S" meter. Mechanical filter. Noise limiter. Bandspread tuning.
HA 800 £57 10s.	Double superhet	3·5–4MHz 7–7·3 MHz 14–14·35MHz 21–21·45MHz 28–29·7MHz 50–54MHz	A.M. C.W. S.S.B.	50 Ω (I/P)	1µV 10dB	24 Semiconductors	A.F. R.F.	Japan	Built-in P.U. or 12V battery operated. "S" meter. Mechanical filters. Noise limiter. Crystal cal. Bandspread tuning.
PF 60 £37 10s.	Superhet	152–174MHz	F.M.	50 Ω (I/P)	0·7µV 20dB	27 Semiconductors		Japan	Built-in P.U. or 12V battery operated. Built-in L.S. Squelch control. Facilities for crystal control.
B. H. MORRIS & CO. (RADIO) LTD.									
Trio 9R59DE £41 10s.	Superhet	550kHz–30Mhz (4 ranges)	C.W. S.S.B.	4–8 Ω (O/P)	6–18dB for 10dB S/N ratio	8 Valves	A.F. R.F.	Japan	Built-in P.U. "S" meter. Noise limiter Bandspread tuning.
JR500SE £69 10s.	Double superhet	Amateur bands between 3·5 and 30MHz (600kHz width)	A.M. C.W. S.S.B.	8 Ω, 500 Ω } (O/P)	1·5µV for 10dB	7 Valves 2 Transistors	A.F. R.F.	Japan	Built-in P.U. "S" meter. Crystal osc. Crystal B.F.O. Bandspread tuning.
JR 310	Double superhet	< —— As for JR 500SE —— >				6 Valves 5 Transistors	A.F. R.F.	Japan	Built-in P.U. "S" meter. Crystal osc. Crystal B.F.O. Mechanical filter.
BROOKES & GATEHOUSE LTD.									
Homer Model K Mk2 (Navigation receiver) £84	Superhet	160–415kHz (1) 600–1,650kHz (2) 1,600–4,150kHz (3)	A.M. C.W.	3,000 Ω, 1,000 Ω } (I/P)	3µV (Band 1) 40µV (Bands 2 & 3)	14 Transistors	A.F.	U.K.	Battery operated. Crystal B.F.O. Expanded scale for radio beacons (250–350kHz). A.G.C. < 6dB O/P for 40dB I/P.
COLLINS RADIO COMPANY OF ENGLAND									
51S–1 £1,250	Double superhet Triple superhet	2–30MHz, 200kHz–30MHz with 55G–1 preselector	A.M. C.W. S.S.B. R.T.T.Y.	50 Ω (I/P) 4 Ω, 600 Ω } (O/P)	0·6µV (S.S.B. and (C.W.) 3µV (A.M.) 10dB	Valve		U.S.A.	

continued on page 308

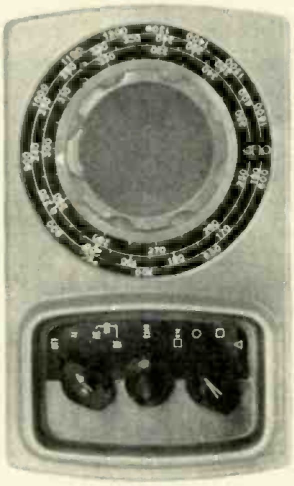
Plessey PR1553

Trio JR-310

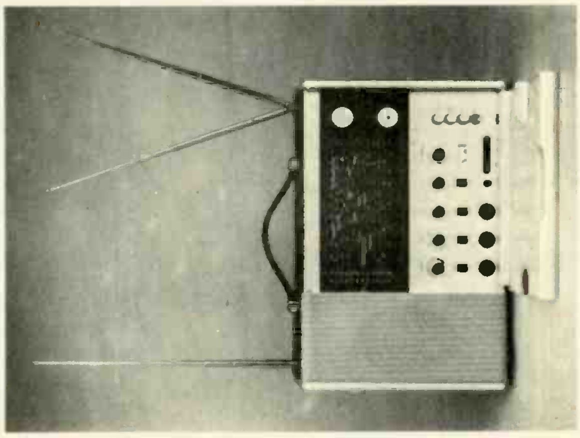
Heathkit GC-1U "Mohican"

Eddystone EC958

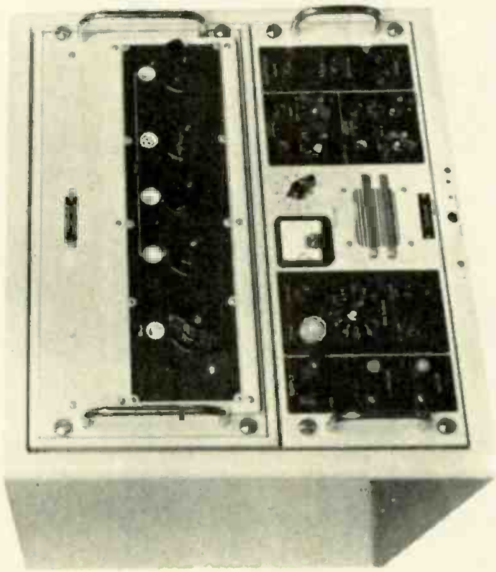
Park Air S Line aircraft monitor



Brookes & Gatehouse Homer/K Mk2



Braun T1000CD (portable)



Marconi N2020

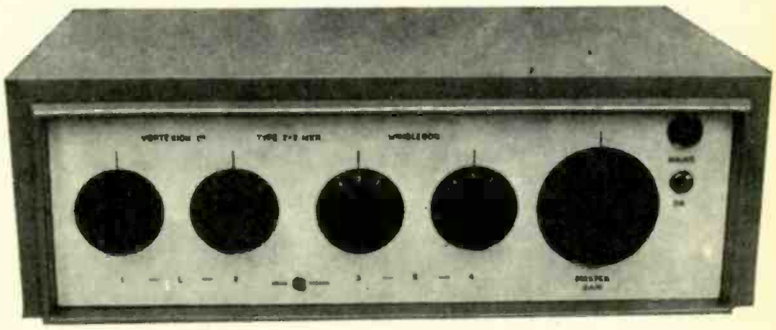
Name, Brand and Model	Type of Circuit	Frequency Coverage	Receiving Modes	Input and Output Impedance	Sensitivity and S/N Ratio	Number of Valves and/or Semi-conductors	Gain Controls	Country of Origin	Additional Information
Collins Radio Co. of England cont.									
651S–1 £2,300	Triple superhet	400kHz–30MHz	A.M./C.W. S.S.B. R.T.T.Y. N.B.S.V.	50Ω (I/P) 8–600Ω unbalanced and 600Ω balanced (O/P)	0·7µV (S.S.B. and C.W.) 3·5µV (A.M.) 10dB	Semiconductor		U.S.A.	
DAYSTROM LTD.									
Heathkit SB–301 £163 6s. (kit)	Double superhet (tunable I.F.)	3·5–4MHz 7–7·5MHz 14–14·5MHz 15–15·3MHz 21–21·5MHz 28–30MHz	A.M. S.S.B. C.W.	50Ω (I/P) 8Ω (O/P) High Z (phone)	< 0·25µV 10dB on S.S.B.	10 Valves 8 Diodes	A.F. R.F.	U.S.A.	Built-in power unit. "S" meter. Crystal filter. Crystal cal. Image rej. 60dB.
SB–310 £156 14s. (kit)	Double superhet (tunable 1st I.F.)	3·5–4MHz 5·7–6·2MHz 7–7·5MHz 9·5–10MHz 11·5–12MHz 14–14·5MHz 15–15·5MHz 17·5–18MHz 26·9–27·4MHz	A.M. S.S.B. C.W.	50Ω (I/P) 8Ω (O/P) High Z (phone)	0·3µV 10dB on S.S.B.	10 Valves 8 Diodes	A.F. R.F.	U.S.A.	Built-in power unit. "S" meter. Crystal filter. Crystal cal. Linear master osc. freq. 5–5·5MHz. Image rej. 60dB.
GR–54 £48 16s. (kit)	Superhet	180–420kHz 550–1,550kHz 2–30MHz	A.M. S.S.B. C.W.	50Ω (I/P) 8Ω (O/P) High Z (phone)	Various from 1–8µV (A.M.) to 0·4–4µV (S.S.B.) 10dB	6 Valves 8 Diodes	A.F. R.F.	U.K.	Built-in power unit. Switched B.F.O. Bandspread. "S" meter. Crystal filter. Image rej. 50dB (average).
GR–64 £24 16s. (kit)	Superhet	550kHz–30MHz	A.M. S.S.B. C.W.	High Z (I/P) 8Ω (O/P) 50Ω–10kΩ (phone)		4 Valves 2 Diodes		U.K.	Built-in power unit. Built-in L.S. tuning indicator meter.
GR–78 £68 18s. (kit)	Superhet Double superhet	200–400kHz 550kHz–30MHz	A.M. S.S.B. C.W.	High Z (I/P) 16Ω (O/P) High Z (phone)	15µV and 4µV 10dB	17 Transistors 7 Diodes	A.F. R.F.	U.S.A.	Rechargeable battery supply. "S" meter. Crystal cal. Image rej. 45dB. Bandspread.
GC–1U £39 16s. (kit)	Superhet	580–1,550kHz 1·69–30MHz	A.M. S.S.B. C.W.	50Ω, High Z (I/P) 25Ω (O/P) High Z (phone)	10µV and 2µV 10dB	10 Transistors 4 Diodes	A.F. R.F.	U.K.	Battery operated. "S" meter. B.F.O. Bandspread. Image rej. 30dB.
EDDYSTONE RADIO LTD.									
830/7 (Price on request)	Superhet Double superhet	300kHz–30MHz (9 ranges)	A.M. C.W. S.S.B.	75Ω (I/P) 250Ω I.F., 3Ω A.F., 600Ω line, Med. Z phone (O/P)	3µV for 15dB 3kHz bandwidth	15 Valves 4 Semiconductors	A.F. I.F. R.F.	U.K.	Built-in P.U. Built-in L.S. "S" meter Crystal cal. Crystal filter. Noise limiter. Image rej. > 70dB and > 50dB. Provision for crystal control.
850/4 (Price on request)	Superhet	10–600kHz (6 ranges)	A.M. C.W.	75Ω, 300Ω (I/P)	< 5µV for 15dB above 100kHz (A.M.) < 5µV for 15dB (all frequencies C.W.)	11 Valves	A.F. I.F. R.F.	U.K.	Built-in P.U. Built-in L.S. Crystal filter. Provision for crystal control. Image rej. > 75dB at 600kHz.
940 (Price on request)	Superhet	480kHz–30MHz (5 ranges)	A.M. C.W. S.S.B.	75Ω (I/P) 100kΩ A.F., 2·5Ω A.F., 600Ω line, 200Ω phone (O/P)	< 3µV for 15dB	13 Valves	A.F. R.F./I.F.	U.K.	Built-in P.U. Built-in L.S. "S" meter. Crystal cal. Image rej. 90dB at 1MHz, 40dB at 20MHz.
958 (Price on request)	Superhet Double superhet Triple superhet	10kHz–30MHz (10 ranges)	A.M. F.M. C.W. S.S.B. F.S.K.(optional)	75Ω, 600Ω (I/P) Ext. synth., 3Ω A.F., 150Ω line, 600Ω line, 75Ω I.F., Low Z phone (O/P)	3µV for 10dB at 3kHz bandwidth (A.M.) 1µV for 10dB at 3kHz bandwidth (C.W./S.S.B.)	97 Semiconductors	A.F. I.F. R.F.	U.K.	Built-in P.U. Built-in L.S. "S" meter. Crystal cal. Crystal filter. Ranges 1–4, local oscillator has drift cancelling loop locked to harmonics derived from oven-controlled crystal oscillator. Image rej. > 60dB below 1·6MHz, > 70dB up to 18MHz, > 50dB to 30MHz.

continued on page 309

Vortexion

STEREO MIXERS

These electronic Stereo Mixers range from 2+2 to 5+5 input channels, with left and right outputs at 500 millivolts into 20K ohms up to infinity.
Separate control knobs are provided for L & R signals on each stereo channel so that a Mono/Stereo changeover switch provided can give from four to ten channels for monaural operation, in which state the L & R outputs provide identical signals.
A single knob ganged Master Volume control is fitted, plus a pilot indicator.
The units are mains powered and have the same overall dimensions as monaural mixers.



Also available Monaural Electronic Mixers:—

4 Way Monaural Mixers	3 Way Monaural Mixers with P.P.M.
6 Way Monaural Mixers	4 Way Monaural Mixers with P.P.M.
8 Way Monaural Mixers	6 Way Monaural Mixers with P.P.M.
10 Way Monaural Mixers	8 Way Monaural Mixers with P.P.M.

50/70 WATT ALL SILICON AMPLIFIER WITH BUILT-IN 4 WAY MIXER USING F.E.T.'s. This is a high fidelity amplifier (0.3% intermodulation distortion) using the circuit of our 100% reliable 100 Watt Amplifier (no failures to date) with its elaborate protection against short and overload, etc. To this is allied our latest development of F.E.T. Mixer amplifier, again fully protected against overload and completely free from radio breakthrough. The mixer is arranged for 3-30/60 Ω balanced line microphones, and a high impedance line or gram. input followed by bass and treble controls. Since the unit is completely free from the input rectification distortion of ordinary transistors, this unit gives that clean high quality that has tended to be lost with most solid state amplifiers.
100uV on 30/60 ohm mic. input. 100mV to 100 volts on gram/auxiliary input 100 KΩ.

CP50 AMPLIFIER. An all silicon transistor 50 watt amplifier for mains and 12 volt battery operation, charging its own battery and automatically going to battery if mains fail. Protected inputs, and overload and short circuit protected outputs for 8 ohms—15 ohms and 100 volt line. Bass and treble controls fitted. Models available with 1 gram and 2 low mic. inputs. 1 gram and 3 low mic. inputs or 4 low mic. inputs.

100 WATT ALL SILICON AMPLIFIER. A high quality amplifier with 8 ohms—15 ohms and 100 volt line output for A.C. Mains. Protection is given for short and open circuit output over driving and over temperature. Input 0.4v on 100K ohms.

200 WATT AMPLIFIER. Can deliver its full audio power at any frequency in the range of 30 c/s—20 Kc/s ± 1 db. Less than 0.2% distortion at 1 Kc/s. Can be used to drive mechanical devices for which power is over 120 watt on continuous sine wave. Input 1 m W 600 ohms. Output 100-120v or 200-240v. Additional matching transformers for other impedances are available.

30/50 WATT AMPLIFIER. With 4 mixed inputs, and bass and treble tone controls. Can deliver 50 watts of speech and music or over 30 watts on continuous sine wave. Main amplifier has a response of 30 c/s-20Kc/s ± 1db. 0.15% distortion. Outputs 4, 7.5, 15 ohms and 100 volt line. Models are available with two, three or four mixed inputs for low impedance balanced line microphones, pick-up or guitar.

VORTEXION LIMITED, 257-263 The Broadway, Wimbledon, London, S.W.19

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WW—007 FOR FURTHER DETAILS

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For pumping lasers. For strobing. For photography. For any application in which quality, reliability and performance are vital, that's where you'll find EEV flash tubes.

There's almost certainly a flash tube in the EEV range that has the right characteristics for your application – and if there isn't we can probably make one!

EEV flash tubes have extra heavy-duty electrodes. They give you long life, with up to 10^6 flashes, *and* they give you high conversion efficiency. Our air-cooled xenon flash tubes have a wide range of input energy levels and can operate at high repetition rates.

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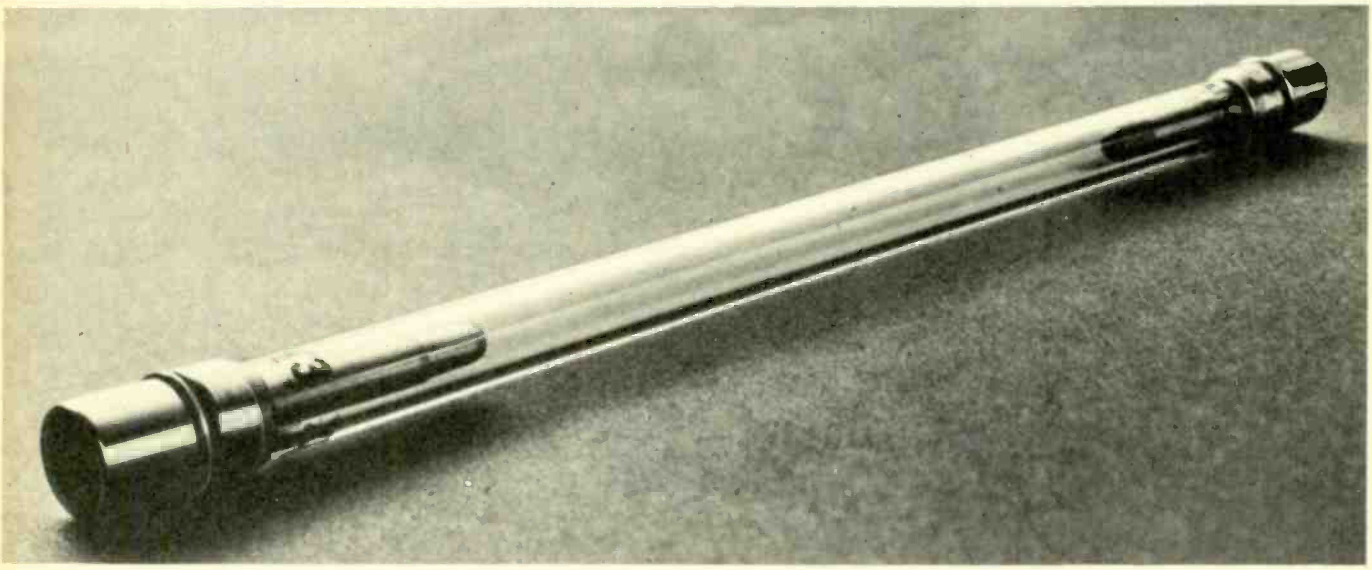
English Electric Valve Co Ltd, Chelmsford, Essex, England. Telephone: 0245 61777 Telex: 99103 Grams: Enelectico Chelmsford



Type	*Energy input per flash max. (J)*	*Arc length (in.)*	*Bore diameter (mm)*	*Typical operating conditions* Voltage (kV)	*Series inductance (µH)*	**Flash rate*	*Trigger voltage (kV)*
XL615/4/3	400	3	4.0	2.5	400	1 per 30 sec.	12-16
XL615/7/3	600	3	7.0	2.5	400	1 per 15 sec.	12-16
XL615/9/4	1500	4	9.0	2.5	400	1 per 30 sec.	16-20
XL615/10/5.5	3500	5.5	10.0	2.5	400	1 per 60 sec.	16-20
XL615/10/6.5	5000	6.5	10.0	2.5	800	1 per 2 min.	20-25
XL615/10/12	9000	12	10.0	2.5	800	1 per 2 min.	25
XL615/13/6.5	10000	6.5	13.0	2.5	800	1 per 2 min.	25
XL615/13/12	18000	12	13.0	2.5	800	1 per 2 min.	25

**At maximum input levels (air-cooled)*

To: English Electric Valve Co Ltd, Chelmsford, Essex, England
Send for full data on EEV flash tubes.

I am interested in ________________ (application)

Name ________________

Position ________________

Company ________________

Address ________________

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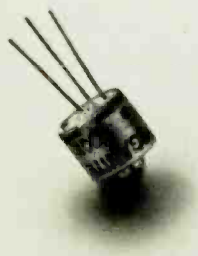
Tel. exchange or code ________________

Number ________________ Ext. ________________

ENGLISH ELECTRIC VALVE CO LTD

CRC 6



Crash Dive

This was a Morganite type 81E Cermet Trimming Potentiometer that didn't make it.

Shame really.
The more so because this particular specimen had already survived several rigorous mechanical and electrical tests. But then, we are unusually strict at Morganite, because our customers like it that way.

Another thing they like is having the right products at the right time, complete with full technical information to match. So our constant research and development is more than an ivory-tower luxury—it's a common-sense necessity.

We reckon that reliable delivery makes sense too. As you'll see when you ring us for samples for evaluation or development projects. Then you can put our Cermet Trimming Potentiometers through *your* test routine and watch how they stand up to it.

You'll like what you see.

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Bede Industrial Estate, Jarrow, County Durham
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Morgan

WW—009 FOR FURTHER DETAILS

UHF klystron efficiency? You can rely on it with EEV.

For reliable UHF klystron performance choose from the largest range available today. The EEV range. 40kW, 25kW, 10kW, 7kW and 5kW.

Each one offers economy and ease of use, solid-state compatibility and, above all, efficiency—even at low drives.

Broadcasting authorities around the world are using EEV klystrons for UHF television—proving their operational flexibility, reliability and efficiency in climatic conditions as varied as those of Australia and Finland.

To get the full facts about the tube *you* need, please post the coupon.

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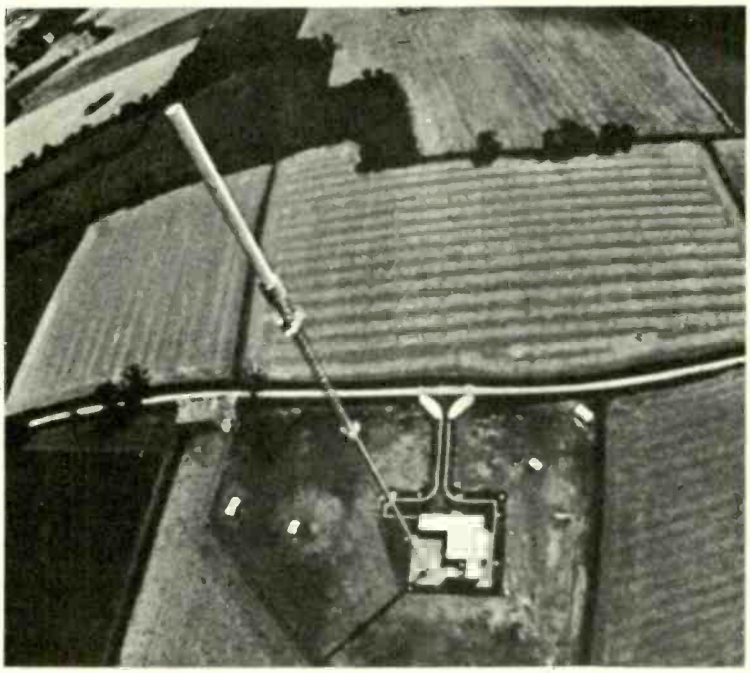


To: English Electric Valve Co Ltd, Chelmsford, Essex, England
Please send EEV data on UHF television amplifier klystrons.
I am interested in a klystron with the following parameters:

Frequency ________ *Bandwidth* ________ *Power* ________

Name & position ________

Company ________

Address ________

____

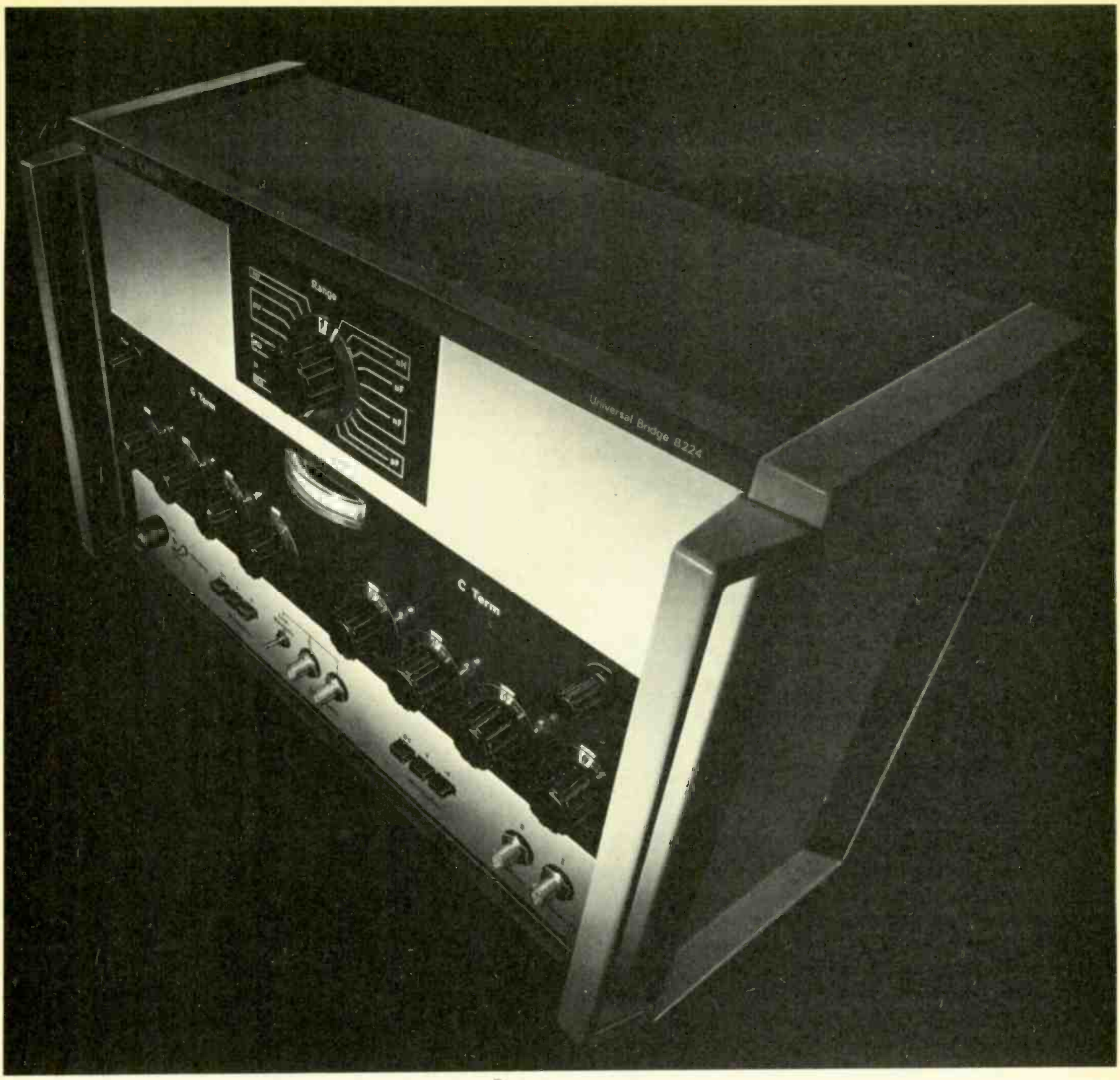
Tel. exchange or code ________

Number ________ Extension ________

ENGLISH ELECTRIC VALVE CO LTD

CRC 3

WW—010 FOR FURTHER DETAILS



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Direct readout accurate to 0·1%

Wayne Kerr B224 is a new audio-frequency bridge giving accurate values for the resistive and reactive terms of any component or complex impedance in the range 2 micro-ohms to 500 gigohms.
Accuracy: $\pm$0.1% ($\pm$0.3% for impedances below 10Ω).
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200Hz-20kHz using external source with internal wide-band detector.
Connections: 2-terminal for isolated components. 3-terminal for in-situ measurements. 4-terminal below 10Ω; cuts lead errors.
Readout: G/R and C/L terms simultaneously. In-line displays with decimal point illuminated. Null meter also indicates correct range.
Power: From internal rechargeable battery.
Ask for B224 data sheet.

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Experience:

Since the beginning of industrial r.f. heating, EEV have been the pace-setters. With this experience, backed by our equal know-how in the transmitter valve field, is it any wonder that we are so well known for power triodes?

EEV make power triodes for industrial heating applications from 1kW up to 250kW. They are all conservatively rated and realistically designed to give good length of life. Whatever your application —for drying paper, baking biscuits, welding plastic, treating metal—r.f. heating the EEV way is economical and dependable.

Our sales engineers are at your service to discuss designs and to recommend the best tube or combination of tubes for your particular application.

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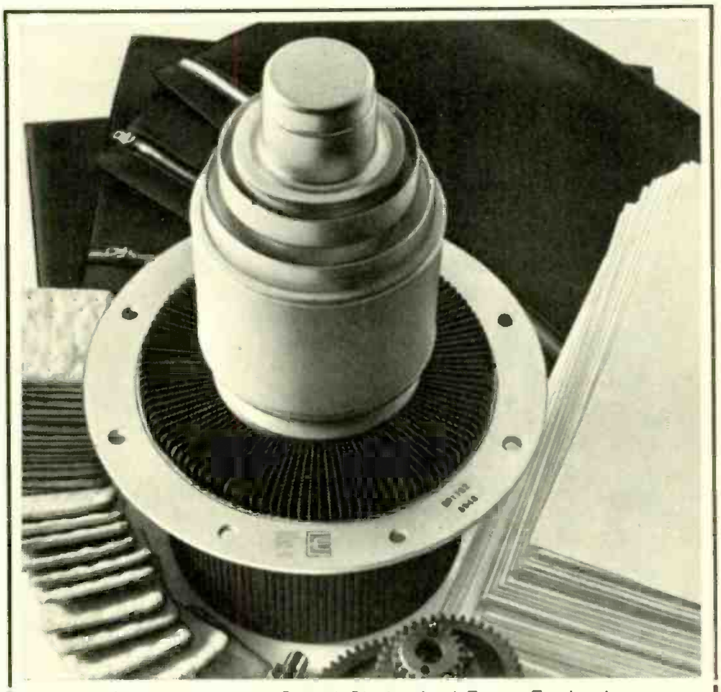
the vital factor of EEV's industrial r.f. heating power triode range



To: English Electric Valve Co Ltd, Chelmsford, Essex, England.

Please send full data on power triodes for industrial heating.
Please recommend triodes for an equipment with these ratings.

Output power (kW) ___ *Anode voltage max. (kV)* ___ *Frequency (MHz)*

Name & Position

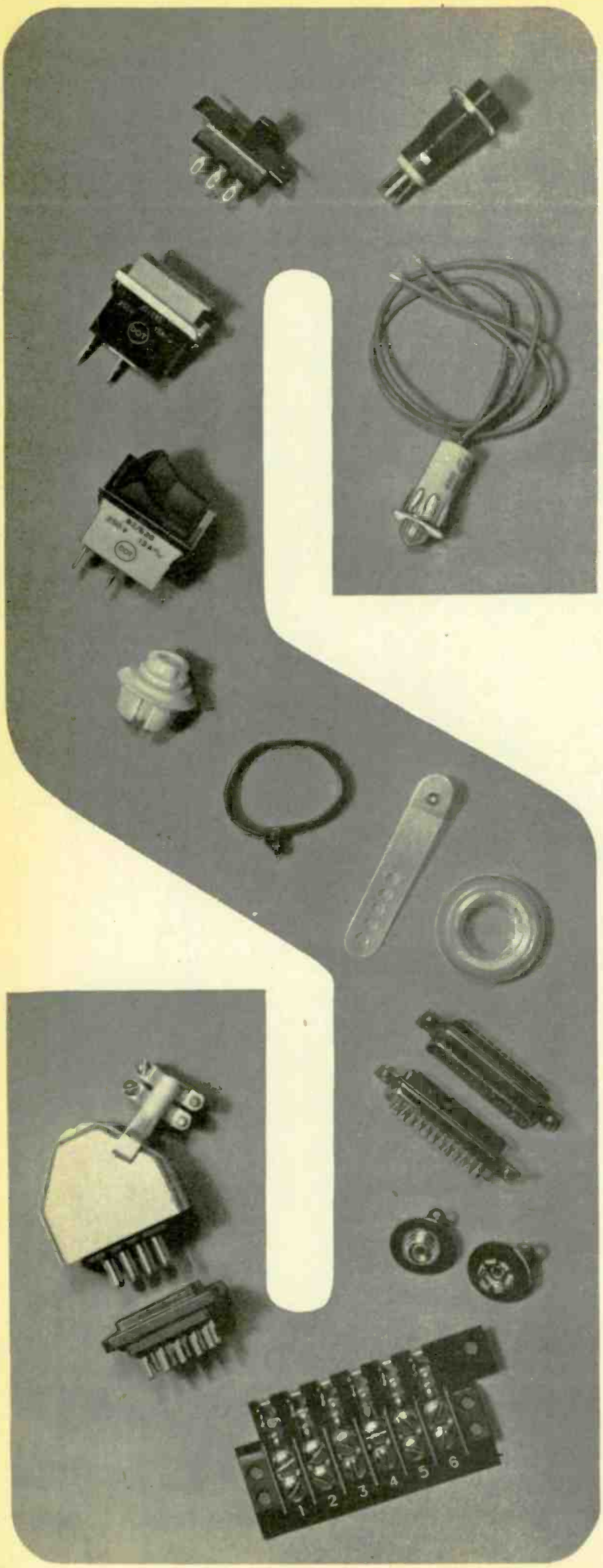
Company

Address

Telephone exchange or STD code

Number Extension

WW—014 FOR FURTHER DETAILS



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MICROPHONES & ACCESSORIES

Our range of microphones includes all types, ribbon, omnidirectional and cardioid, with or without switches, for hand or stand use. All microphones are manufactured in a special section of our works, under strictly controlled conditions with stringent test and inspection at every stage. Each and every microphone is individually tested both aurally and on Bruel & Kjoer visual and graphic recording test equipment for conformity to a prescribed performance. Accessories such as desk or floor stands, wind shields and parabolic reflectors are also well catered for.
Besides microphones, every need of Public Address is met by a wide range of amplifiers, both mains and battery operated, mixers and ambiophonic units, loudspeakers and associated equipment, disc recorder amplifiers and cutter heads.

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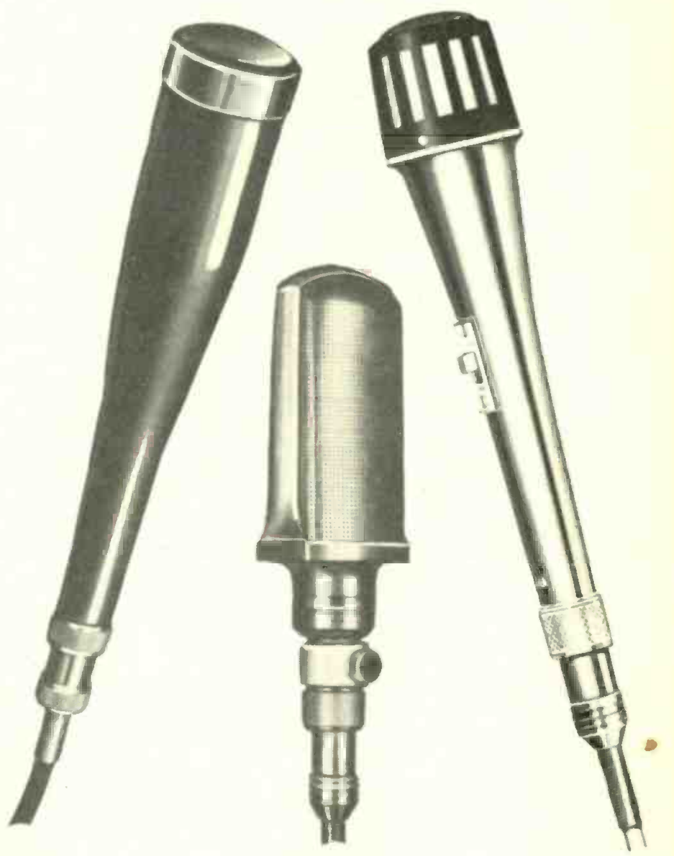

DP4 GR1 GC2

JACW/X/59 (M22)

WW—019 FOR FURTHER DETAILS

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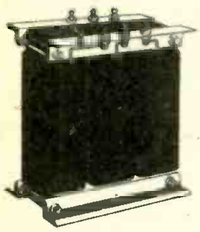
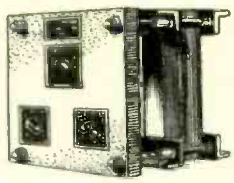
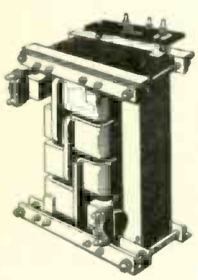
Saturable Reactors
Voltmobile voltage regulators
Rectifier Sets



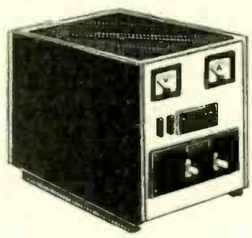
Transformers
Air cooled power transformers from 0.5 to 300kVA at voltages up to 2kV. 1 or 3 phase, double or auto wound, step-up or step-down. We have manufactured transformers to over 5,000 different designs for many applications and the experience which has been accumulated from these designs is built into every Harmsworth, Townley transformer



Voltmobiles
The most robust and useful control device for loads such as furnaces, ovens, bar heating and high temperature research. Our Voltmobiles are in use in their thousands to control transformers and rectifier sets or they can be used directly between supply and load. 64 step on load switching. Voltmobiles are auto-transformers which give control from 1.6% to 100% of input volts. Over-Volts up to 125% of input is also available. Standard models are made for single and 3 phase supply and for outputs from 20 Amps to 200 Amps with on-load switching.



High Current Transformers
Years of experience have gone into the design and production techniques used in the manufacture of our low voltage, high current transformers for use in furnaces, high temperature research, heating and other applications. These techniques enable us to produce transformers with output currents up to tens of thousands of amps at economical prices



Rectifiers
Sturdily built air cooled equipment from 50W to 500kW for plating, plasma arc welding, electrolytic machining and many other applications. Equipment incorporates either silicon or selenium rectifiers and can be built with fixed or variable output. Variable outputs are obtained by the use of continuously variable auto transformers, saturable reactors or Voltmobile regulator.

Saturable Reactors
From 5kVA up to 300kVA for controlling the outputs from transformers or rectifier units. Saturable reactors are infinitely variable reactors which can control outputs from transformers etc, from 10% to 100% of full output.

Chokes
A.C. and D.C. chokes

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Harmsworth, Townley
Transformers
Rectifiers

HARMSWORTH, TOWNLEY & CO. LTD.
2 Hare Hill, Todmorden, Lancs.
Telephone Todmorden 2601 Extension 22

WW—020 FOR FURTHER DETAILS

do a 'which?' hunt on mini-meters

Which has a d.c. sensitivity of 20,000 ohms per volt?
Which has an a.c. sensitivity of 2,000 ohms per volt?
Which has a d.c. accuracy $\pm 2\frac{1}{4}$% F.S.D.?
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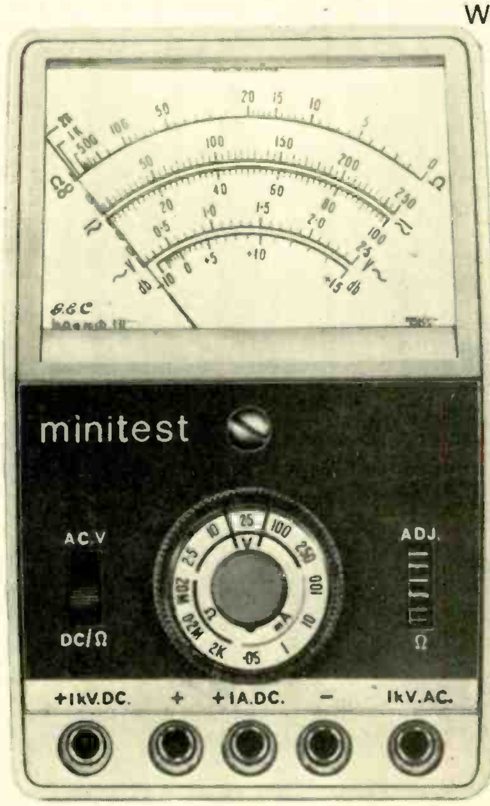
Which maintains a.c. accuracy to 20 kc/s?
Which provides high voltage probes to extend the range to 25 or 30 kV d.c. for testing electronic equipment with high source impedance?
Which provides probes that can be used with any other meter of similar sensitivity?
Which type of case would you like? Leather or Vinyl. Both available.
Which meter makes every user a devil's advocate for its performance and handiness?



The pocket size **Minitest**

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A Member Company of GEC Electrical Components Ltd.

Cut the crackle they said – so we did!

And now Erie have added the NEW 500 SERIES to their wide range of hot moulded track potentiometers. *Quiet* potentiometers that retain low noise levels through a long operational life (upwards of 100,000 cycles).

With the 500 Series comes reduction in size, improved mechanical construction and improved reliability PLUS all the advantages of the standard range: hot moulded track element of large cross-sectional area giving low current densities, high voltage ratings and eliminating local high spots and over-heating. Less wear, longer life. The 500 Series includes single and dual ganged, and dual concentric versions. With or without mains switch.

The NEW DOUBLE BRUSH MECHANISM glides over the large cross sectional area hot moulded track with low noise, low torque and increased reliability.

An integral moulding of base, track and terminals gets rid of solders, rivets, welds; provides excellent humidity characteristics and fewer mechanical joints. And Erie provide you with a good choice of resistance values, from 47Ω to 2.2MΩ linear 1W, and from 1kΩ to 1MΩ non-linear ½W.

Cases are in glass filled nylon; spindles are of plastic or steel.

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Let us send you the 500 Series data today. We'll also include details of our full range.

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ERIE MOULDED TRACK POTENTIOMETERS

P6

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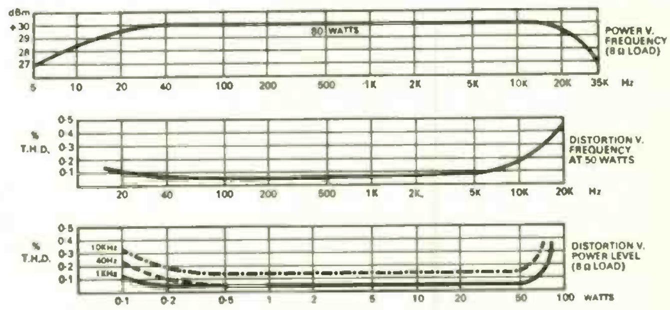
"Studio 80" amplifier

POWER OUTPUT:	Max 80W into 8 ohm.
POWER BANDWIDTH:	5 Hz to 35 KHz at 80 W.
FREQUENCY RESPONSE:	+ 0 dB − .5 dB 20 Hz to 20 KHz.
TOTAL DISTORTION:	Less than 0.05 at 1 KHz.
SIGNAL TO NOISE RATIO:	Better than−95 dB below maximum output.
POWER SUPPLY:	100/120–200/250 A/C 50-60 Hz.



The "Studio 80" Power Amplifier has been produced to high performance standards for Studio and Laboratory applications.

Its proven characteristics puts it in a class beyond anything yet available in power, performance, and price, and is the ultimate in economic functional engineering design – Write for full details of guaranteed performance specification.

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(STD 027-971)

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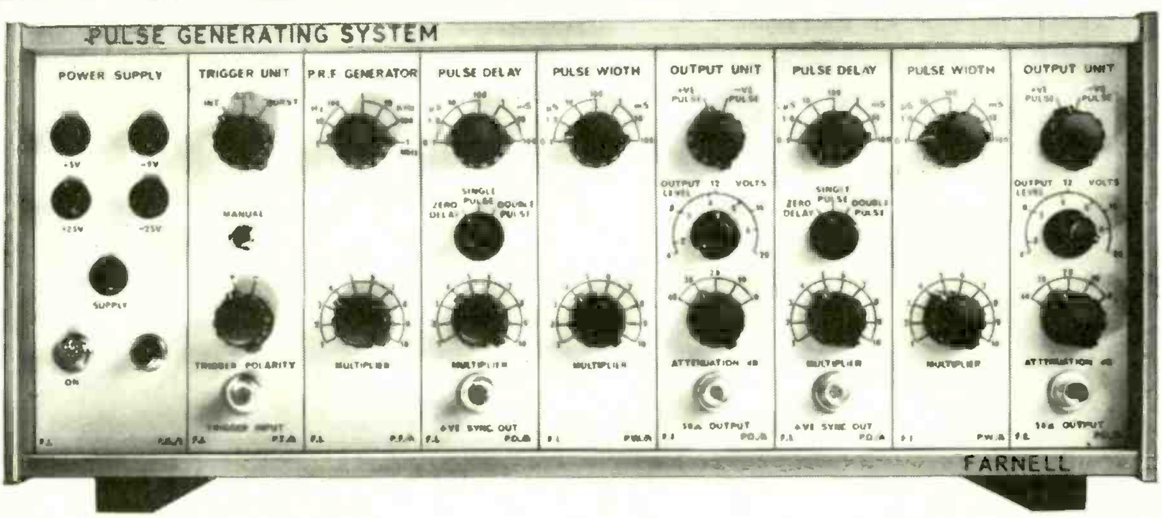
P.R.F.-0·01Hz to 10MHz



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Component modules available: Power Supply, Trigger Unit, PRF Generator, PRF Divider, Delay Unit, Pulse Width Unit, Output Unit. Variable Slope Output Unit.

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ENTHOVEN offers you Europe's Widest Range

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Available in a wide range of sizes and specifications—flux cored and solid-standard grade or high purity*
(*up to 99.99995%)

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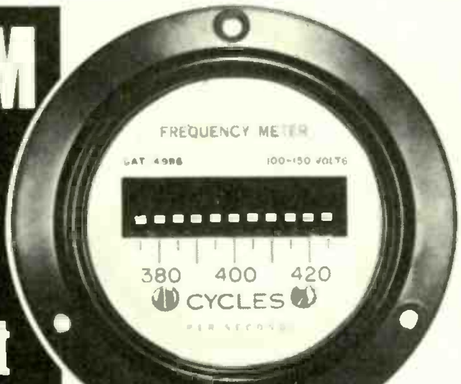

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used as standards in many industries

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Note a few of the specification details below:—

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ATTRACTIVE NEW MODELS

FROM APT

Three of them shown are part of the new family of Power Packs in the Series 10 range. These compact power supply units give you high performance and top quality at an economical price. It's worth finding out more about the Series 10, so write to-day. P.S. Our other model illustrated is for display only.

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WW—038 FOR FURTHER DETAILS

Now you can get a fully equipped CCTV studio from GVS for as little as £3,000

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The widespread need for this type of package deal within industry, commerce and education fields are numerous. And each individual requirement can be met from the simplest operation to a full broadcast studio.

If you are about to invest in CCTV equipment or would like to discuss your requirements, let GVS "put you in the picture"

Write or telephone:

GENERAL VIDEO SYSTEMS LTD.
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Telephone: 01-202 8056

WW—039 FOR FURTHER DETAILS

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With every Claude Lyons Regulac comes the benefit of 35 years' experience in variable transformers. Regulacs come in hundreds of models from small single units for laboratory or instrument use to large ganged assemblies for high-power 3-phase operation at outputs from 210VA to 28·8 kVA and above.

The range includes portable, dual-output and oil-immersed models plus many high-frequency and special types—and is constantly being extended.

Regulacs provide smooth, continuous adjustment of voltage output from zero to line voltage and above, either hand-operated or motor-driven. No device is more useful, versatile and reliable for the control of AC voltage.

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WW—040 FOR FURTHER DETAILS

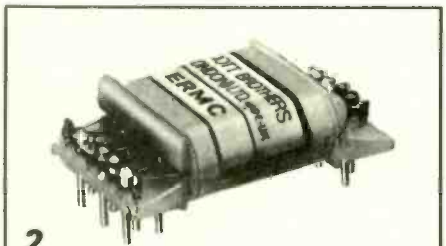
SHRINK YOUR SWITCHING PROBLEMS...

with 4 new improved miniature relays from

Associated Automation

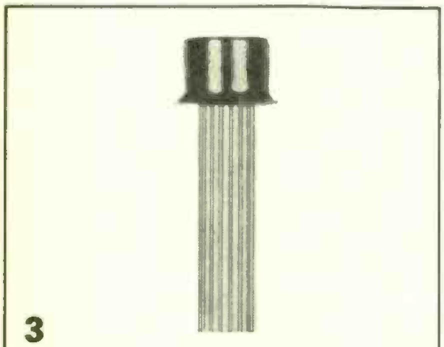
1

Mercury Wetted Contact Relay Type EBRM:
Height only 10mm for low profile pcb mounting; 20mW bi-stable, 40mW single-side-stable; operate time lms nominal at max. coil power; life over 25 x 10^9 operations at rated load of 100VA; bounce-free for both Form C or D contact resistance.



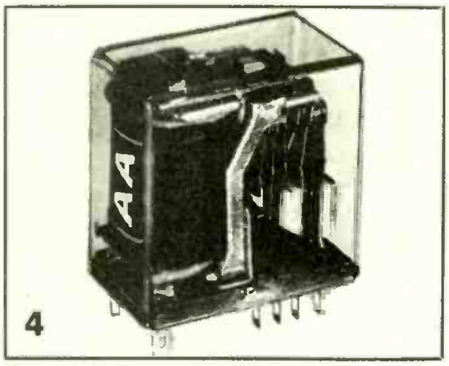
2

Dry Reed Relay Type ERMC/D/E:
Miniature open, shielded and encapsulated styles with up to 5 poles, offering all the advantages of reeds at low cost; standard relays operate from 35mW depending on contact arrangement; electrostatic shielding, high voltage insulation and low thermal types can be specified; life expectancy 10 x 10^6 operations at full load, contact rating 10VA.



3

Hermetically Sealed Relay Type TF:
All-welded, T.O.5 transistor can envelope giving high isolation switching with high shock and vibration characteristics; full CPL approval for standard versions; switching capability 1 amp at 28V D.C. to low level; single and double pole; operate powers down to 40mW.



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Enclosed Industrial Relay Series 20:
Wide range of coils, contact arrangements and mountings; up to 6 poles, up to 5 amp 100W; life over 10 x 10^7 operations; single or twin contacts in wide range of materials; low-priced, readily available, easy to apply.

All these illustrations are full size.

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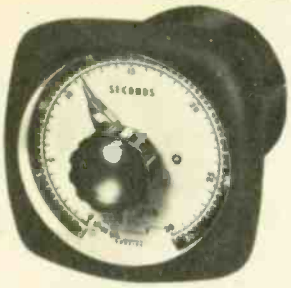
WW—045 FOR FURTHER DETAILS

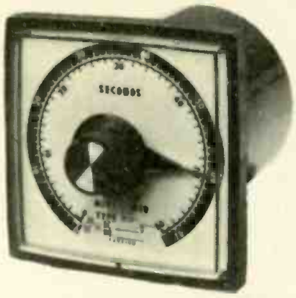
OMRON PROCESS TIMERS



SYS TIMER

- ★ SYNCHRONOUS MOTOR & CLUTCH
- ★ 10 MILLION OPERATIONS
- ★ Instantaneous & Timed out 6 AMP contacts
- ★ Repeat Accuracy ± ½%
- ★ Dial ranges 0-10 secs up to 0-28 hrs. May also be used as impulse start

£11 dependent on quantity



NSY TIMER

- ★ 2 sets 5 amp changeover output contacts
- ★ 5 Million operations
- ★ Repeat accuracy ±½%
- ★ Set time can be altered whilst in operation

Dial ranges from seconds to hours

Approx. **£8.10.0** each dependent on quantity.

STP TIMER

SYNCHRONOUS MOTOR & CLUTCH
Matchbox size frontal area
Automatic re-set

- ★ PLUG-IN OCTAL BASE
- ★ INSTANTANEOUS AND TIMED OUT 2 AMP CONTACTS
- ★ RANGES: 0-26 SECS TO 0-2 MINS

£6 dependent on quantity

TDS TRANSISTORISED TIMER

- ★ On/Off Signal Lamps fitted.
- ★ Instantaneous & timed out contacts.
- ★ Plug in Octal base.
- ★ Timer Ranges up to 180 secs.

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S.I.A.

S.I.A. Sub-miniature Micro-Switch. ★ 100,000 ops. ★ 5 amps c/o contacts. ★ Size less than 2cm x 1cm x 0.5cm.

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FLOATLESS LIQUID LEVEL CONTROLS, PROXIMITY SWITCHES

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★ OUTPUT 0-260V ★ INPUT 230V 50/60CPS

Inset shows latest pattern Brush gear ensuring smooth continuous adjustment.

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★ SHROUDED FOR BENCH OR PANEL MOUNTING

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2.5 amp	£6.15.0	8 amp	£14.10.0	12 amp	£21.0.0
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50 AMP 0-24V DC L.T. SUPPLY UNIT

- ★ Continuously Rated.
- ★ Large Ammeter and Voltmeter.
- ★ Ideal for Plating Units.
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Size and weight 16" x 12" x 27" High 70lbs. Rear wheels fitted for ease of handling.

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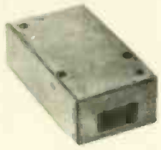

- ★ REFLECTIVE TYPE WITH BUILT-IN LIGHT SOURCE
- ★ WILL ALSO OPERATE FROM REMOTE LIGHT SOURCE
- ★ MATCHBOX SIZE
- ★ SENSES ANY OBJECT—COLOURS, THICK SMOKE

Operates from 12 V.A.C. Output signal 0.2 amp. 100 V.

Approximately **£5.10.0** dependent on quantity

SOLID STATE VARIABLE VOLTAGE CONTROL

- ★ Output 25-240V
- ★ Input 240V 50 CPS
- ★ 5 amp & 10 amp models
- ★ Completely sealed

5 amp model
£8.7.6
10 amp model
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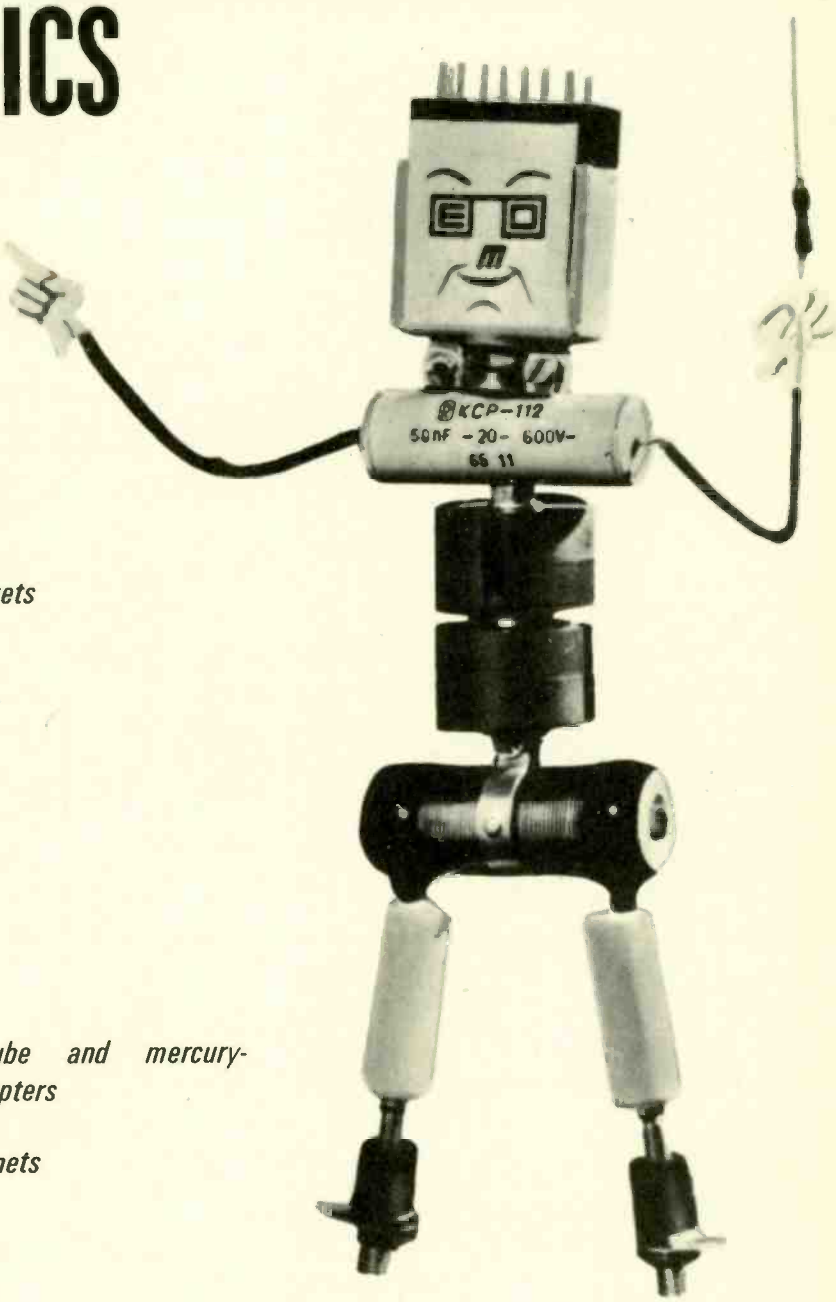

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WW—050 FOR FURTHER DETAILS

QUARNDON NEW PRODUCTS

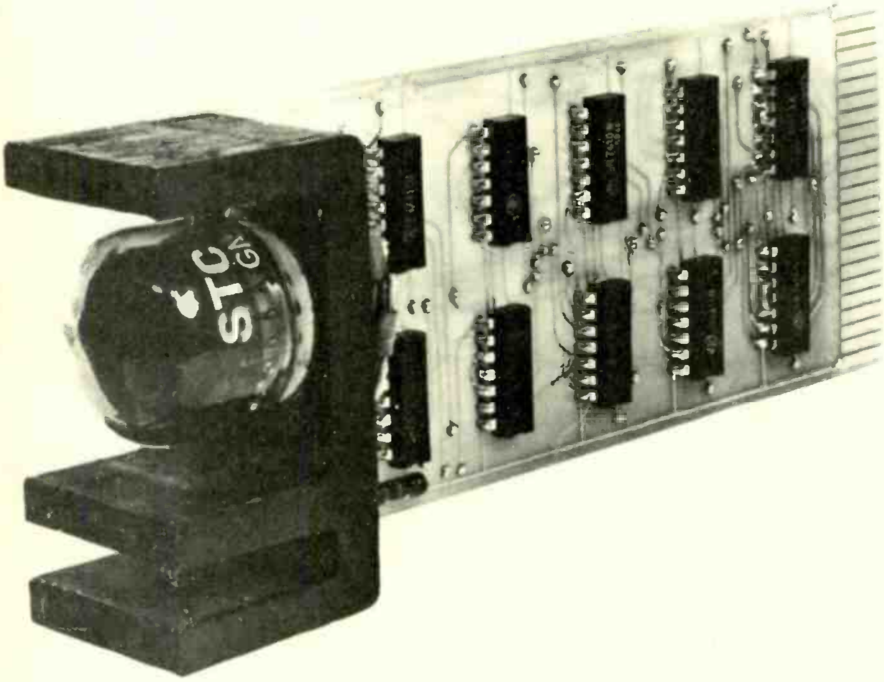
NEW REVERSIBLE COUNTER MODULE

An important addition to the range of integrated circuit decade counter modules manufactured by Quarndon Electronics Ltd., is the DCM1711 reversible or up/down counter. These modules use TTL logic elements and incorporate readout on a numerical indicator tube.

The DCM1711 reversible counter is intended for industrial control and counting applications at up to at least 15 MHz in either direction. The unique carry/borrow circuit simplifies the wiring between modules and provides a zero sense output for sign change purposes.

Another decade counter module, designed for general purpose counting and frequency measurement, is the DCM1709 which will operate at up to 10 MHz. An alternative version of this counter is the DCM 1708 which has a discrete component decoder-tube driver giving the clearest possible display. Where a static readout is required whilst counting is in progress, the DCM 1749 is available incorporating a store. BCD outputs are available on all modules and provision is made for the display of a decimal point. All modules fit a standard ISEP rack.

For further information WW200



DCM 1711 REVERSIBLE COUNTER MODULE

NEW PRICES FOR SGS LINEAR INTEGRATED CIRCUITS

Large price reductions have just been announced by SGS (UK) Ltd on their extensive range of linear integrated circuits. The new prices are as follows:—

	1–24			25–99			100+		
	£	s	d	£	s	d	£	s	d
μA702C, μA709C, μA710C	1	0	3		16	3		13	6
μA711C	1	4	9		19	9		16	6
L141T1 (formerly μA741C)	2	2	9	1	14	3	1	8	6
L123T1 (formerly μA723C)	2	2	9	1	14	3	1	8	6

For further information WW201

NEW TTL ELEMENTS

SN74153N DATA SELECTOR

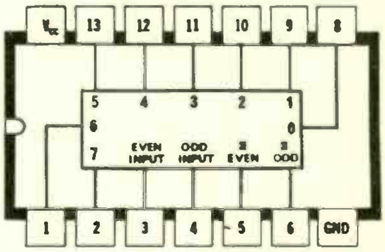
One of six new Texas Instruments data selectors and decoders, the SN74153N is a dual four input multiplexer. Separate strobe inputs are provided for each section.

Price (1-29) £2.13.2.

SN74180N 8 BIT PARITY GENERATOR

The SN74180N will generate either an odd or even parity bit for the 8 bit word applied to its inputs. Several SN74180N devices can be cascaded for longer word lengths.

Price (1-29) £5.5.7.



SN7486N EXCLUSIVE OR ELEMENT

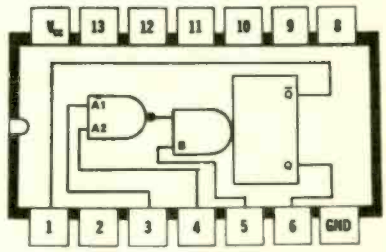
The SN7486N contains four 2 input exclusive OR gates. These elements are used widely in digital systems, such as applications requiring error detection, comparison schemes and counting.

Price (1-29) £1.12.7.

SN74121N MONOSTABLE

The SN74121N high performance monostable multivibrator or one shot, can be triggered by negative going edge applied to either of the A inputs or by a positive going voltage applied to the B input which incorporates a Schmitt circuit. Internal components provide a delay of 50nS. but this can be extended to 40 Seconds with external capacitor and resistor.

Price (1-29) £2.8.3.



For further information WW202

QUARNDON ELECTRONICS

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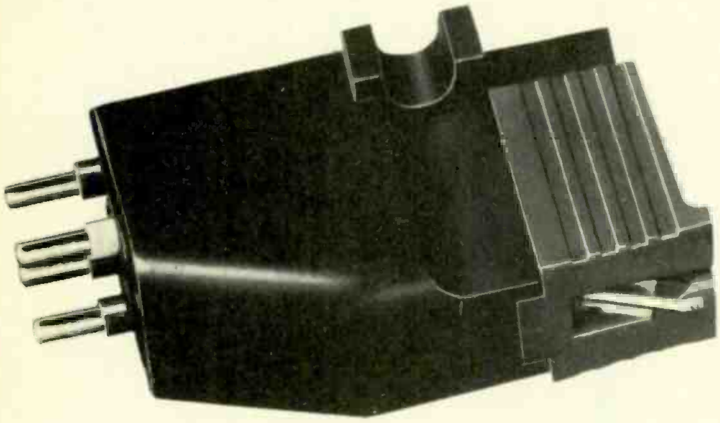
On Goldring's 850 cartridge, even the price is magnetic.



£6/10/0

(tax paid.)

Fact: magnetic cartridges are more compatible with transistor amplifiers than crystal cartridges.

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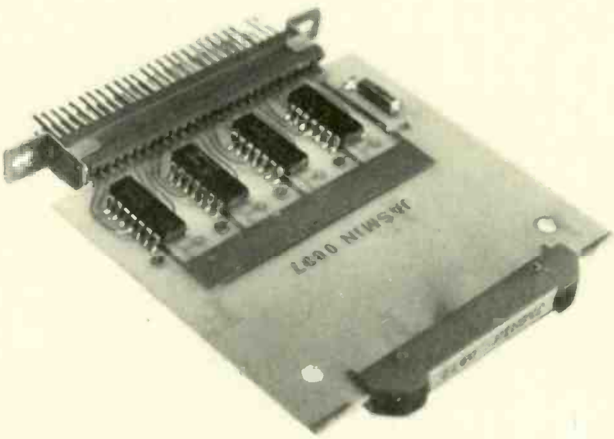

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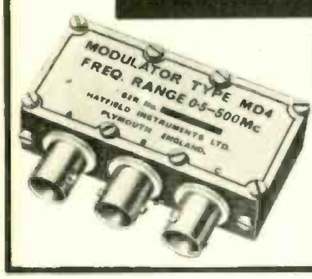

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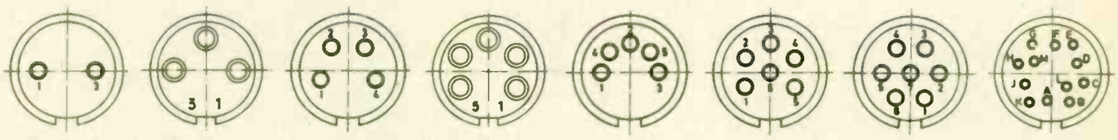

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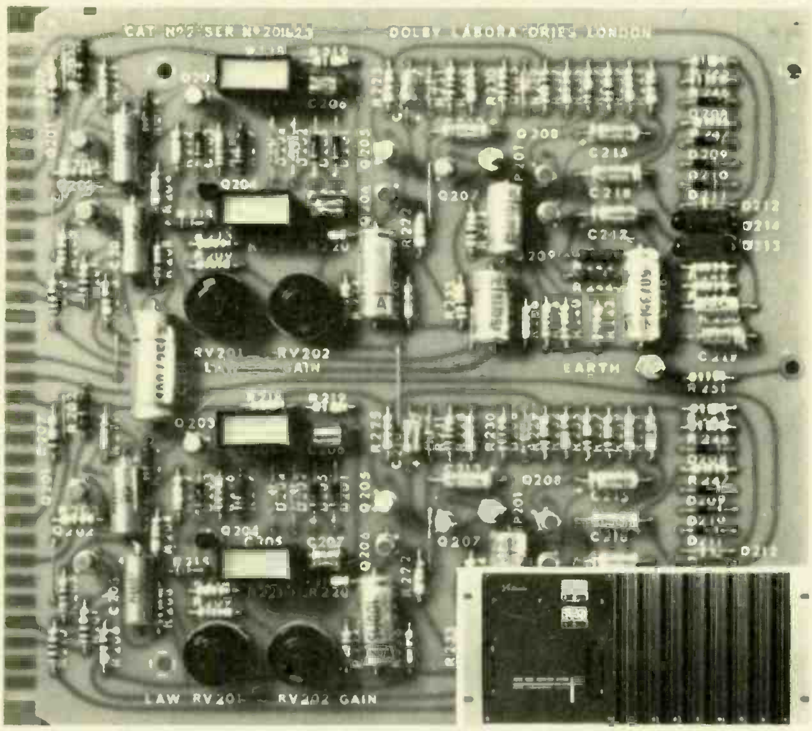

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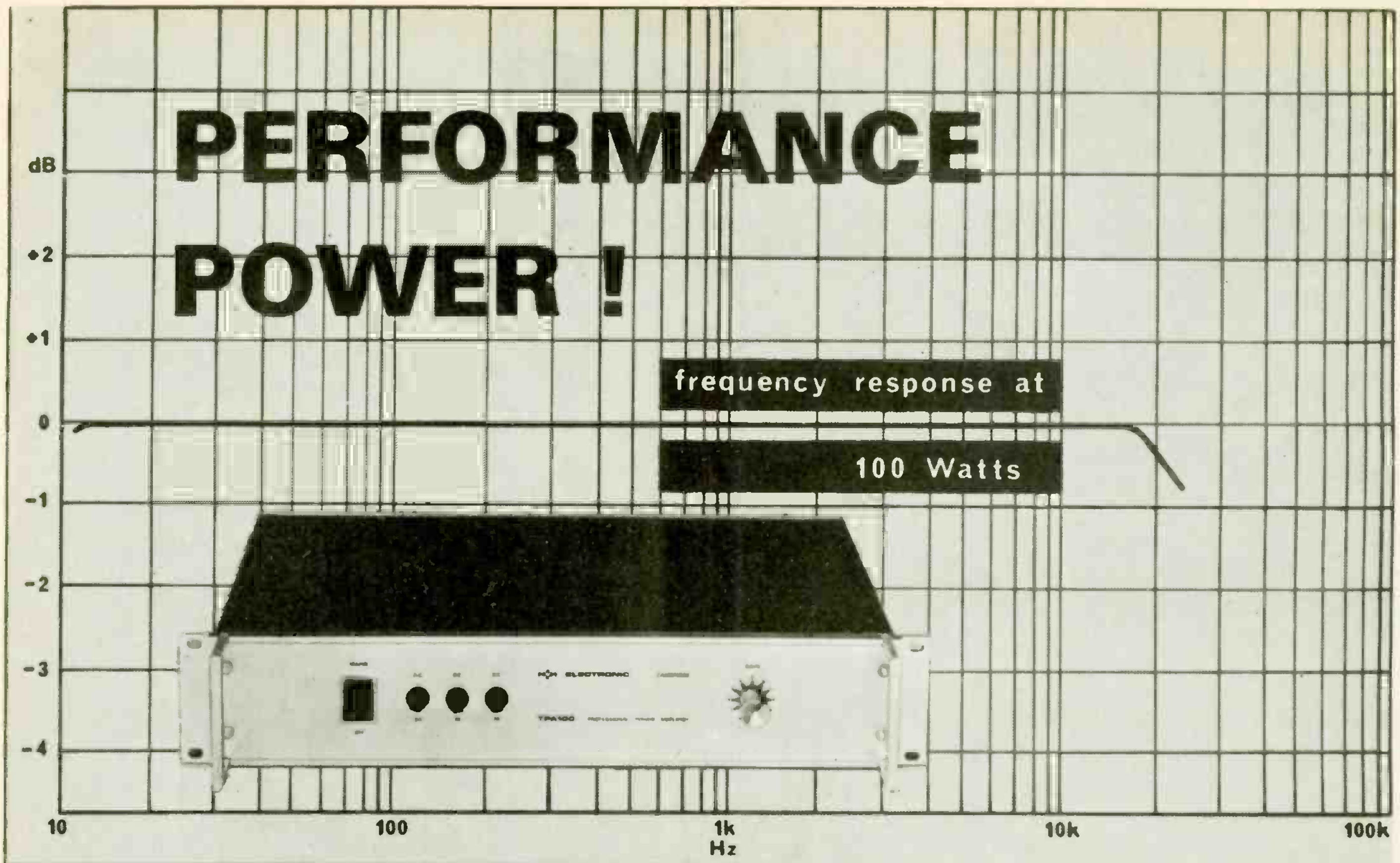

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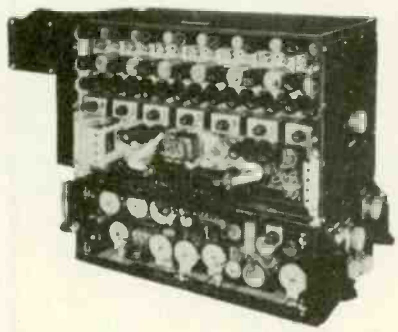

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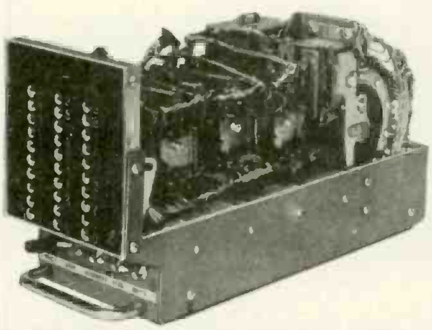

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Wireless World

Electronics, Television, Radio, Audio

Sixtieth year of publication

June 1970

Volume 76 Number 1416

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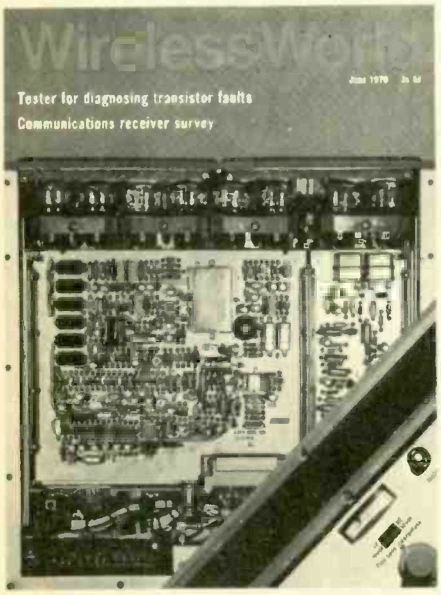

Communications receivers being the theme of the first article in this issue, our **cover illustration** is of part of the chassis of the Racal RA1220 on which is superimposed the "Racalok" digital frequency readout.

IN OUR NEXT ISSUE

Constructional details for a simple stereo pre-**amplifier** based on two integrated circuits. **Class AB audio amplifier.** Having discussed the pros and cons of class A and B amplifiers in this issue (p.278) J. L. Linsley Hood gives details of an amplifier with class A performance but reduced thermal dissipation.
Understanding and using **operational amplifiers.**

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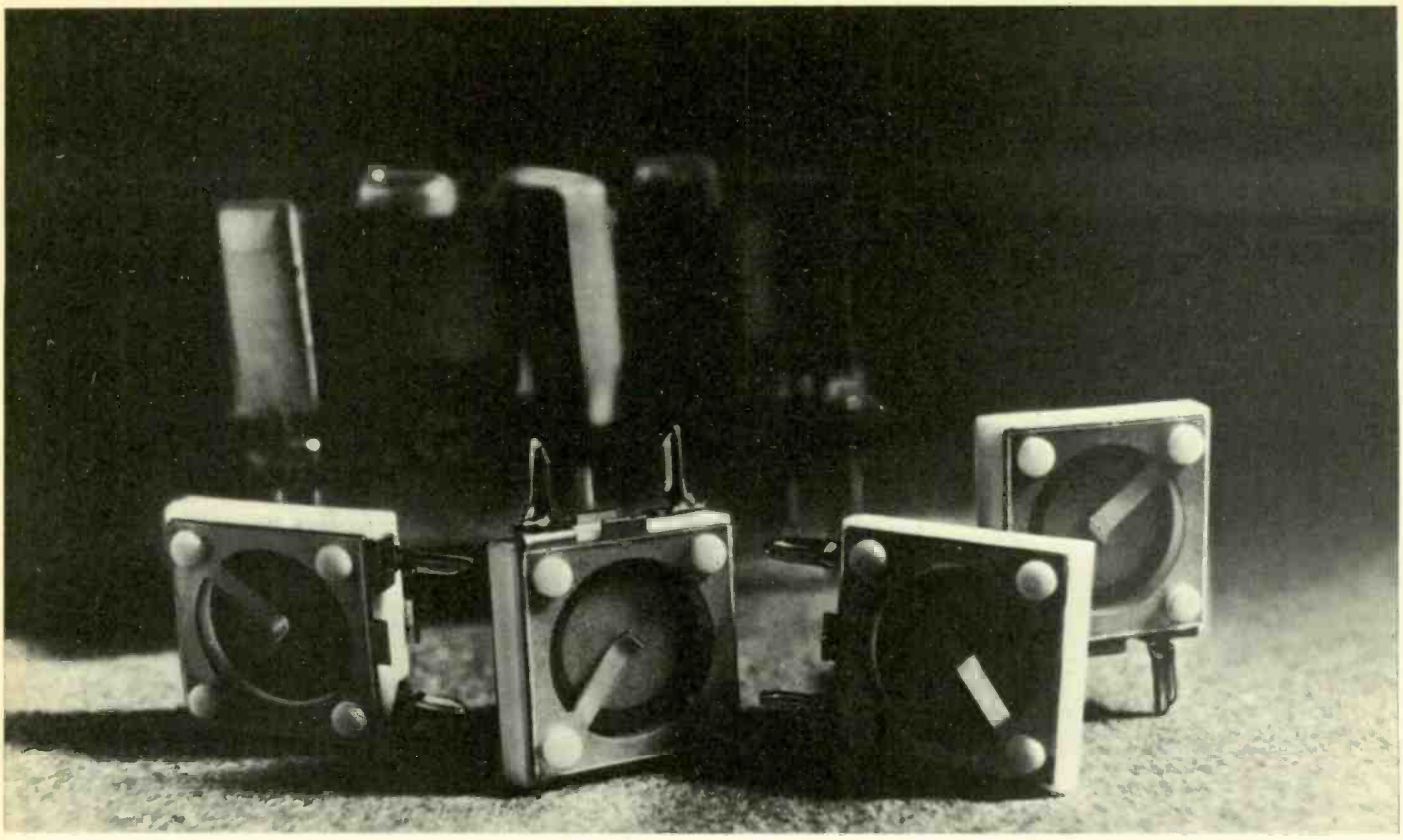

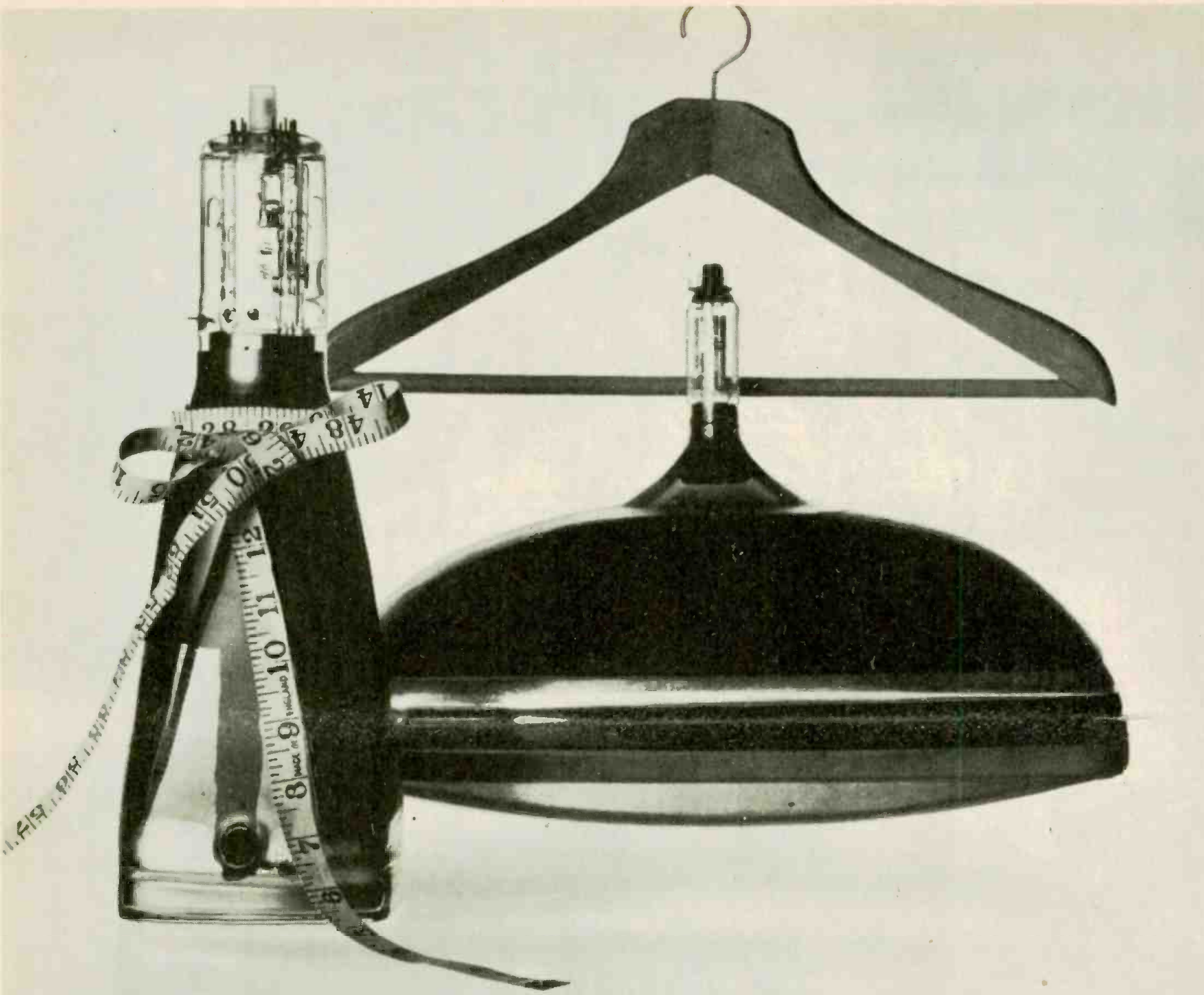

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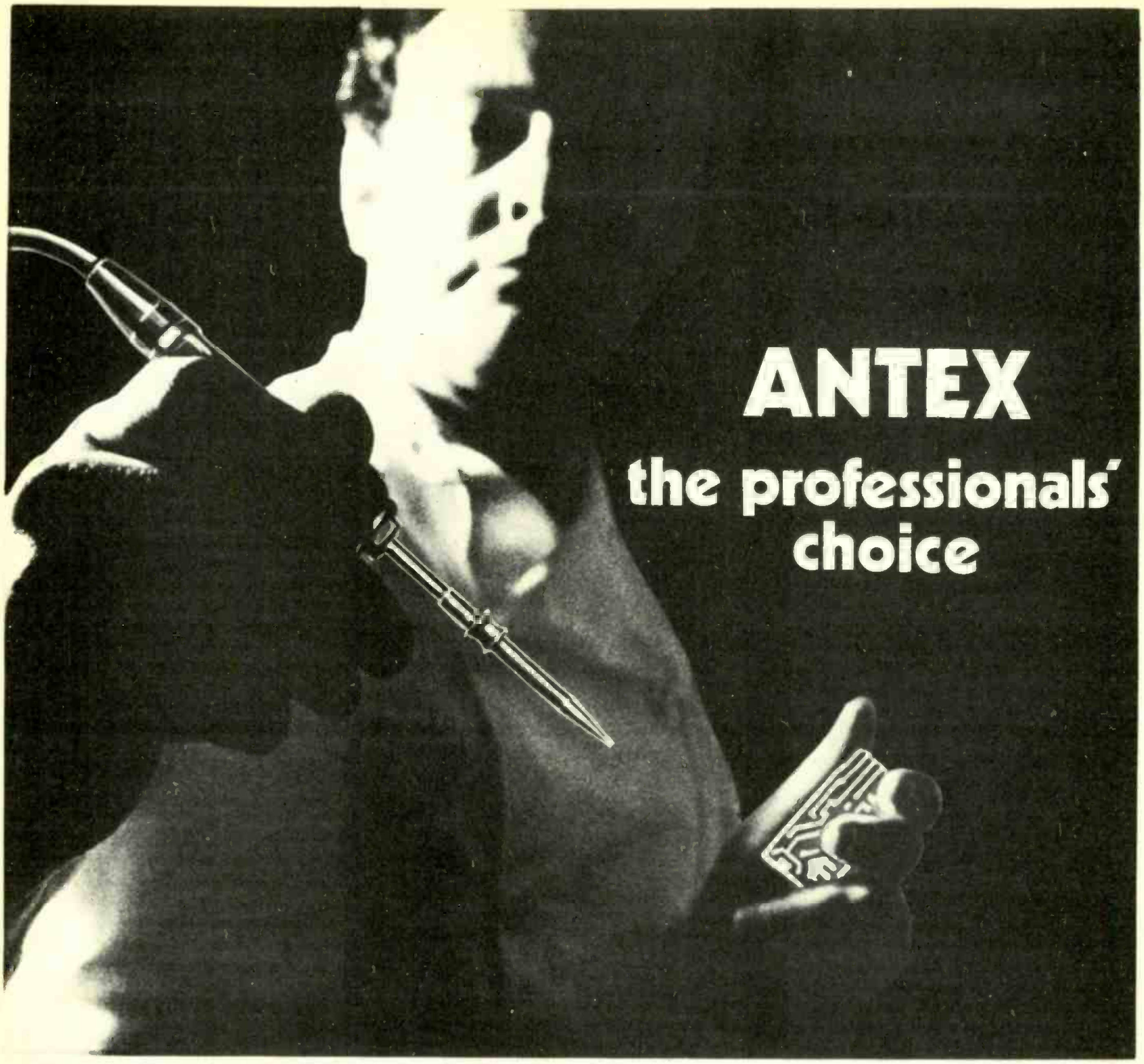

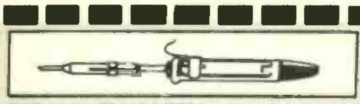

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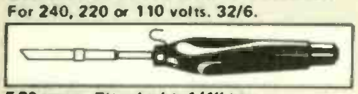

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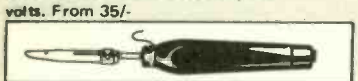

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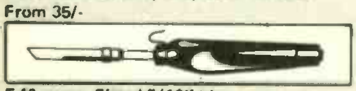

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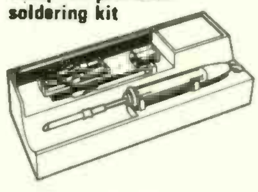

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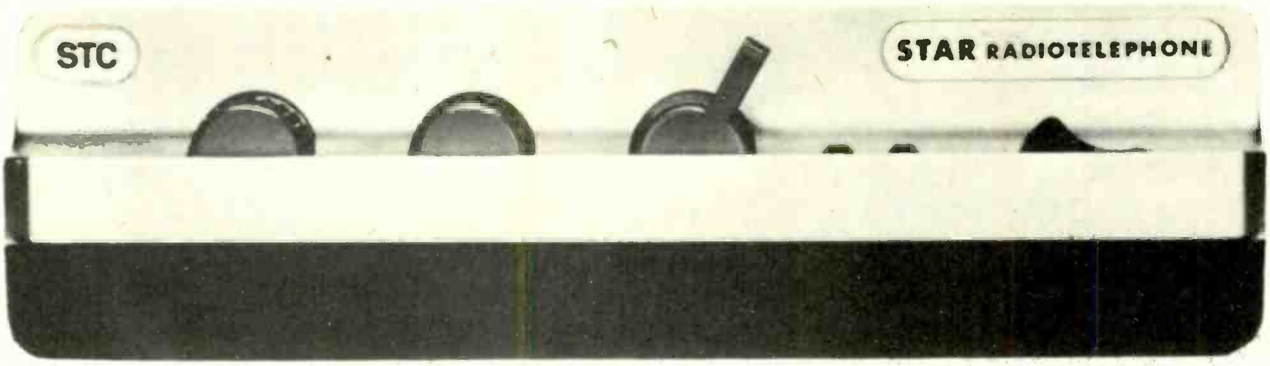

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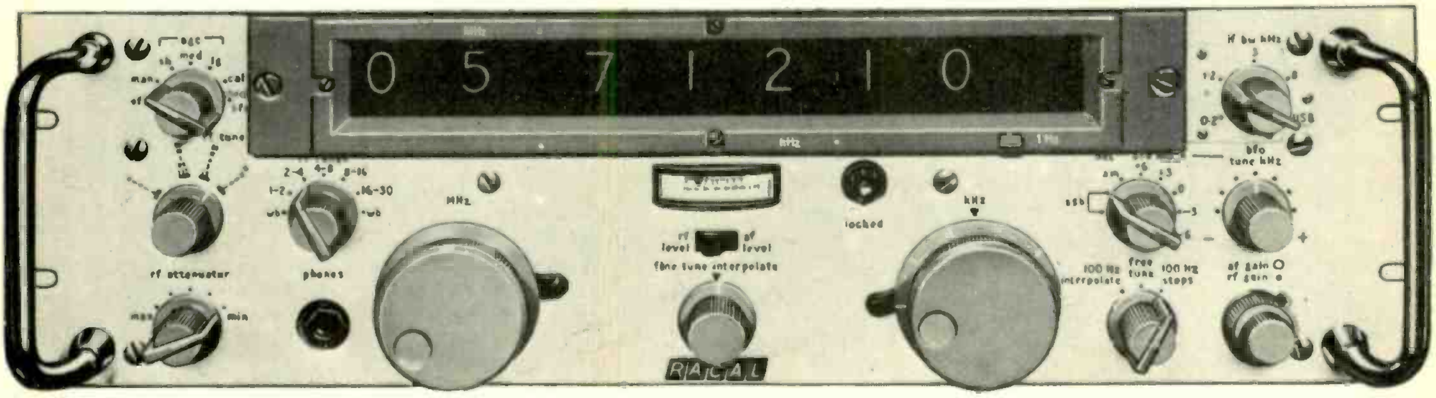

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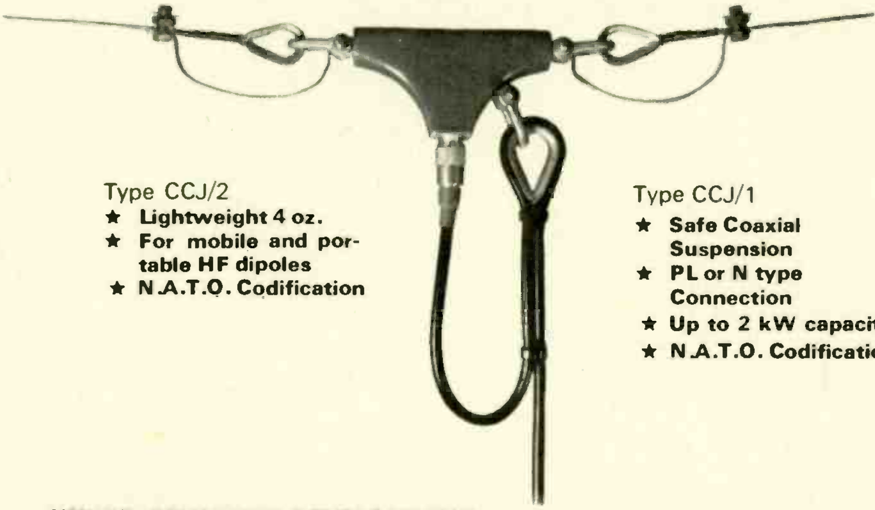

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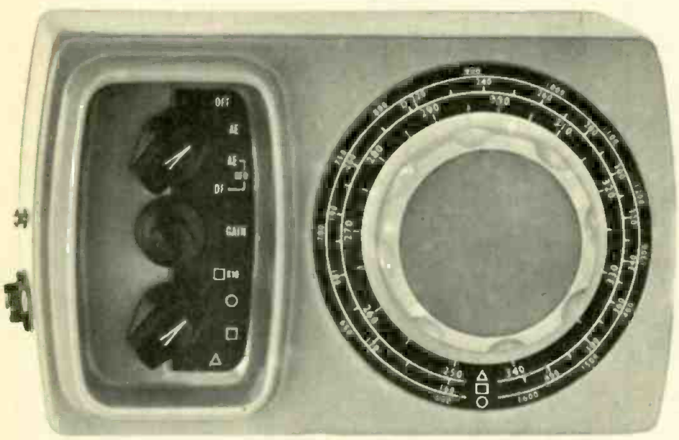

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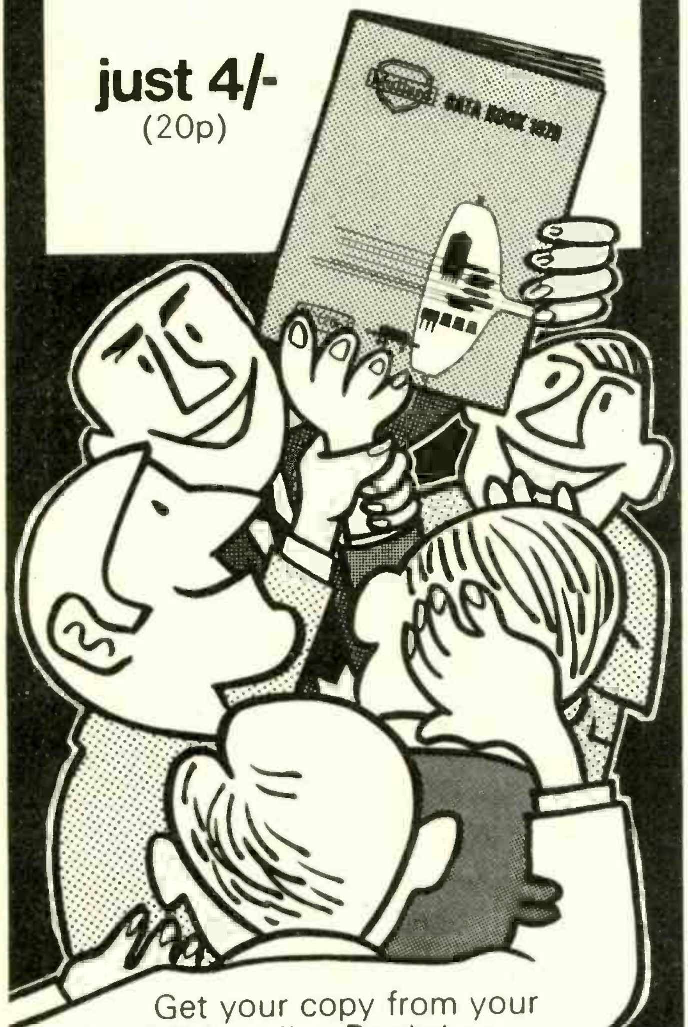

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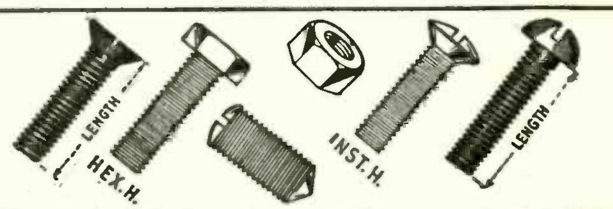

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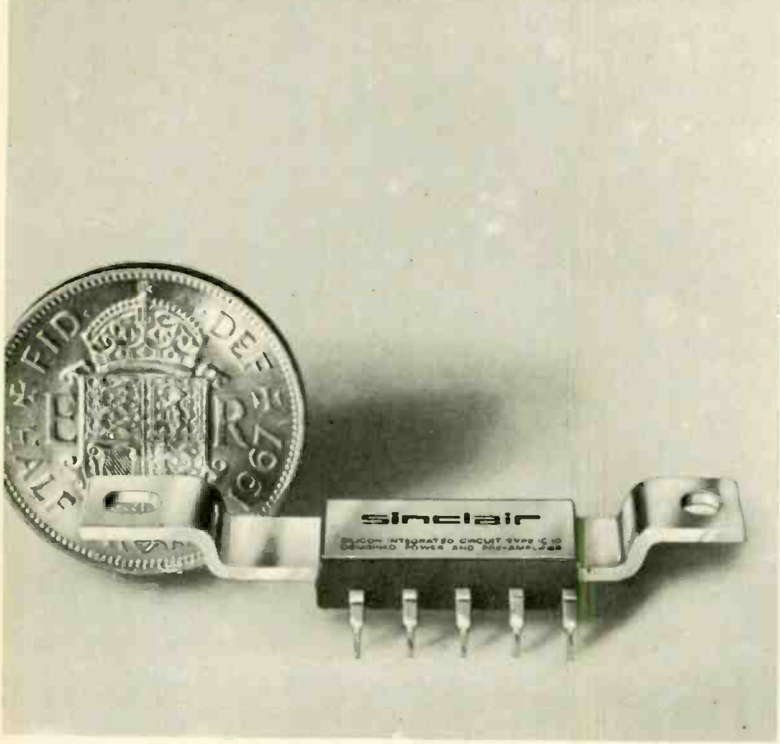
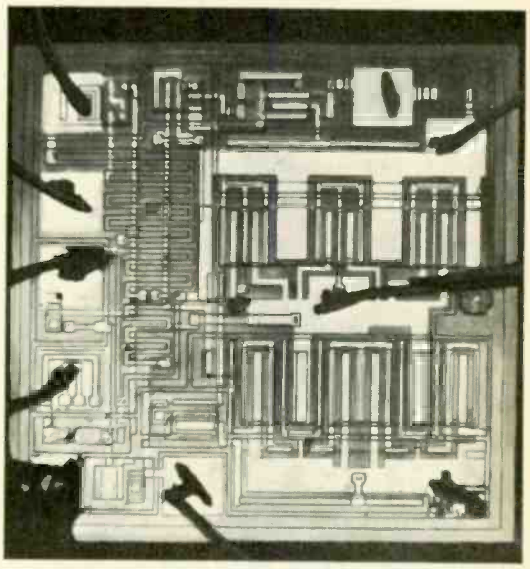
SINCLAIR IC-10



MONOLITHIC INTEGRATED CIRCUIT AMPLIFIER AND PRE-AMP



A 13 transistor circuit measuring only one twentieth of an inch square by one hundredth of an inch thick!

the world's most advanced high fidelity amplifier

The Sinclair IC-10 is the world's first monolithic integrated circuit high fidelity power amplifier and pre-amplifier. The circuit itself, a chip of silicon only a twentieth of an inch square by one hundredth of an inch thick, has 5 watts R.M.S. output (10w. peak). It contains 13 transistors (including two power types), 2 diodes, 1 zener diode and 18 resistors, formed simultaneously in the silicon by a series of diffusions. The chip is encapsulated in a solid plastic package which holds the metal heat sink and connecting pins. This exciting device is not only more rugged and reliable than any previous amplifier, it also has considerable performance advantages. The most important are complete freedom from thermal runaway due to the close thermal coupling between the output transistors and the bias diodes and very low level of distortion.

The IC-10 is primarily intended as a full performance high fidelity power and pre-amplifier, for which application it only requires the addition of such components as tone and volume controls and a battery or mains power supply. However, it is so designed that it may be used simply in many other applications including car radios, electronic organs, servo amplifiers (it is d.c. coupled throughout), etc. Once proven, the circuits can be produced with complete uniformity which enables us to give a full guarantee on every IC-10, knowing that every unit will work as perfectly as the original and do so for a lifetime.

■ SPECIFICATIONS

Output:	10 Watts peak, 5 Watts R.M.S. continuous
Frequency response:	5 Hz to 100 KHz ± 1dB
Total harmonic distortion:	Less than 1% at full output.
Load impedance:	3 to 15 ohms.
Power gain:	110dB (100,000,000,000 times) total.
Supply voltage:	8 to 18 volts.
Size:	1 x 0.4 x 0.2 inches.
Sensitivity:	5mV.
Input impedance:	Adjustable externally up to 2.5 M ohms.

■ CIRCUIT DESCRIPTION

The first three transistors are used in the pre-amp and the remaining 10 in the power amplifier. Class AB output is used with closely controlled quiescent current which is independent of temperature. Generous negative feedback is used round both sections and the amplifier is completely free from cross-over distortion at all supply voltages, making battery operation eminently satisfactory.

■ APPLICATIONS

Each IC-10 is sold with a very comprehensive manual giving circuit and wiring diagrams for a large number of applications in addition to high fidelity. These include stabilised power supplies, oscillators, etc. The pre-amp section can be used as an R.F. or I.F. amplifier without any additional transistors.

SINCLAIR
IC-10 *with IC-10 manual Post free.* **59/6**

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WW—091 FOR FURTHER DETAILS

Project 60

laboratory-standard high fidelity modules

Sinclair Project 60 comprises a range of modules which connect together simply to form a complete stereo amplifier with really excellent performance. So good, in fact, that only 2 or 3 amplifiers in the world can compare in overall performance. Now with the addition of three new modules to the range, the constructor has choice of assemblies with either 20 or 40 watts output per channel, with or without filter facilities.

The modules are: **1.** The Z-30 and Z-50 high gain power amplifiers, each of which is an immensely flexible unit in its own right. **2.** The Stereo 60 pre-amplifier and control unit. **3.** The Active Filter unit with both high and low audio frequency cut-offs. **4.** The PZ-5 and PZ-6 power supplies. A complete system could comprise, for example, two Z-30's, one Stereo-60, and a PZ-5. The P-Z6 is stabilised and should be used where the highest possible continuous sine wave rating is required. An A.F.U. may be added as required. In a normal domestic application, there will be no significant difference between using a PZ-5 or PZ-6 unless loudspeakers of very low efficiency are being used, in which case the PZ-6 will be required. For assemblies using two Z-50's there is the new PZ-8 stabilised supply unit to ensure maximum performance from these more powerful amplifiers.

All you need to assemble your Project 60 system is a screwdriver and soldering iron. No technical skill or knowledge whatsoever is required and, in the unlikely event of you hitting a problem, our customer service and advice department will put the matter right promptly and willingly. Project 60 modules have been carefully designed to fit into virtually all modern plinth or cabinets and only holes need be drilled into the wood of the plinth to mount the control unit and the A.F.U. Any slight slip here will be covered by the aluminium front panels of these two units.

The Project 60 manual gives all the building and operating instructions you can possibly want, clearly and concisely. Perhaps the greatest beauty of the system is that it is not only flexible now but will remain so in the future as the latest additions to the range show. A stereo F.M. tuner is next to come. These and all other modules we introduce will be compatible with those already available and may be added to your system at any time. And because Sinclair are the largest producers of constructor modules in Europe, Project 60 prices are remarkably low.

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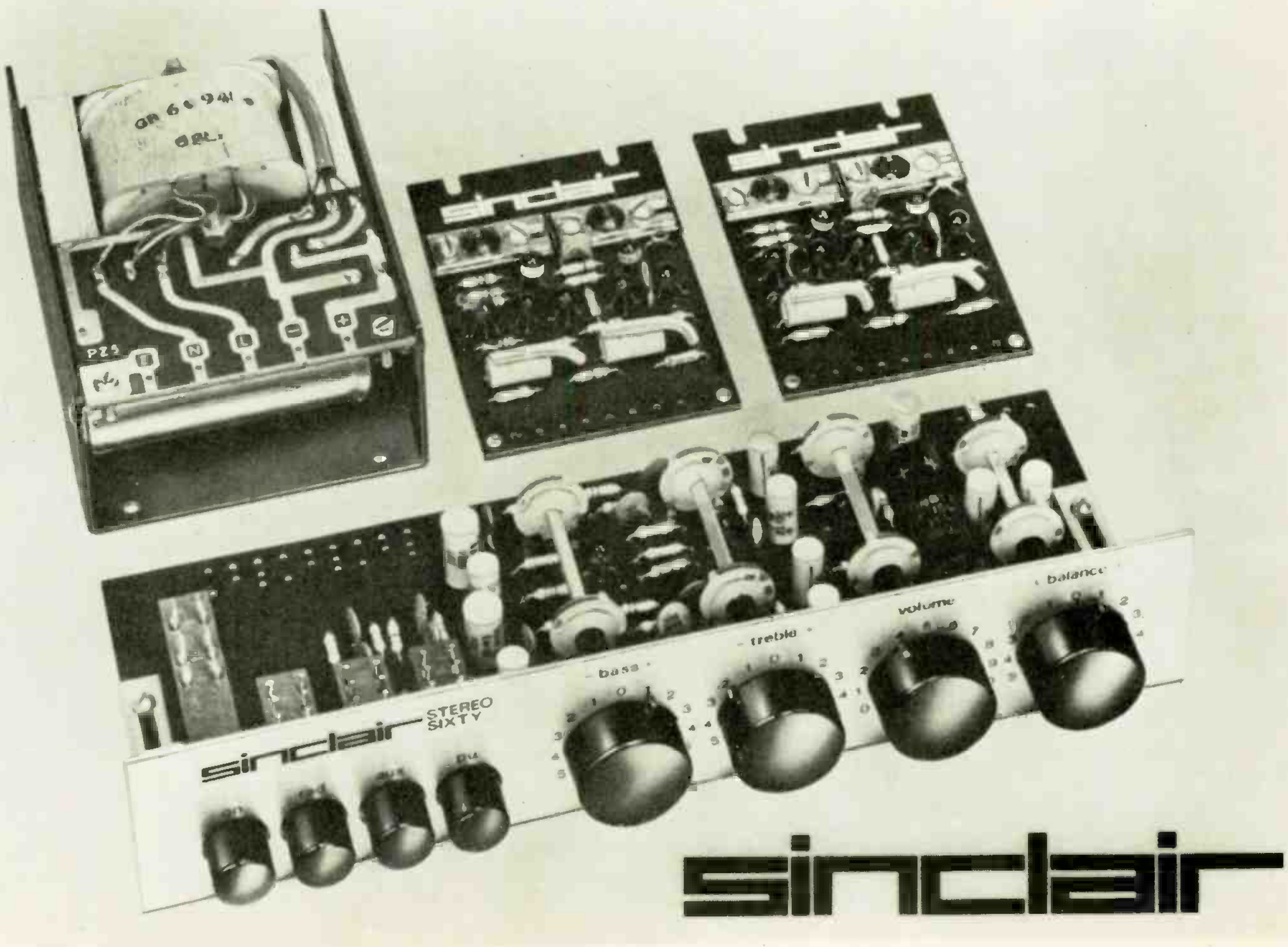


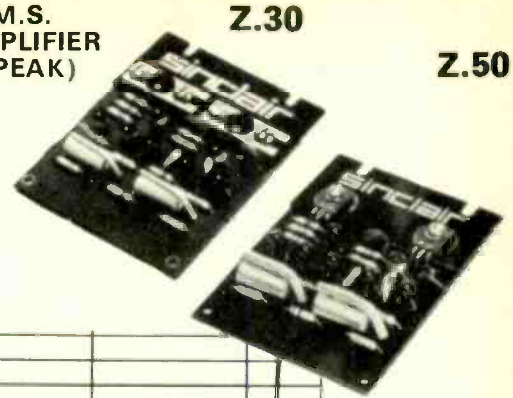
WW—092 FOR FURTHER DETAILS

Z.30 20 Watt R.M.S. POWER AMPLIFIER (40 WATTS PEAK)

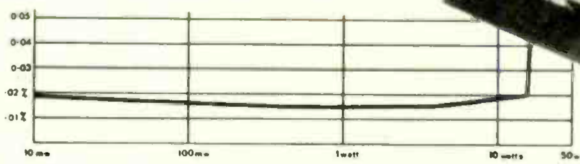
Z.50 40 WATT R.M.S. POWER AMPLIFIER (80 WATTS PEAK)

Z.30

Z.50



The Z.30, together with the higher powered Z.50 are both of advanced design using silicon epitaxial planar transistors to achieve unsurpassed standards of performance. Total harmonic distortion is an incredibly low 0.02% at full output and all lower outputs. Whether you use the Z.30 or Z.50 power amplifiers in your Project 60 system will depend on personal preference. But they are both the same physical size and may be used with other units in the Project 60 range equally well. The Z.30 is unique in that it may be used with any power source between 8 and 35 volts without need for adjustment and may thus be driven from a car battery for example. For operating from mains, for the Z.30 use PZ.5 power supply unit for most domestic requirements, or P.Z.6 if you have very low efficiency loudspeakers. For Z.50, use the PZ.5, PZ.6 or PZ.8 described below.



SPECIFICATIONS

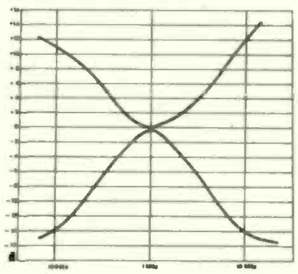
Power Outputs Z.30 15 watts R.M.S. into 8 ohms, using 35 v.. 20 watts R.M.S. into 3 ohms using 30 volts.
Z.50 40 watts R.M.S. into 3 ohms: 30 watts R.M.S. into 8 ohms, both continuous, operating on 50 v.
Frequency response—30 to 300,000 Hz ±1dB
Distortion 0.02% into 8 ohms
Signal to noise ratio better than 70dB unweighted
Input sensitivity 250mV into 100 K ohms
For speakers from 3 to 15 ohms impedance
Size 3½in. x 2½in. x ½in.

Z.30 Built, tested and guaranteed, with manual **89/6**

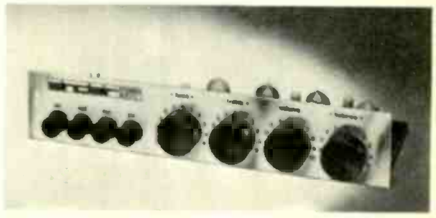
Z.50 Built, tested and guaranteed, with manual **109/6**

STEREO 60 Pre-amp Control Unit

The Stereo 60 is a stereo preamplifier and control unit designed for the Project 60 range but suitable for use with any high quality power amplifier. Again silicon epitaxial planar transistors are used throughout and great attention has been paid to achieving a really high signal-to-noise ratio and excellent tracking between the two channels. Input selection is by means of push buttons and accurate equalisation is provided for all the usual inputs. The tone controls are also very carefully designed and tested.



Treble and bass cut and boost curves



SPECIFICATIONS FOR STEREO 60

- Input sensitivities—Radio—up to 3mV Magnetic P.U.—3mV: correct to R.I.A.A. curve ± 1dB; 20 to 25,000 Hz. Ceramic P.U.—up to 3mV. Aux.—up to 3mV.
- Output—250mV.
- Signal-to-noise ratio—better than 70dB.
- Channel matching—within 1dB.
- Tone Controls—TREBLE+15 to —15dB. at 10 kHz: BASS+15 to —15dB at 100 Hz.
- Front panel—brushed aluminium with black knobs and controls.
- Size 8¼ x 1½ x 4 ins.

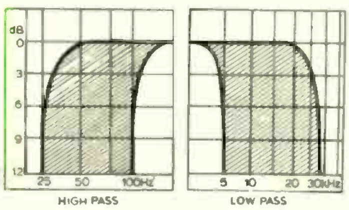
ACTIVE FILTER UNIT

The purpose of the filter unit is to reject frequencies *above* (scratch) or *below* (rumble) a specific cut off frequency when they contain unwanted interference. The Sinclair A.F.U. is unique in that the cut off frequency is continuously variable for both the scratch and rumble units and, as the attenuation in the rejection band is rapid (12dB per octave), the removal of interference can be achieved with less loss of the wanted signal than has previously been possible.
Each channel has an overall gain of unity and the unit may be connected between the pre-amplifier and power amplifier sections of any system. Both amplitude and phase distortion have been made quite negligible by careful design and generous negative feedback employed.

SPECIFICATIONS

Employs two Sallen & Key type active filter stages, one rumble (high pass) and one scratch (low pass)
The two stages use complementary transistors to minimise distortion.
Supply voltage 15 to 35 V Current 3mA max.
Gain at 1 kHz, filters flat 0.98 (−0.2dB)
H.F. cut off (−3dB) variable from 28kHz to 5kHz at 12dB/octave
L.F. cut off (−3dB) variable from 25Hz to 100Hz at 12dB/octave
Distortion at 1 kHz (35V supply) 0.02% at rated output

Built, tested and guaranteed **£5.19.6**



BUILDING A PROJECT 60 ASSEMBLY

The illustration here shows quite clearly how easily Project 60 can be contained in one of today's slim, modern plinths. Very little space is required to house these Sinclair units, and within the space of the motor plinth, you can install a stereo amplifier of the very highest quality. If, for example you have already put together an assembly as illustrated here, adding the Active Filter Unit would be very easy.

SINCLAIR POWER SUPPLY UNITS

PZ-5 30 volts unstabilised—sufficient to drive two Z.30's and a Stereo 60 for the majority of domestic applications £4.19.6
PZ-6 35 volts stabilised—ideal for driving two Z.30's and a Stereo 60 when very low efficiency speakers are employed £7.19.6
PZ-8 45 volts power supply unit for use with Z.50 amplifiers (less mains transformer) £5.19.6

GUARANTEE

If at any time within 3 months of purchasing Project 60 modules from us, you are dissatisfied with them, we will refund your money at once. Each module is guaranteed to work perfectly and should any defect arise in normal use we will service it at once and without any cost to you whatsoever provided that it is returned to us within 2 years of the purchase date. There will be a small charge for services thereafter. No charge for postage by surface mail. Air-mail charged at cost.

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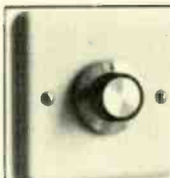

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MPF103	7/6
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MPF105	8/-
MPS3638	6/6
NKT12/152	5/5
NKT0013	9/6

NKT121	11/-
NKT122	8/-
NKT123	6/-
NKT125	5/6
NKT127	5/6
NKT128	5/6
NKT129	6/-
NKT141	7/-
NKT142	6/-
NKT143	5/6
NKT144	8/-
NKT161	6/-
NKT162	6/-
NKT163	5/6
NKT164	5/6
NKT165	6/-
NKT211	6/-
NKT212	6/-
NKT213	4/-
NKT214	4/-
NKT215	4/-
NKT216	10/-
NKT217	13/-
NKT218	5/3
NKT219	6/-
NKT221	5/6
NKT222	4/-
NKT223	3/6
NKT224	4/6
NKT225	3/6
NKT226	10/-
NKT227	5/6
NKT228	6/-
NKT261	4/3
NKT262	4/3
NKT264	4/3
NKT271	4/-
NKT272	4/-
NKT273	4/-
NKT274	4/-
NKT275	5/-
NKT276	3/6
NKT279A	2/6
NKT281	5/-
NKT301	16/-
NKT302	11/-
NKT303	10/-
NKT304	9/6
NKT351	8/-
NKT352	7 6
NKT401	17/6
NKT402	24/-
NKT403	15/-
NKT404	12/6
NKT405	15/-
NKT406	15/-
NKT451	12/6
NKT452	12/6
NKT453	10/-
NKT613F	5/-
NKT674F	5/-
NKT675	5/-
NKT676	5/-
NKT677F	5/-
NKT703	8/-
NKT713	7/6
NKT773	5/-
NKT10339	6/6
NKT10419	6/-
NKT10429	11/-
NKT10519	6/6
NKT16229	11/-
NKT20329	11/-
OC20	19/6
OC22	8/-
OC23	8/-
OC24	8/-
OC25	7/6
OC26	6/6
OC28	12/-
OC29	15/-
OC35	9/-
OC36	12/6
OC41	4/6
OC42	4/6
OC43	4/6
OC44	3/-
OC45	3/-
OC70	2/6

OC71	3/-
OC72	4/6
OC75	4/6
OC76	2/6
OC77	5/6
OC81	4/6
OC81D	3/-
OC82	5/-
OC82D	3/-
OC83	4/6
OC84	5/-
OC123	7/-
OC139	5/-
OC140	7/-
OC170	5/-
OC171	6/-
OC200	6/3
OC201	9/6
OC202	18/-
OC203	7/6
OC204	8/-
OC205	9/-
OC206	10/6
OC207	7/6
OC309	12/-
OCP71	19/6
ORP12	9/6
ORP60	8/-
ORP61	8/-
ORP63	9/-
P346A	5/-
RAS310AF	6/-
RAS508AF	15/-
SIM	19/-
S4M	33/6
ST140	3/-
ST141	5/-
ST2	9/9
TI407	9/8
TIS34	17/6
TIS44	1/9
TIS45	3/3
TIS46	3/3
TIS47	3/3
TIS48	3/3
TIS49	3/6
TIS50	5/6
TIS51	4/-
TIS52	4/-
TIS53	6/6
TIS60	6/6
TIS61	7/-
TIP31A	19/6
TIP32A	22/6
TSW30C	18/-
U23AAA	5/-
V205	20/-
V405A	9/3
XA102	6/-
XA702	15/-
ZT22	19/-
ZT86	27/6
ZT2270	19/6
40250	12/6
40309	9/6
40310	13/-
40311	10/6
40312	13/6
40314	10/6
40315	10/6
40316	13/-
40317	11/-
40319	15/-
40320	10/6
40323	10/6
40324	12/6
40326	10/6
40329	7/6
40344	8/-
40347	9/6
40348	14/6
40360	11/6
40361	12/-
40362	14/-
40370	8/6
40406	16/-
40408	14/-
40467	16/6
40468A	16/6
40602	9/9
2G301	3/9
2G302	3/9

2G306	8/6
2G339A	5/-
2G371	3/-
2G371B	3/-
2G374	5/-
2G378	7/-
2G381	5/-
2N109	11/-
2N174	16/-
2N217	7/6
2N370	15/-
2N384	17/-
2N386	12/-
2N385A/ 2N388A	15/-
2N404	4/6
2N410	8/-
2N458A	25/-
2N511A	49/6
2N513A	122/6
2N599	10/-
2N601	25/-
2N657	20/-
2N696	4/-
2N697	4/-
2N698	6/-
2N706	2/6
2N706A	2/6
2N708	4/-
2N711	7/6
2N711A	7/6
2N715	7/6
2N716	7/6
2N743	4/6
2N744	6/-
2N753	5/6
2N914	4/6
2N918	7/6
2N929	5/6
2N930	7/6
2N1090	6/6
2N1091	6/6
2N1131	6/6
2N1132	8/-
2N1302	4/-
2N1303	4/-
2N1304	5/-
2N1305	5/-
2N1306	5/-
2N1307	5/-
2N1308	7/-
2N1309	7/-
2N1496	34/-
2N1507	4/8
2N1613	5/6
2N1671A	29/6
2N1711	6/6
2N1893	10/-
2N2147	17/-
2N2152	27/6
2N2148	12/6
2N2160	14/9
2N2243	26/-
2N2368	5/-
2N2369	5/-
2N2369A	5/6
SN2432	67/-
2N2484	8/-
2N2613	7/6
2N2614	4/-
2N2646	10/-
2N2711	6/-
2N2712	6/-
2N2713	5/6
2N2904	8/6
2N2904A	8/-
2N2905	10/-
2N2905A	8/-
2N2923	4/-
2N2924	4/-
2N2925	3/6
2N2926 Green	2/-
2N2926 Yellow	2/-
2N2926 Orange	2/-
2N2926 Brown	2/-
2N3011	12/6
2N3036	39/-
2N3053	5/-
2N3054	12/6
2N3055	15/-

2N3133	6/-
2N3135	6/-
2N3136	6/-
2N3235	28/6
2N3234	27/6
2N3391A	6/-
2N3392	5/-
2N3393	5/-
2N3394	4/9
2N3402	5/6
2N3403	5/6
2N3404	7/6
2N3414	5/6
2N3415	6/-
2N3416	7/6
2N3436	15/-
2N3525	21/9
2N3528	19/-
2N3606	5/6
2N3607	4/6
2N3702	3/3
2N3703	3/-
2N3704	3/3
2N3705	3/-
2N3706	2/9
2N3707	3/-
2N3708	2/-
2N3709	3/-
2N3710	3/-
2N3711	3/-
2N3819	8/-
2N3820	18/9
2N3826	6/-
2N3854	5/6
2N3854A	5/6
2N3855	5/6
2N3855A	6/-
2N3856	6/-
2N3856A	6/-
2N3858	5/-
2N3858A	6/-
2N3859	5/6
2N3859A	6/3
2N3860	6/-
2N3866	25/-
2N3877	9/-
2N3877A	9/6
2N3900	10/6
2N3900A	11/6
2N3903	7/-
2N3904	7/-
2N3905	7/6
2N3906	7/6
2N4037	15/-
2N4058	4/6
2N4059	5/-
2N4060	5/-
2N4061	4/-
2N4062	4/6
2N4284	3/-
2N4285	3/-
2N4286	3/-
2N4287	3/-
2N4288	3/-
2N4289	3/-
2N4290	3/-
2N4291	3/-
2N4292	3/-
2N4871	6/9
2N5027	10/6
2N5028	11/6
2N5029	9/6
2N5030	8/6
2N5172	3/-
2N5174	10/6
2N5175	10/6
2N5176	9/-
2N5232	5/6
2N5249	13/6
2N5249A	13/6
2N5305	7/6
2N5306	8/-
2N5309	12/6
2N5354	5/6
2N5355	5/6
2N5356	10/6
3N128	18/6
3N140	19/6
3N141	21/6
3N142	16/6
3N143	19/6
3N152	24/-
2S001	10/-
2S002	12/6

2S003	12/6
2S004	15/-
2S005	15/-
2S006	15/-
2S012	25/-
2S012A	22/6
2S017	15/-
2S018	17/6
2S019	19/6
2S104	12/6
2S301	8/6
2S302	7/6
2S303	10/-
2S304	12/6
2S306	15/-
2S320	9/-
2S321	6/-
2S323	10/-
2S701	8/6
2S703	12/6
2S720	25/-
2S732	8/6
2S1002	10/-

DIODES AND RECTIFIERS

AA119	2/-
AAY11	2/-
AAZ12	6/-
AAZ13	2/6
BA110	6/-
BA111	6/-
BA112	18/-
BA115	1/6
BA130	3/-
BAY31	2/6
BAY38	3/-
BY100	5/-
BY125	3/6
BY127	4/-
BY234	2/3
BYX10	3/-
BYX36 150	2/6
BYX36 300	2/10
BYX36 600	3/9
BYY21	25/-
BYY23	26/3
BYY25	31/9
BYY142	3/9
BYZ10	9/-
BYZ12	6/-
BYZ13	5/-
CG6E	4/-
CG63	2/-
EA403	3/6
EC401	5/-
EC402	4/8
EB383	3/6
GEX45/1	4/-
GJ3M	4/-
OA5	3/8
OA10	6/-
OA47	1/6
OA70	1/6
OA73	1/6
OA79	1/6
OA81	1/6
OA85	1/6
OA90	1/6
OA91	1/6
OA95	1/6
OA200	2/-
OA202	2/-
SD19	-/7
TD716	12/-
IN34A	4/-
IN60	4/-
IN64	4/-
IN82A	9/6
IN87A	4/6
IN191	5/-
IN914	1/9
IN4001	2/-
IN4005	4/-
IN4007	5/-
IN4148	1/9
IS44	1/9
IS130	2/-
IS131	2/6
IS132	3/-
IS113	4/6

LOWEST I.C. PRICES YET!

IC10	59/6	Sinclair IC amp.
PA230	20/-	IC Preamplifier
PA234	20/-	1 watt audio amp.
PA237	32/6	2 watt audio amp.
PA246	52/6	5 watt audio amp.
SL403A	49/6	3 watt Plessey amp.
SL702C	29/6	Plessey linear amplifier
TAA263	15/-	Mullard linear amp.
TAD100	45/-	IC receiver
TAA293	20/-	Mullard gen. purp. amp.
TAA310	30/-	Record/Playback preamp.
TAA320	13/-	MOS LF amplifier
3N84	26/-	Silicon controlled switch

Data sheets available on request 1/- per copy.

PLEASE NOTE: Only new—full specification integrated circuits, no below-specification types.

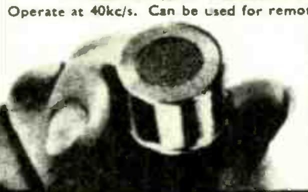
FAIRCHILD MICRO-LOGIC

	1–6	7–11	12+
ul 900	9/9	9/-	8/-
ul 914	9/9	9/-	8/-
ul 923	12/6	11/9	11/-

Prices for 100+ and 1,000+ on application.
5 page data and circuits article—2/6.
Plastic spreaders—1/6 each.

ULTRASONIC TRANSDUCERS

Operate at 40kc/s. Can be used for remote control systems without cables or electronic links. Type 14C4 transducers can transmit and receive. FREE: With each pair our complete transmitter and receiver circuit. PRICE £5.18.0 Pair (Sold only in pairs)



ZENER DIODES

400mW 10% GLASS CASE
TEXAS Mfr.

IS2036	3·6 volt
IS2039	3·9 volt
IS2043	4·3 volt
IS2047	4·7 volt
IS2056	5·6 volt
IS2062	6·2 volt
IS2068	6·8 volt
IS2075	7·5 volt
IS2082	8·2 volt
IS2100	10 volt
IS2110	11 volt
IS2120	12 volt
IS2160	16 volt
IS2180	18 volt
IS2270	27 volt
IS2300	30 volt

1-24 3/6d. 25-99 2/9d. 100+ 2/3d.

2N3819 8/-
Texas FET
25 + 6/9 100 + 5/9

2N4871 6/9
Motorola unijunction
25 + 5/9 100 + 4/9

2N3055 15/-
115 watt silicon power transistor
25 + 13/- 100 + 11/-

IRC 20 8/6
Plastic SCR Thyristor, 200 piv 1·2amp (similar C106E1)
25 + 7/9 100 + 7/-

BC107/8/9 2/9
NPN Planar transistors
BC107 & 9 25+2/5 100+2/2
BC108 25+2/3 100+2/-

BY 127 4/-
Mullard Plastic HV rectifier 800 piv 1 amp (similar BY100 etc.)
25 + 3/3 100 + 3/-

2N2926 2/-
NPN Planar transistors
25 + 1/8 100 + 1/6

INFRA-RED DEVICES

56 CAY 29/6
Gallium arsenide emitter

MGA 100 35/-
Gallium arsenide emitter

31F2 28/6
Infra-red detector diode

AD161/2 10/-
Siemens/Telefunken NPN/PNP output pair
25 + 9/- 100 + 8/-

OCP 71 19/6
Mullard Phototransistor
25 + 17/3 100 + 14/9

Prices quoted are current at time of going to press and may be subject to variation without notice.
Semiconductors offered in this advertisement bear the relevant Manufacturers' original markings and are subject to our full replacement guarantee if not to published specifications.
WE DO NOT offer "Re-marked" makers' rejects or similar out of specification devices.
Please enclose a stamped self-addressed envelope with any query.
Quantity prices on application: many more types in stock and expected daily. If you buy in bulk we can save you money!
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TERMS OF BUSINESS: Retail orders; cash with order please.
TRADE: Please furnish references if credit account required.
POSTAGE: 1/- per order inland; 4/- Europe; 12/- Commonwealth.

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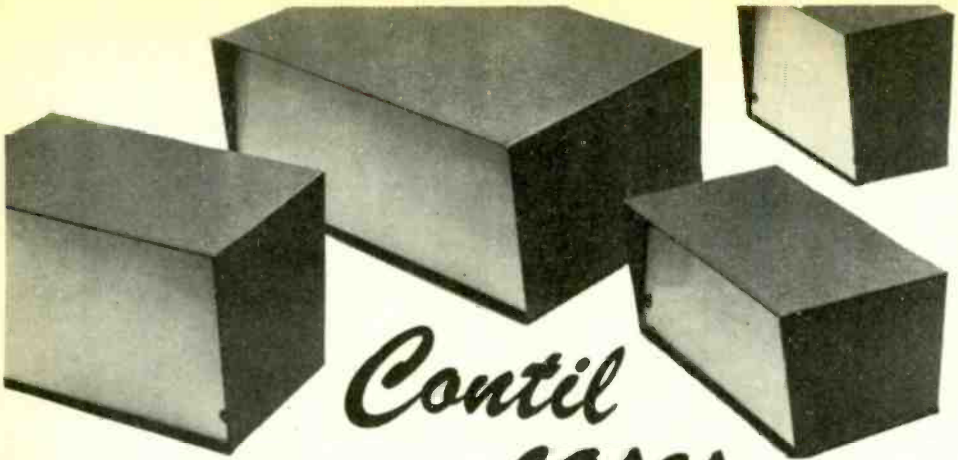
DIRECT LINES TO SALES DEPT: BRENTWOOD (ESSEX) 226470/1



Contil cases

Contil cases are mass-produced to give lowest prices yet. In 21-gauge steel. Finished hammer blue, with 18-gauge front panel supplied with easy-to-strip protective covering for easy marking out. For ease of ordering Contil cases are described by their dimensions, i.e. 755 is 7 × 5 × 5. Individually packed, including feet and screws.

Contil cases are also available with aluminium panels and Contilcote, which is applied after drilling and cutting.

CASE PRICES *(All supplied with protective coated steel panels)*

Nos. denote size in inches	1	5	10	25	50	100	P&P
755	48/-	46/-	45/-	44/-	43/-	41/-	6/-
867/975	50/-	49/-	48/-	46/-	45/-	43/-	6/-
1277 white or black panel	55/-	52/-	51/-	50/-	49/-	48/-	8/-
1277 unpainted	45/-	44/-	43/-	40/-	39/-	37/-	8/-
16127	106/-	104/-	102/-	101/-	99/-	97/-	9/6
191010	143/-	140/-	137/-	135/-	134/-	133/-	10/6
191010D	199/-	197/-	196/-	194/-	192/-	190/-	18/-

Your third hand

The ONTOS UNIVERSAL VICE is a new type of multi-purpose, multi-position light engineering vice and stand, fully adjustable for any angle and location in any desired plane. Applications are virtually limitless within its size capacity; i.e. holding P.C. boards for assembly or testing, building up modules, as a micrometer or gauge stand, as a light general purpose vice, in the chemical laboratory, or in fact for all those occasions when you could use a third hand! The ONTOS TWIN TWO-IN-ONE UNIVERSAL VICE is a unique two-in-one version of the Ontos vice, with two sets of jaws, each capable of rotation through 360 deg. of every plane independently of each other. Positive locking enables any such setting to be maintained for repetition work. Ideal for copying P.C. boards, assembly, soldering, bonding, welding, laboratory testing, etc.

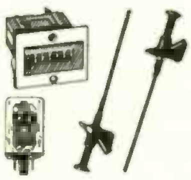
ONTOS: 68/- plus P&P 4/6.
ONTOS TWIN: £5 18 0 plus P&P 6/-.

NIBBLING TOOL

ADEL

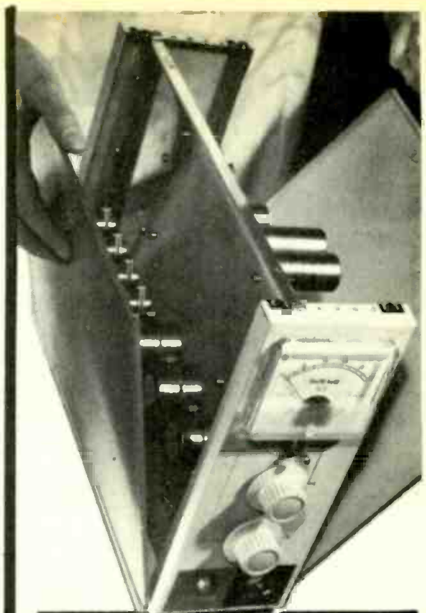
CUTS, NOTCHES AND TRIMS

The Adel cuts holes to virtually any shape and size. Starting with a 7/16" hole it then 'nibbles' to the size required, cutting cleanly like a punch and die. The cutter is so designed that it causes little strain or distortion to the edges or to the original form. With the Adel any shape or size hole over 7/16" can be cut whether it be round, square or irregular. It is ideal for notching clearances on flanges of cabinets or chassis, or for trimming undersized holes to fit parts.



ACCESSORIES

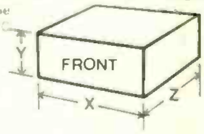
Flexible insulated test prods, colour red or black, at 13/– each with fine steel clips at the tip, opened by button on top. High speed resetting counter including bezel and socket with speed of over 40 operations per second 165/–. Plug in octal relay, 24 volts, with two changeovers 17/6.



CONTIL MOD·2

ideal for development cheaper for production

PVC COATED MATERIALS. No outside paint to be scratched. PVC easy to clean, surface is scuff resistant. PVC/ALUMINIUM FOR FRONT & BACK PANELS gives easy cutting with rigidity PVC/STEEL FOR SIDES, TOP & BOTTOM gives rigidity, low cost, ease of assembly. 3 HEIGHTS OF CASE, 4 WIDTHS, 2 DEPTHS, make 24 cases with screws on top and 24 cases with screws on side, that's 48 different cases. LOW COST. Prices include chassis. MODERN DESIGN. Metal work on front and back and chassis is made easier by aluminium with PVC cladding. PVC/steel on sides and bottom for strength. GOOD DELIVERY. Off the shelf range of all PVC coated cases.



NOTE THE LOW COST

	X	Y	Z	1 off	P. & P.
A	4.5	3	6.5	34/-	3/–
B	4.5	7	6.5	40/-	4/6
C	4.5	10	6.5	50/-	4/6
D	9	3	6.5	50/-	4/6
E	9	7	6.5	55/-	4/6
F	9	10	6.5	65/-	4/6
G	13	3	6.5	55/-	4/6
H	13	7	6.5	65/-	4/6
I	13	10	6.5	73/-	6/–
J	18	3	6.5	65/-	4/6
K	18	7	6.5	89/-	6/–
L	18	10	6.5	107/-	6/–
M	4.5	3	13	40/-	4/6
N	4.5	7	13	55/-	4/6
O	4.5	10	13	73/-	6/-
P	9	3	13	55/-	4/6
Q	9	7	13	73/-	6/–
R	9	10	13	89/-	6/–
S	13	3	13	73/-	6/–
T	13	7	13	89/-	6/–
U	13	10	13	109/-	7/6
V	18	3	13	89/-	6/–
W	18	7	13	107/-	7/6
X	18	10	13	138/-	7/6

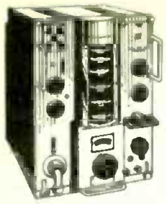
Sizes in inches

WH WEST HYDE

WEST HYDE DEVELOPMENTS LTD.
30 HIGH STREET NORTHWOOD MIDDX.
Telephone: Northwood 24941/26732

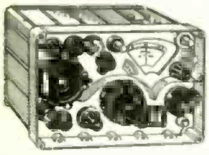
PLEASE NOTE
All products ex-stock for normal quantities. Return of post service. Minimum order £1. Fully detailed leaflets available.

ADMIRALTY B.40 RECEIVERS



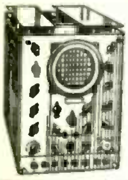
High quality 10 valve receiver manufactured by Murphy. Coverage in 5 bands 650 Kc/s-30 Mc/s. I.F. 500/Kc/s. Incorporates 2 R.F. and 3 I.F. stages, bandpass filter, noise limiter, crystal controlled B.F.O. calibrator I.F. output, etc. Built-in speaker, output for phones. Operation 150/230 volt A.C. Size 19½ × 13¼ × 16in. Weight 114lb. Offered in good working condition. **£22/10/0.** carr. 30/-. With circuit diagrams. Also available B41 L.F. version of above. 15 Kc/s-700 Kc/s. **£17/10/-**. Carr. 30/-.

R209 Mk. II COMMUNICATION RECEIVER



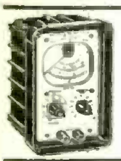
11 valve high grade communication receiver suitable for tropical use. 1-20 Mc/s. on 4 bands. AM/CW/FM operation. Incorporates precision vernier drive, B.F.O. Aerial trimmer, internal speaker and 12v. D.C. internal power supply. Supplied in excellent condition, fully tested and checked. **£15.0.0** Carr. 20/-.

TYPE 13A DOUBLE BEAM OSCILLOSCOPES BARGAIN



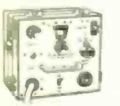
An excellent general purpose D/B oscilloscope. T.B. 2 cps-750 Kc/s. Bandwidth 5.5 Mc/s Sensitivity 33 Mv/cm. Operating voltage 0/110/200/250 v. A.C. Supplied in excellent working condition, **£22/10/-**. Or complete with all accessories, probe, leads, lid, etc. **£25.** Carriage 30/-.

MARCONI CT44 TF956 AF ABSORPTION WATTMETER



1 µ/watt to 6 watts. **£20.** Carr. 20/-.

CLASS D. WAVEMETERS



A crystal controlled heterodyne frequency meter covering 1.7-8 Mc/s. Operation on 6 v. D.C. Ideal for amateur use. Available in good used condition **£5.19.6** Carr. 7/6. Or brand new with accessories **£7.19.6** Carr. 7/6.

CLASS D WAVEMETERS No. 2

Crystal controlled. 1.2-19 Mc/s. Mains or 12v. D.C. operation. Complete with calibration charts. Excellent condition **£12/10/0.** Carr. 30/-.

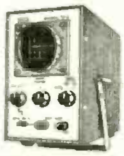
LELAND MODEL 27 BEAT FREQUENCY OSCILLATORS

0-20 Kc/s. Output 5K or 500 ohms. 200/250 v. A.C. Offered in excellent condition. **£12/10/-**. Carriage 10/-.

VOLTAGE STABILISER TRANSFORMERS.

180-260v. input. Output 230v. Available 150w or 225w. **£12.10.0.** Carr. 5/-.

TO-2 PORTABLE OSCILLOSCOPE

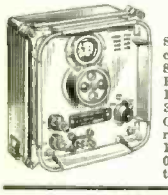


A general purpose low cost economy oscilloscope for everyday use. Y amp. Bandwidth 2 CPS—1 MHZ. Input imp. 2 meg Ω. 25 PF. Illuminated scale. 2" tube. 115 × 180 × 230 mm. Weight 8lbs. 220/240v. A.C. Supplied brand new with handbook. **£22/10/-**. Carr. 10/-.

TO-3 PORTABLE OSCILLOSCOPE. 3" TUBE

Y amp. Sensitivity. .1v p-p/CM. Bandwidth 1.5 cps —1.5 MHZ. Input imp. 2 meg Ω. 25 PF. X amp sensitivity. ·9v p-p/CM. bandwidth 1.5 cps—800 KHZ. Input imp. 2 meg Ω 20 PF. Time base. 5 ranges 10 cps—300 KHZ. Synchronization. Internal/external. Illuminated scale. 140 × 215 × 330 mm. Weight 15½lbs. 220/240 V. A.C. Supplied brand new with handbook. **£37.10.0** Carr. 10/-.

CRYSTAL CALIBRATORS NO. 10



Small portable crystal controlled wavemeter. Size 7in. × 7½in. × 4in. Frequency range 500 Kc/s—10 Mc/s (up to 30 Mc/s on harmonics). Calibrated dial. Power requirements 300 V.D.C. 15mA and 12 V.D.C. 0.3A. Excellent condition. **89/6** Carr. 7/6.

MARCONI TF885 VIDEO OSCILLATORS

0-5 mc/s Sine Square Wave **£45.** Carr. 20/-.

MARCONI TF195M BEAT FREQUENCY OSCILLATORS

0-40 kc/s. **£20.** Carr. 30/-.

WS62 TRANCEIVERS

Large quantity available for EXPORT! Excellent condition. Enquiries invited.

UNR-30 4 BAND COMMUNICATION RECEIVER

Covering 550 Kc/s-30 Mc/s. Incorporates BFO. Built-in speaker and phone jack. Metal cabinet. Operation 220/240 v. A.C. Supplied brand new, guaranteed with instructions. **13gns.** Carr. 7/6.

EDDYSTONE V.H.F. RECEIVERS

770R. 19-165 Mc/s. **£150.**
Both types in excellent condition.

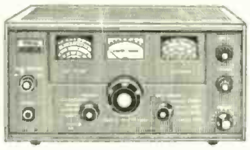
LAFAYETTE SOLID STATE HA600 RECEIVER

5 BAND AM/CW/SSB AMATEUR AND SHORT WAVE. 150 kc/s-400 Kc/s AND 550 Kc/s-30 Mc/s. F.E.T. front end ● 2 mechanical filters ● Huge dial ● Product detector ● Variable BFO ● Noiselimiter ● S Meter ● 24½in. Bandspread ● 230 v. A.C./12 v. D.C. neg earth operation ● RF gain control. Size 15in. × 9½in. × 8½in. Wt. 18 lbs. EXCEPTIONAL VALUE **£45.** CARR. 10/-. S.A.E. FOR FULL DETAILS.

UR-1A SOLID STATE COMMUNICATION RECEIVER

4 bands covering 550 Kc/s-30 mc/s continuous. Special features are use of FET transistors, S meter, built-in speaker and telescopic aerial, variable BFO for SSB reception, noise limiter, bandspread control, sensitivity control. Output for low impedance headphones. Operation 220/240 volt A.C. or 12 volt D.C. Size 12½" × 4½" × 7". Excellent value. Only **£24.** carr. 7/6.

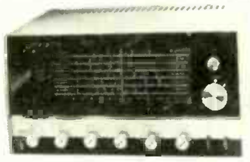
TRIO COMMUNICATION RECEIVER MODEL 9R-59DE



4 band receiver covering 500 Kc/s to 30 Mc/s, continuous and electrical bandspread on 10-15, 20, 40 and 80 metres. 8 valve plus 7 diode circuit. 4/8 ohm output and phone jack. SSB-CW ● ANL ● Variable BFO ● S meter. ● Sep. Bandspread dial ● IF 455 Kc/s ● audio output 1.5 w. ● Variable RF and AF gains controls. 115/250 v. A.C. mains. Beautifully designed. Size 7 × 15 × 10in. With instruction manual and service data. **£42.** Carriage paid Trio Communication Type Headphones. Normally £5.19.6. Our price **£3.15.0** if purchased with above receiver.

TRIO TS 510 Amateur Transceiver with speaker and mains P.S.U.	**£180**
TRIO JR 500SE 10-80 Metre Amateur Receiver	**£65**

LAFAYETTE HA.800 SOLID STATE AMATEUR COMMUNICATION RECEIVER SIX BANDS 3.5-4, 7-7.3, 14-14.35, 21-45, 28-29.7, 50-54 Mc/s.



Dual conversion on all bands. 2 × 455 Kc/s mechanical filters. Product detector. Variable B.F.O. 100 Kc/s crystal calibrator. 'S' meter. Huge slide rule dial. Operation 230v AC or 12v DC. Size 15" × 9½" × 8½". Complete with instruction manual. **£57.10.0.** Carr. Paid. (100 Kc/s Crystal **39/6** extra.)

TRIO JR-310 NEW AMATEUR BAND 10-80 METER RECEIVER IN STOCK £77.10.0

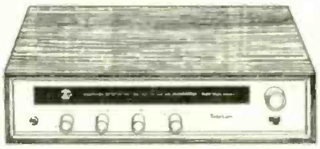
RCA COMMUNICATIONS RECEIVERS AR88D

Latest release by ministry BRAND NEW in original cases. 110-250v. A.C. operation. Frequency in 6 Bands. 535 Kc/s—32 Mc/s continuous. Output impedance 2.5-600 ohms. Incorporating crystal filter, noise limiter, variable BFO, variable selectivity, etc. Price **£65.** Carr. £2.

LAFAYETTE PF-60 SOLID STATE VHF FM RECEIVER

A completely new transistorised receiver covering 152-174 Mc/s. Fully tuneable or crystal controlled (not supplied) for fixed frequency operation. Incorporates 4 INTEGRATED CIRCUITS. Built-in speaker and illuminated dial. Squelch and volume controls. Tape recorder output. 75 Ω aerial input. Headphone jack. Operation 230 v. A.C./12 v. D.C. Neg. earth. **£37/10/-**. Carr. 10/-.

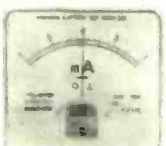
TELETON MODEL CR-10T AM/FM STEREO TUNER AMPLIFIER



A new model from Teleton. 31 solid state devices. 4+4 watt output. Inputs for ceramic/crystal cartridge. Frequency range AM 540-1600 KHz, FM 88-108 MHz. Automatic FM Stereo reception. Stereo Indicator. Controls: Tuning, function selector, Tone and R & L volume controls. AFC switch. Stereo headphone socket. Size 13¾in. × 3¼in. × 9¼in. approx. Price **£34/0/0.** Carr. 7/6.

SEW PANEL METERS

Type MR.38P. 1 21/32in. square fronts.



50µA	40/-	50mA	27/6	100V. D.C.	27/6
50-0-50µA	37/6	100mA	27/6	150V. D.C.	27/6
100µA	37/6	150mA	27/6	300V. D.C.	27/6
100-0-100µA	35/-	200mA	27/6	500V. D.C.	27/6
200µA	35/-	300mA	27/6	750V. D.C.	27/6
500µA	30/-	500mA	27/6	15V. A.C.	27/6
500-0-500µA	27/6	750mA	27/6	50V. A.C.	27/6
1mA	27/6	1 amp	27/6	150V. A.C.	27/6
1-0-1mA	27/6	2 amp	27/6	300V. A.C.	27/6
2mA	27/6	5 amp	27/6	500V. A.C.	27/6
5mA	27/6	3V. D.C.	27/6	S meter 1mA	32/-
10mA	27/6	10V. D.C.	27/6	VU meter	42/-
20mA	27/6	20V. D.C.	27/6		

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POWER RHEOSTATS

High quality ceramic construction. Windings embedded in vitreous enamel. Heavy duty brush wiper. Continuous rating. Wide range available ex-stock. Single hole fixing, ¼in. dia. shafts. Bulk quantities available.
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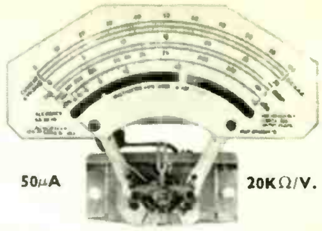
50 WATT. 10/25/50/100/250/500/1000/2500 or 5000 ohms. 21/-. P. & P. 1/6.
100 WATT. 1/5/10/25/50/100/250/500/1000 or 2500 ohms. 27/6. P. & P. 1/6.

AVOMETER MOVEMENTS



50µA 20KΩ/V.

Spare movements for Model 8 or 9. (Fitted with Model 9 scale) or basis for any multimeter. Brand New and Boxed **89/6** P. & P. 3/6

MARCONI TF.142E DISTORTION FACTOR METERS

Excellent condition. Fully tested **£20.** Carr. 15/-.

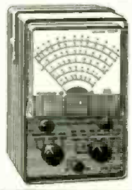
T.E.40 HIGH SENSITIVITY A.C. VOLTMETER

10 meg. input 10 ranges: .01/.03/.1/.3/1/3/10/30/100/300 v. R.M.S. 4 cps.-1.2 Mc/s. Decibels −40 to +50 dB. Supplied brand new complete with leads and instructions. Operation 230 v. A.C. **£17/10/-**. Carr. 5/-.

PLESSEY SL 403A

3-watt. integrated amplifier circuit.
49/6 post paid.

TE-65 VALVE VOLTMETER

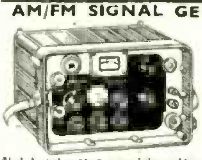


High quality instrument with 28 ranges. D.C. volts 1.5-1,500 v. A.C. volts 1.5-1,500 v. Resistance up to 1,000 megohms. 220/240v. A.C. operation. Complete with probe and instructions **£17/10/0.** P. & P. 6/-. Additional Probes available; R.F. 35/- H.V. **42/6.**

COSSOR 1049 DOUBLE BEAM OSCILLOSCOPES

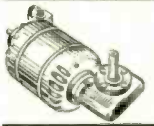
D.C. coupled. Band width 1 Kc/s. Perfect order. **£25.** Carr. 30/-.

AM/FM SIGNAL GENERATORS



Oscillator Test No. 2. A high quality precision instrument made for the Ministry by Airmec. Frequency coverage 20-80 Mc/s. AM/CW/FM. Incorporates precision dial, level meter, precision attenuator 1µV-100Mv. Operation from 12 volt D.C. or 0/110/200/250 v. A.C. Size 12 x 8½ x 9in. Supplied in brand new condition complete with all connectors, fully tested. **£45.** Carr. 20/-.

GEARED MAINS MOTOR

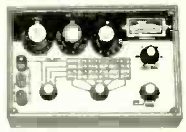


Parvalux type SD19 230/250 v. A.C. Reversible. 30 r.p.m. 40 lb. ins. Complete with capacitor. Excellent condition. **99/6.** Carr. 10/-.

TE-16A TRANSISTORISED SIGNAL GENERATOR

5 Ranges 400 KHZ-30 MHZ. An inexpensive instrument for the handyman. Operates on 9v. battery. Wide easy to read scale. 800 KHZ modulation. 5½" × 5½" × 3½". Complete with instructions and leads. **£7/19/6.** P/P 4/-.

TRANSISTORISED L.C.R. A.C MEASURING BRIDGE.



A new portable bridge offering excellent range and accuracy at low cost. Ranges: R. 1Ω—11.1 MEG Ω 6 Ranges ± 1%. L 1µH—111 HENRIES. 6 Ranges — 2%. C. 10PF ± 1110MFD. 6 Ranges ± 2%. TURNS RATIO 1:1/1000—1:11100. 6 Ranges ± 1%. Bridge voltage at 1,000 CPS. Operated from 9 volts. 100µA. Meter indication. Attractive 2 tone metal case. Size 7¾" × 5" × 2". **£20.** P. & P. 5/-.

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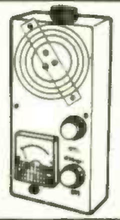
QUANTITIES AVAILABLE FOR EXPORT

✻ SINE/SQUARE WAVE AUDIO GENERATOR

Provides audio output on 4 bands, Sine wave 20c/s to 200 kc/s, output up to 7V: square wave 60c/s to 30kc/s, 7V p-p. Distortion under 2%. Output impedance 1kΩ. Variable output amplitude control. Supplied with leads and instructions. A.C. mains operated.

TE22 **Price £16.10.0**
Also TE22D (Size as TE20D) £16. 0.0

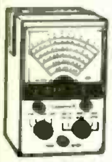
✻ GRID DIP METER



All transistor grid dip meter, absorption wavemeter and osc. detector. Frequency range 440kc/s to 280Mc/s in 6 coils. Uses 3 transistors plus diode with 500μA meter. Internal battery.

TE15 £11.10.0 p.p. 3/6

✻ VACUUM TUBE VOLTMETER

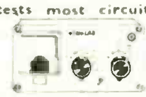


Features low price for such an instrument. Large 6in. full view scaled meter. 28 ranges. **D.C. volts:** 0/1½/5/15/50/150/500/1500. **A.C. volts:** 0/1½/5/15/50/150/500/1500 r.m.s.: 0/1.4/4/14/40/140/400/1400/4000 p-p. **Resistance:** R x 10-100-1k-10k-100k-1m-10m. Range 0.2 ohm to 1000MΩ. dB scales: —10 to +65dB. Complete with instructions and leads.

TE65 £17.10.0 p.p. 7/6

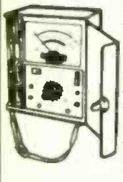
✻ 10 in 1 TEST UNIT

A new design tests most circuits.
Model SE400
Price £9.10.0.



- ★ A.c./d.c. Volts (4K/Volt) 0/15/50/150/500.
- ★ Resistance 0/10K/100k/1 Meg.
- ★ Five values resistance and capacitance substitution.
- ★ RF F/S Meter 1 to 140Mc/s.
- ★ 455/700kc/s RF Generator Size 7¼in. x 3⅜in. x 1 7/16in.
- ★ D.c. Ammeter 0/500mA.
- ★ 400c/s Audio Generator.

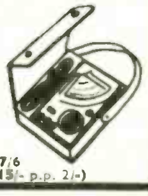
✻ 50,000 OHMS PER VOLT MULTIMETER



Recommended quality instrument with mirror scale and overload protection. 0/0.3/3/12/60/120/300/600/1200V d.c. (50KΩ/V); 0/6/30/120/300/600/1200V a.c. (10KΩ/V); 0/30μA/6/60/300mA, 0/12A; resistance 0/10kΩ/1/10/100MΩ. Meter movement 20μA. Polarity reversing switch. Complete with batteries, leads and instructions.

AF105 £8.10.0 p.p. 2/6
Leather case 28/6

✻ 20,000 OHMS PER VOLT MULTIMETER



Popular model but with extra scale range. 20.000 ohms per volt. 0/5/25/50/250/500/2500 V d.c., 0/10/50/100/500/1000V a.c., 0/50μA, 0/2½/250mA. Resistance 0-6kΩ and 6MΩ. Also dB scales or capacitance.

Model 200H **Price 77/6**
(Leather case, Price 15/- p.p. 2/-)

✻ RF SIGNAL GENERATOR

Accurate wide range signal generator covering 120Kc/s-500Mc/s on 6 bands. Directly calibrated. Variable RF. attenuator, audio output. Xtal socket for calibration. 220/240V. A.C. Brand new with instructions. Size 140 x 215 x 170mm.

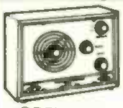
TE20D **Price £15** p.p. 7/6

✻ TRANSISTORISED RF MILLIVOLTMETER

Mains or battery operated. 0/3mV up to 300V AC. Input 1Meg. Response ±0.2dB 20c/s to 1Mc/s and ±1dB at higher and lower frequencies. Fully stabilised. Size: 150 x 240 x 114mm. Complete with handbook. 11 scales 0.003 FSD to 300V FSD. Also dBM and dBV scales.

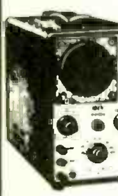
VM51 **Price £32** p.p. 8/6

NOMBREX TRANSISTORISED Test Equipment



MODEL		PRICE £	s.	d.
29s	RF.Generator } Spin wheel	21	0	0
29x	Xtal RF Gen. } Spin wheel	29	10	0
30	Audio Generator ..	19	10	0
31	R.F. Generator ..	12	10	0
32	C.R. Bridge	10	10	0
33	Inductance Bridge ..	20	0	0

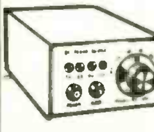
✻ PORTABLE OSCILLOSCOPE



Features 3in. clear view tube, easy to use controls and good stability. Y amp. Sensitivity. 1V p-p/CM. Bandwidth 1.5cps-1.5 MHz. Input imp. 2 meg Ω. 25 PF. X amp sensitivity. 9V p-p/CM. Bandwidth 1.5 cps-800 KHz. Input imp. 2 meg Ω. 20 PF. Time base. 5 ranges 10 cps-300 KHz. Synchronization. Internal/external. Illuminated scale.

TO3 **Price £37.10.0** p.p. 10/-

✻ DC STABILISED POWER SUPPLY

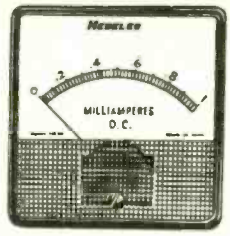


Switched DC Stabilised Outputs UP TO 1 AMP. 3-6-9 & 12 VOLTS. Indicator lamp for each voltage. Fully fused. Mains operated. Negligible ripple. Regulation 1%.

SE101A £8.15.0

FREE 18 PAGE TEST EQUIPMENT CATALOGUE (Ref. No. 33)

QUALITY PANEL METERS



38 SERIES
Face Size 42 x 42mm. DC types.

50	μA	37/6
100	,,	35/–
200	,,	32/6
500	,,	27/6
50-0- 50	,,	35/–
100-0-100	,,	32/6
500-0-500	,,	25/–
1	mA	25/–
5	,,	25/–
10	,,	25/–
50	,,	25/–
100	,,	25/–
500	,,	25/–
1	Amp	25/–
5	,,	25/–
10	Volts	25/–
20	,,	25/–
50	,,	25/–
300	,,	25/–
500	,,	25/–
'S' Meter 1mA		29/6
VU Meter		37/6

65 SERIES
Face Size 86 x 78mm. DC types.

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100	,,	52/6
200	,,	47/6
500	,,	45/–
50-0- 50	,,	52/6
100-0-100	,,	49/6
500-0-500	,,	37/6
1	mA	37/6
5	,,	37/6
10	,,	37/6
100	,,	37/6
500	,,	37/6
10	Volts	37/6
20	,,	37/6
50	,,	37/6
100	,,	37/6
300	,,	37/6
500	,,	37/6
'S' Meter 1mA		42/6

85 SERIES
Face Size 120 x 110mm. DC types.

50	μA	69/6
100	,,	59/6
500	,,	52/6
100-0-100	,,	59/6
1	mA	49/6
100	,,	49/6

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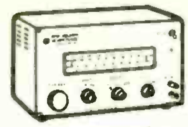
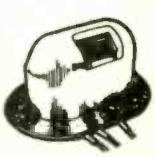
✻ DE-LUXE SINE-SQUARE WAVE RC AUDIO GENERATOR



ORC 27A Price £30 p.p. 10/-.

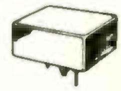
Weinbridge RC Audio oscillator featuring four overlapping scales covering 18c/s to 200 Kc/s. Output waveforms are sine, square and complex. Mirrored scale with smooth geared tuning control. Output 5 volts RMS or 10 volts P-P. Sinewave response ± ½dB, Distortion under 1% at 1Kc/s. Stability ± 1%. Accuracy ± 2%. O/P impedance under 3K ohms. Variable attenuator. Mains operated. With handbook.

GRAVINER FIRE DETECTOR UNIT



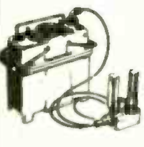
Fire Detector Unit containing G31A photo multiplier and cold cathode tube. Shock and fire proof. Originally made for £74. Price complete with data sheet £6 Brand new.

STC CRYSTAL FILTER ±7.5 K/cs BAND WIDTH



25Kc/s Spacing. New purchase, brand new type 445 LQU 923E. 10.7 Mc/s. 6dB ± 7½Kc/s. Insertion Loss 3.5dB. Terminations 820 Ohms. Usually £12. Price £6 with Data Sheet.

PORTABLE 0-10mr GEIGER COUNTERS



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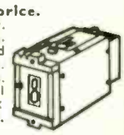

At a fraction of normal price. Moving Coil 0 to 9 Display. One inch character size. Light beam lens operated meter. Movement 500μA. Character lamp 6.3 volts. Also lamp for decimal point. Overall size: 4½ x 1½ x 2½. Brand new. **Price 79/6.**

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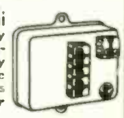

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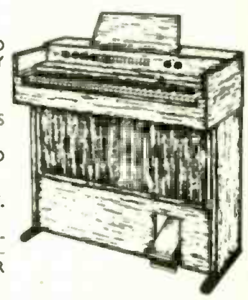

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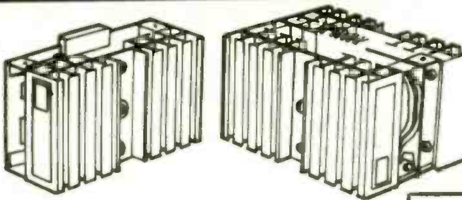

LOOK AT THE SPECIFICATION!

✻ HENELEC 'PA25' POWER AMPLIFIER

This silicon design uses complementary transistors in the symmetrical output stage, direct coupled to a loudspeaker of 8 ohms impedance or higher. Power output is 25 watts RMS with an 8 ohm load or 12 watts into 15 ohms, Power Response 11Hz—40KHz—1dB Distortion under 0·3% at full power. Cool running is assured by the use of generously dimensioned black anodised heatsinks. Input 700mV 15Kohm. **PRICE £7.10.0**

✻ HENELEC 'PA50' POWER AMPLIFIER

Basically similar to the 'PA25', the 'PA50' will deliver 50 watts RMS to a 3-4 ohm load. Extra power is handled by complementary triplet circuits using the latest PNP and NPN silicon power transistors. As a result of extra heatsinking, the 'PA50' runs as cool as the 'PA25'. **PRICE £9.10.0**

✻ HENELEC MU442 POWER SUPPLY

Designed to run one or two 'PA25's' or one 'PA50' the MU442 connects to the amplifiers by means of plug-on harnesses. No soldering is required to connect up the system. Audio input plug and speaker plug go to the panel of the MU442. **PRICE £6.3.0**

✻ Mk.1 100 watts RMS with stabilised power supply overcurrent trip 100mV input sensitivity. Ideal for public address and discotheque equipment. **PRICE £49.10.0**

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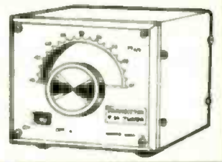

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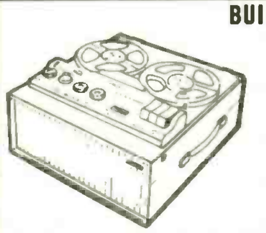

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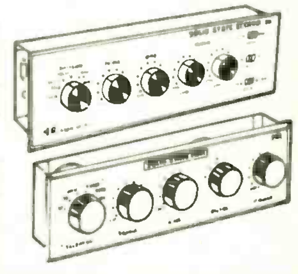

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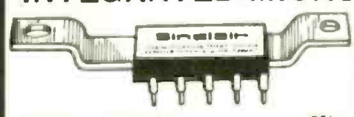

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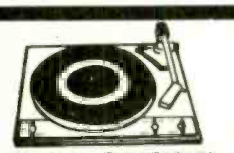

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GL75P	46 0 0	—	53 10 0	60 0 0*	55 10 0	53 0 0	70 0 0*	53 10 0
GL69P	35 0 0	37 0 0	42 10 0	40 0 0	44 10 0	42 0 0	59 0 0*	42 0 0
MA70	12 10 0	14 10 0	20 0 0	17 12 6	—	—	16 10 0	20 0 0
AT60 Mk II	13 10 0	15 15 0	21 7 6	19 0 0	18 0 0*	—	17 12 6	21 10 0
GL75	33 0 0	35 0 0	40 10 0	47 0 0*	42 10 0	40 0 0	57 0 0*	40 10 0
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SL75B	31 0 0	33 0 0	33 10 0	36 10 0	40 10 0	40 0 0	35 0 0	38 10 0
SL95B	39 0 0	41 0 0	46 10 0	53 10 0*	48 10 0	48 0 0	43 0 0	46 10 0
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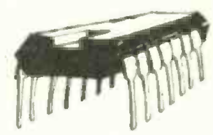

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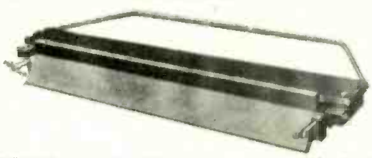

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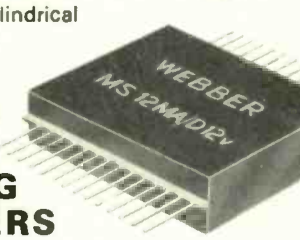

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Sensitivies for 10 watt output at 1 KHz into 3 ohms. Tape Head: 3mV (at 3¾ i.p.s.). Mag. P.U.: 2 mV. Cer. P.U.: 80 mV. Tuner: 100 mV. Aux. 100 mV. Tape/Rec. Output: Equalisation for each Input is correct to within ±2dB (R.I.A.A.) from 20 Hz to 20KHz. Tone Control Range: Bass ±13 dB at 60 Hz. Treble ±14 dB at 15 KHz. Total Distortion: (for 10 watt output) < 1.5%. Signal Noise: < −60dB. AC Mains 200-250v. Size 12½" long. 4½" deep. 2¾" high.

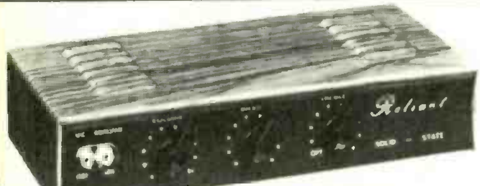
The Viscount

INTEGRATED HIGH FIDELITY TRANSISTOR STEREO AMPLIFIER
£14 5s. + 7/6 p. & p.

SIZE: 12½" x 6" x 2¾" in teak-finished case.
Built and tested.

SPECIFICATION

OUTPUT: 10 watts per channel into 3 to 4 ohms speakers (20 watts) monoral.
INPUT: 6-position rotary selector switch (3 pos. mono and 3 pos. stereo). P.U. Tuner. Tape and Tape Rec. out Sensitivities: All Inputs 100 mV into 1.8M ohm.
FREQUENCY RESPONSE: 40Hz-20KHz ± 2DB.
TONE CONTROLS: Separate bass and treble controls. TREBLE 13dB lift and cut (at 15KHz) BASS: 15dB lift and 25dB cut (at 50Hz).
VOLUME CONTROLS: Separate for each channel. AC MAINS INPUT: 200-240v. 50-60Hz.
Viscount Mark II for use with magnetic pick ups specification as above. Fully equalised for magnetic pick ups. Suitable for cartridges with minimum output of 4mV/cm/sec. at 1kc. Input Impedance 47k. **£15 15s.** plus 7/6 p. & p.



THE RELIANT MK.II

Solid State
General Purpose Amplifier
In teak-finished case
£6 16s.
+ 7/6 p. & p.

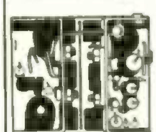
SPECIFICATION

OUTPUT: 10 watts into a 3 ohms speaker.
INPUTS: (1) for mike (10 m.v.). Input (2) for gram. radio (250 m.v.) individual bass and treble control.
TRANSISTORS: 4 silicone and three germanium.
MAINS INPUT: 220/250 volts.
SIZE: 10¼" x 4¾" x 2¼".

Mk. 1 £5 15s. + 7/6d. p. & p. less Teak-finished case.

X101 10w. SOLID-STATE HI-FI AMP

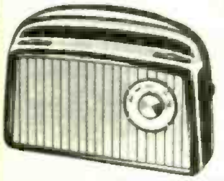
With Integral Pre-amp.



Specifications: Power Output (Into 3 ohms speaker) 10 watts. Sensitivity (for rated output): 1mV into 3K ohms (0.33 microamp) Total Distortion (at 1 KHz): At 5 watts 0.35%; At rated output 1.5%. Frequency Response: Minus 3 dB points 20 Hz and 40 KHz. Speaker: 3-4 ohms. (3-15 ohms may be used). Supply voltage: 24v D.C. at 800 mA. (6-24v may be used).

69/6 plus 2/6 p. & p.

CONTROL ASSEMBLY: (including resistors and capacitors). 1. Volume: **Price 5/-**. 2. Treble: **Price 5/-**. 3. Comprehensive bass and treble: **Price 10/-**. The above 3 items can be purchased for use with the X101. **POWER SUPPLIES FOR X101:** P101 M (mono) 35/- p. & p. 4/6: P101 (stereo) 42/6 p. & p. 4/6.



THE DORSET

(600mW Output)
£5.5.0
plus 7/6 p. & p.
Circuit 2/6. FREE WITH PARTS
MAINS POWER PACK KIT: 9/6 extra.

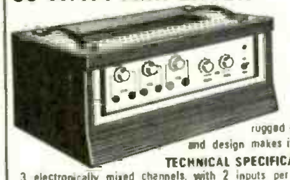
7-transistor fully tunable M.W.-L.W. superhet portable—with baby alarm facility. Set of parts. The latest modulized and pre-alignment techniques makes this simple to build. Sizes: 12" x 8" x 3".

ELEGANT SEVEN MK. III

(350mW Output)
£5.5.0
plus 7/6 p. & p.
Circuit 2/6. FREE WITH PARTS
MAINS POWER PACK KIT: 9/6 extra.

7-transistor fully tunable M.W.-L.W. superhet portable. Set of parts. Complete with all components, including ready etched and drilled printed circuit board—back printed for foolproof construction.

50 WATT AMPLIFIER



AC MAINS 200-250V
£28 10s.
plus 20/- p. & p.

An extremely reliable general purpose valve amplifier. Its rugged construction yet space age styling and design makes it by far the best value for money.

TECHNICAL SPECIFICATIONS

3 electronically mixed channels, with 2 inputs per channel, enables the use of 6 separate instruments at the same time. The volume controls for each channel are located directly above the corresponding input sockets. **SENSITIVITIES AND INPUT IMPEDANCES.** Channels 1 & 2 4mV at 470K. These 2 channels (4 inputs) are suitable for microphone or guitars. Channels 3 & 4 300mV at 1m. Suitable for most high output instruments (gram. tuner, organ, etc.). Input sensitivity relative to 10w output. **TONE CONTROLS ARE COMMON TO ALL INPUTS.** Bass Boost +12dB at 60 Hz. Bass Cut—13dB at 60 Hz. Treble Boost +11dB at 15 KHz. Treble Cut −12dB at 15 KHz. With bass and treble controls central −3dB points are 30 Hz and 20 KHz. **POWER OUTPUT:** For speech and music 50 watts rms. 100 watts peak. For sustained music 45 watts rms. 90 watts peak. For sine wave 38.5 watts rms. Nearly 80 watts peak. Total distortion at rated output 3.2% at 1KHz. Total distortion at 20 watts 0.15% at 1KHz. **NEGATIVE FEEDBACK** 20dB at 1 KHz **SIGNAL TO NOISE RATIO** 60dB. **MAINS VOLTAGES** adjustable from 200-250V. A.C. 50-60 Hz. A protective fuse is located at the rear of unit. Output impedance 3, 8 and 15 ohms.

NEW COMPLETE HI-FI STEREO SYSTEM £41

comprising SP25 Garrard Mk II with diamond stereo cartridge or 2025TC. Viscount amplifier Mk I. Two type 2 speakers, plinth and cover.

£41 plus £2 10s. p. & p.

SPECIAL OFFER

Complete stereo systems comprising BALFOUR 4 speed auto player with stereo head 2 DUO speaker systems size 12 x 6¾ x 5¾. Plinth (less cover) and the DUETTO stereo amplifier. All above items

£25 plus £2 p. & p.

BRAND NEW SEMICONDUCTORS & COMPONENTS GUARANTEED

TRANSISTORS Brand new and fully guaranteed. PLEASE NOTE:—A large number of our transistors have now been reduced in price. Many more semi-conductors in stock. Please enquire for types not listed.

2G301	4/-	2N3402	5/6	3N143	19/6	BC168C	3/9	BPX25	45/-	NKT272	4/-
2G302	4/-	2N3403	5/6	3N152	24/-	BC169B	3/6	BPX29	42/6	NKT274	4/-
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2N929	4/6	2N3711	4/-	40406	16/-	BCY54	7/6	BSY39	4/6	NKT10519	6/6
2N930	7/-	2N3713	27/6	40408	16/-	BCY58	4/6	BSY40	6/6	NKT20329	9/6
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2N1303	3/6	2N3854A	5/6	AC127	5/-	BCY72	4/-	BSY56	18/-	NKT80211	18/6
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2N1638	7/6	2N3877A	9/6	ACY28	4/-	BDY18	49/6	GET102	6/-	OC28	12/6
2N1639	7/6	2N3900	10/6	ACY40	4/-	BDY19	62/6	GET113	4/-	OC29	15/-
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2N2218	6/6	2N4244	9/6	AF117	5/-	BF178	10/6	GET898	4/6	OC75	4/6
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2N2696	6/6	2N5174	10/6	ASY28	5/6	BFX29	8/-	MPF102	8/6	OCP71	8/6
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2N2865	12/6	2N5246	12/6	ASY53	5/-	BFX84	7/6	NKT0013	9/6	TIS34	17/6
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2N2905	8/-	2N5265	62/6	ASY63	3/6	BFX87	6/6	NKT126	5/6	TIS45	3/6
2N2905A	9/-	2N5266	57/6	ASY72	5/-	BFX88	5/-	NKT128	5/6	TIS46	3/6
2N2906	6/-	2N5267	52/6	ASY83	5/-	BFX89	12/6	NKT135	5/6	TIS47	3/6
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2N2907	8/-	2N5306	8/-	ASZ20	7/6	BFY11	4/6	NKT210	6/-	TIS49	3/6
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Yellow	2/9	2N5355	5/6	BC113	6/6	BFY24	9/-	NKT216	7/6	TIS61	6/6
Orange	2/9	2N5356	10/6	BC115	6/6	BFY25	5/-	NKT217	8/6	TIP29A	17/6
2N3011	12/6	2N5365	9/6	BC116	12/6	BFY26	4/-	NKT219	6/-	TIP30A	21/6
2N3014	6/6	2N5366	10/-	BC118	6/6	BFY29	10/-	NKT223	5/6	TIP31A	19/6
2N3053	5/6	2N5367	11/6	BC121	4/-	BFY30	10/-	NKT224	5/-	TIP32A	22/6
2N3054	12/6	2N5457	7/6	BC122	4/-	BFY41	10/-	NKT225	4/6	ZTX107	3/6
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2N3391A	6/-	3N128	18/6	BC159	4/-	BFY90	12/6	NKT261	4/-	ZTX502	6/-
2N3392	5/-	3N140	19/6	BC160	12/6	BFW58	5/6	NKT262	4/-	ZTX503	5/-
2N3393	5/-	3N141	21/6	BC167	3/6	BFW59	5/-	NKT264	4/-	ZTX504	12/6
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SILICON RECTIFIERS

PIV	50	100	200	400	600	800	1000	1200	1400
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3A	3/-	—	—	4/6	—	6/-	—	—	—
6A	—	—	5/-	6/-	6/6	7/-	10/-*	—	—
10A	—	10/6	11/6	13/-	15/6	17/6	19/6	25/-	32/-
17A	—	11/6	12/6	15/6	18/-	19/6	24/-	31/6	37/6
35A	—	27/6	32/-	39/6	47/6	54/-	62/-	70/-	90/-

* 5 amp only. 1 amp are plastic encapsulation.

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1N916	1/6	AAZ13	2/-	BY103	4/6	OA9	2/-
1N4007	4/6	AAZ15	2/6	BY122	7/6	OA47	1/6
1S010	3/-	AAZ17	2/6	BY124	3/-	OA70	1/6
1S021	4/-	BA100	2/6	BY126	4/-	OA73	2/-
1S025	5/-	BA102	6/6	BY127	4/6	OA79	1/9
1S44	2/-	BA110	7/-	BYX10	5/6	OA81	1/6
1S113	3/-	BA115	1/6	BYX10	9/-	OA85	1/6
1S120	2/6	BA144	5/6	BYZ11	7/6	OA90	1/6
1S121	2/6	BAX13	2/6	BYZ12	6/6	OA91	1/6
1S130	2/6	BAX16	2/6	BYZ13	5/-	OA95	1/6
1S131	3/-	BAY18	3/6	FST3/4	4/6	OA200	2/-
1S132	2/6	BAY31	1/6	FST3/8	6/-	OA202	2/-
1S940	1/6						

MAINS TRANSFORMERS

1 amp Charger. Sec. 0-3.5-9-17v 19/6
2 amp Charger. Sec. 0-3.5-9-17v 25/6
1 amp (Douglas) MT103 Sec. tappings from 6v to 50v .. 32/6
2 amp (Douglas) MT104 Sec. tappings from 6v to 50v .. 42/6
Post and packing 4/6.
5 amp (Douglas) MT107 Sec. tappings from 6v to 50v .. 110/-
Post and packing 7/6.
Various other Douglas Transformers ranging from ½A to 5A in stock (details in catalogue).

TRIACS

SC41A (GE) 6 amp 100v 19/6
SC41B (GE) 6 amp 200v 22/-
SC41D (GE) 6 amp 400v 27/6
SC50D 15 amp 400v 60/-
40512 (RCA) TO-5 mod. 6 amp 400v 33/-
40430 (RCA) TO-66 6 amp 400v 27/6
40486 (RCA) TO-5 mod. 6 amp 400v 24/-
Economy Range Triacs (Delivery end of May)
TC4/10 (Pressfit) 4 amp 100 PIV 15/-
TC4/20 (Pressfit) 4 amp 200PIV 17/-
TC4/40 (Pressfit) 4 amp 400 PIV 19/6
TC3/40 (TO-5) 3 amp 400 PIV 22/6

INTEGRATED CIRCUITS
SEE OUR SEPARATE ADVERTISEMENT ON PAGE 123 SHOWING NEW I.C.s AND NEW LOW PRICES.

THYRISTORS

PIV	50	100	200	300	400
1A	5/-	5/6	7/6	8/-	9/6
3A	6/-	7/6	8/-	9/-	10/6
5A	—	11/-	13/-	—	15/-
7A	—	11/-	13/-	14/-	19/6
25A	27/6	30/-	33/-	—	37/6

TIC47 0.6 amp. 200 PIV 6/6.
Also 12 Amp 100 PIV 15/-, 600 PIV 35/6, 2N3525 at 25/6

VEROBOARD

	.15 Matrix	.1 Matrix
2½" × 3¾"	3/6	4/-
2½" × 5"	4/3	4/9
3¾" × 3¾"	4/3	4/9
3¾" × 5"	5/6	5/6
2½" × 17"	12/6	—
3¾" × 17"	16/-	21/6
3¾" × 17" (Plain)	—	11/6
5" × 17" (Plain)	17/-	—
2½" × 17" (Plain)	9/6	—

Vero Pins (Bag of 50) 5/-.
Vero Cutter 9/-.
Pin Insertion Tools (.1 and .15 matrix) at 11/-.

RESISTORS

Carbon Film
¼ watt 5% .. .. 4d. 1 watt 10% .. 6d.
½ watt 5% .. .. 5d.
2 watt 10% .. .. 1/- ⅛ watt 5% .. 4d.
(Bag of 100) 8/-

Wire Wound
2.5 watt 5% (Up to 270 ohms only) 1/6
5 watt 5% (Up to 8.2k ohms only) 2/-
10 watt 5% (Up to 25k ohms only) 2/6

CAPACITORS.

Polyester, ceramics, Polystyrene, silver mica, tantalum, trimmers etc.
Electrolytics

MFD.	V.		MFD.	V.		MFD.	V.	
1	40	1/6	25	50	1/6	320	10	1/6
1.6	25	1/6	32	40	1/6	400	16	2/9
2	350	2/-	32	450	5/6	500	6	2/6
2.5	16	1/6	40	6.4	1/6	500	25	3/9
4	10	1/6	40	16	1/6	500	50	4/9
4	40	1/6	50	12	1/6	640	16	3/6
4	350	2/3	50	25	1/6	640	25	5/-
5	18	1/6	50	50	2/-	1000	16	5/-
5	50	1/6	64	25	1/6	1000	25	5/-
6.4	6.4	1/6	80	16	1/6	1000	50	7/6
8	40	1/6	80	25	1/6	2000	25	8/6
8	450	3/-	100	6.4	1/6	2000	50	12/6
10	12	1/6	100	12	1/6	2500	12	5/-
10	25	1/6	100	25	2/-	2500	25	9/6
12.5	25	1/6	100	50	2/6	2500	50	13/6
16	10	1/6	125	10	1/6	2500	64	15/6
16	15	1/6	200	10	1/6	3000	25	10/6
16	450	3/3	250	25	2/9	5000	25	12/6
25	6.4	1/6	250	50	3/9	5000	50	19/6
25	10	1/6						
25	25	1/6						

THERMISTORS (MULLARD)

R53 (STC)	25/6	VA1010	2/6	VA1039	3/-	VA1077	4/-
K151 (Siemens) 1K	2/6	VA1015	3/9	VA1040	2/6	VA1091	4/6
VA1005	3/-	VA1033	2/6	VA1053	2/6	VA1096	4/-
		VA1034	2/6	VA1066	3/9	VA1097	4/-
		VA1037	2/6	VA1074	2/6	VA1098	4/-
		VA1038	2/6	VA1075	4/6		

Send 2/6 for our latest comprehensive catalogue containing transistor selection charts and all prices, and free vouchers value 6/-.

PANEL METERS

38 Series—FACE SIZE 42 × 42 mm. All prices for 1-9 pieces.

50	Microamp	37/6	5	Milliamp	25/-
100	"	35/-	10	"	25/-
200	"	32/6	50	"	25/-
500	"	27/6	100	"	25/-
50-0-50	"	35/-	500	"	25/-
100-0-100	"	32/6	1	Amp	25/-
500-0-500	"	25/-	5	"	25/-
1	Milliamp	*25/-	10	Volts	25/-
			20	"	25/-
			50	"	25/-
			300	"	25/-
			500	"	25/-

SPEAKERS (3ohm)

10" × 6"	37/6	3"	11/6
9" × 4"	23/6	5"	14/6
8" × 5"	19/6	8"	27/6
7" × 4"	15/6	12"	39/6
5" × 3"	12/6		

Post and packing 2/9.

PRESETS Carbon Miniature and Sub miniature. Vertical and Horizontal. 0.1 watt 1/-, 0.2 watt 1/3, 0.3 watt 1/6.

CARBON POTENTIOMETERS

Log. and Lin. Less switch 3/3
Log. and Lin. With switch 4/6
Wire-wound Pots (3 watts) 6/6
Twin Ganged Stereo Pots. Log. and Lin. Less Switch 7/6

HEAT SINKS

4.8" × 4" × 1" Finned. For Two To-3 Trans. .. 9/6
4.8" × 2" × 1" Finned. For One To-3 Trans. .. 6/6
For SO-1 6d. For TO-5 1/- Finned
For TO-18 1/- Finned For TO-1 1/- Finned

ZENER DIODES

400 m W (from 3.3v to 33v) 5/-
1 Watt (from 2.4 to 200v) 7/6
10 Watt (from 3.9v to 100v) 7/6
20W. BZY93 Series (from 7.5v to 75v) 12/6

CIR-KIT

5 ft. × 1/16 in. or ⅛ in. 2/-
D.G. 30 W. Soldering Irons .. .. .. 17/6 each

POSTAGE & PACKING CHARGES

U.K. 1/6
EUROPE .. .. 5/- (minimum)
COMMONWEALTH (AIR) .. .. 13/- (minimum)

Telex 21-492
Tel: 01-452 0161/2/3

A. MARSHALL & SONS LTD

28 CRICKLEWOOD BROADWAY, LONDON, N.W.2

CALLERS WELCOME
Hours: 9-6 pm Mon-Fri 9-5 pm Sat

CURRENT RANGE OF BRAND NEW L.T. TRANSFORMERS. FULLY SHROUDED (*excepted) TERMINAL BLOCK CONNECTIONS. ALL PRIMARIES 220/240v

No.	Sec. Taps	Amps	Price	Carr.
1A	25–33–40–50	15	£10 10 0	12/6
1B	25–33–40–50	10	£7 12 6	9/6
1C	25–33–40–50	6	£6 15 0	9/6
1D	25–33–40–50	3	£4 0 0	7/6
2A	4–16–24–32	12	£7 2 6	8/6
2B	4–16–24–32	8	£5 7 6	8/6
2C	4–16–24–32	4	£3 12 6	7/6
2D	4–16–24–32	2	£2 7 6	5/-
3A*	25–30–35	40	£16 10 0	12/6
3B*	25–30–35	20	£10 5 0	10/6
3C	25–30–35	10	£7 5 0	8/6
3D	25–30–35	5	£4 2 6	7/6
3E	25–30–35	2	£3 2 6	7/6
4A*	12–20–24	30	£13 0 0	12/6
4B	12–20–24	20	£8 5 0	9/6
4C	12–20–24	10	£4 5 0	8/6
4D	12–20–24	5	£3 12 6	7/6
5A	3–12–18	30	£9 12 6	9/6
5B	3–12–18	20	£7 2 6	8/6
5C	3–12–18	10	£4 5 0	7/6
5D	3–12–18	5	£2 17 6	7/6
6A	48–56–60	2	£3 12 6	6/6
6B	48–56–60	1	£2 12 6	6/6
7A*	6–12	50	£10 7 6	10/6
7B	6–12	20	£6 2 6	8/6
7C	6–12	10	£3 17 6	7/6
7D	6–12	5	£2 15 0	6/6
8A	12–24	1	£1 12 6	6/6
9A	17–32	8	£6 5 0	8/6
10A*	9–15	2	£1 9 6	6/6
11A	6·3	15	£2 10 0	7/6
12A	30–25–0–25–30	2	£3 12 6	6/6

Note: By using the intermediate taps many other voltages can be obtained.
Example: No. 1 .. 7–8–10–15–17–25–33–40–50v.
No. 2 .. 4–8–12–16–20–24–32v.
No. 5 .. 3–6–9–12–15–18v.

AUTO TRANSFORMERS

240v.-110v. or 100v. Completely Shrouded fitted with Two-pin American Sockets or terminal blocks. Please state which type required.

Type	Watts	Approx. Weight	Price	Carr.
1	80	2½ lb	£1 19 6	5/6
2	150	4 lb	£2 12 6	6/6
3	300	6½ lb	£3 12 6	6/6
4	500	8½ lb	£5 2 6	8/6
5	1000	15 lb	£7 2 6	9/6
6*	1500	25 lb	£9 15 0	10/6
7*	1750	28 lb	£14 15 0	12/6
8*	2250	30 lb	£17 17 6	15/-

* Completely enclosed in beautifully finished metal case fitted with two 2-pin American sockets, neon indicator, on/off switch, and carrying handle.

DOUBLE WOUND STEP DOWN TRANSFORMERS

240/110v. completely shrouded. Fitted with 2-pin American sockets or terminal blocks. 150 watts, £4.2.6, P. & P. 8/6. 300 watts, £5.15.0, P. & P. 9/6. 500 watts, £8.5.0, P. & P. 10/6. 1000 watts, fitted in metal case, with twin 2-pin American socket, neon indicator, on/off switch, £17.17.6, carriage 15/-.

HEAVY DUTY L.T. TRANSFORMERS

Pri. 220-240v., Sec. 12v. 90A. Open frame. Flying leads. Size: 7½×6½×6 ins., £15.0.0, carriage 15/-. Pri. 200-240v., Sec. tapped 14, 15·5, 28, 31v., 20A. Open frame. Table top connections, £12.10.0, carriage 12/6.

Samson's

(ELECTRONICS) LTD.

9 & 10 CHAPEL ST., LONDON, N.W.1

01-723-7851 01-262-512

G.P.O. L.T. SUPPLY UNIT

Type 19. A.C. input, tapped 200-250v., 100-120v. D.C. output, 12 or 24 volts, very conservatively rated at 3 amps. Can be connected to give 12 volts 6 amps. Built into strong metal case size 19 × 7 × 6½ ins. With fitted fuses. On/off switch. Socket outlet. Circuit supplied, £7.19.6, carriage 15/-.

ADVANCE C/V TRANSFORMERS

Type CV 15/95. Input 95-130v., 190-260v. Output 4v. rms + or — 1%. 3 watts. Open frame type. 25/-, P. & P. 5/-.

BRAND NEW GARDERS TRANSFORMERS

Pri. tapped 200-250v., Sec. 350-0-350v. 60 M/A. 6·3v. 4A.. 5v., 2·5A. Completely enclosed. 27/6, P. & P. 6/6. Pri. tapped 200-250v., Sec. 2250v., 22 M/A. Completely enclosed. 75/-, P. & P. 7/6. Pri. 200-250v., Sec. tapped 3000-3300v., 10 M/A. 4v.-6·3v. 1·5A. 3kV. wkg., 2-4v. 2A. 3kV. wkg. Completely enclosed. £4.19.6, carriage 10/-. Pr. 200-250v., Sec. 63v., 1·6A., 20-22-24v., 0·8A. 6·3v., 1A., 65/-, P. & P. 7/6. Pri. 200-250v., Sec. 118v., 90 M/A, 15/-, P. & P. 4/6.

LOW VOLTAGE ISOLATION TRANSFORMERS

Sec. 6·3 v., Sec. 2-0-2v., 4A., 5kV. wkg. "C" core potted type. 17/6, P. & P. 3/6.

PARMEKO NEPTUNE SERIES TRANSFORMERS

Pri. tapped 200-220-240v., Sec. 250-0-250v. 50 M/A., 6·3v. 1A. Size H: 4×3×2½ ins., with fixing bolts. Brand new in maker's carton. 22/6, P. & P. 4/6.

PARMEKO CHOKES—NEPTUNE SERIES

10H. 180M/A., 25/-. P. & P. 5/-. 10H. 120M/A., 12/6. P. & P. 4/-. 10H. 75M/A., 15H. 75M/A, 15H. 50M/A., 5H. 120M/A., 5H. 60M/A., 50H. 25M/A., all types, 8/6 each, P. & P. 3/6. 0·7H. 450M/A. 12/6. P. & P 4/6. 1H. 300M/A. 10/6 P. & P. 4/6. 5H. 150M/A. 17/6.

JUPITER SERIES SWINGING CHOKE

34H. 60M/A.-70H. 35M/A., 2·8kv., D.C. Wkg. 25/-. P. & P. 6/-.

PARTRIDGE TOTALLY ENCLOSED CHOKES

5H. 250M/A. 19/6. P. & P. 6/-. **GRESHAM SEALED OIL-FILLED CHOKES**: 12H. 200M/A. 29/6. P. & P. 7/6. **HADDONS**: 12H. 60M/A. 10/6. P. & P. 5/-. **L.T. SMOOTHING CHOKE**: 16M/H. 8 amps. 35/-. P. & P. 5/-. **GRESHAM SWING CHOKE**: 20H. 100M/A. 10H. 450M/A. 49/6. P. & P. 7/6.

SPECIAL OFFER OF SLIDING RESISTORS

Single tube sliders. 14 Ω 1·4A. 15/-. P. & P. 3/6. 1 Ω 12A. 15/-. P. & P. 3/6. 1000 Ω 1A. 47/6. P. & P. 8/6. R/angle geared drive 30 Ω 1·5A. 19/6. P. & P. 4/6. Normal geared drive. 782 Ω 1A. 52/6. Carr. 8/6. Single tube fixed 45 + 12 Ω 6·5/4A. 27/6. P. & P. 6/6. Single tube adjustable 57·2 Ω 2·8A. 27/6. P. & P. 5/6. Single tube fixed 71·5 Ω 2·8A. 25/-. P. & P. 5/6. Single tube adjustable 0·6 Ω 16A. 15/-. P. & P. 3/6. vitreous fixed 1K Ω 70 watts. 5/-. P. & P. 1/6.

OIL-FILLED BLOCK CAPACITORS

T.C.C. 8 mfd. 2500v. wkg. at 70°C. 37/6, P. & P. 8/6. 0·5 mfd. 10,000v. wkg. at 70°C. 37/6, P. & P. 8/6. Dubilier 4 mfd. 2500v. wkg. at 70°C. 25/-, P. & P. 7/6. 2 mfd. 4000v. wkg. at 70°C. 25/-, P. & P. 7/6. 0·25 mfd. 7500v. wkg. 17/6, P. & P. 4/6. American Micamold 8 mfd. 600v. wkg. at 100°C. 10/6, P. & P. 2/-. 4 mfd. 600v. wkg. Tubular S-hole fixing. 6/6, P. & P. 2/-. T.C.C. Visconol tubular S-hole fixing. 1 mfd. 2500v. wkg. at 60°C. 12/6, P. & P. 2/6. 0·1 mfd. 8000v. wkg. at 60°C. 10/6, P. & P. 2/-. 0·1 mfd. 5000v. wkg. at 60°C. 7/6, P. & P. 2/-. 0·05 mfd. 10.000v. wkg. at 60°C. 8/6, P. & P. 2/-.

AMPEX HYSTERESIS SYN. MOTORS

A.C. 117, A.C. 48-62 CY. 2-speed, reversible. 1200-1800 r.p.m. with capacitor. New. £7.10.0, carriage 12/6.

G.P.O. 20-WAY JACK STRIPS

Type 320 BN. New and boxed. 17/6, P. & P. 2/6.

TAPE SPOOLS

Standard 10½ inch dia. N.A.B. spools for ¼ inch tape. New and boxed. 15/-, P. & P. 2/-.

RANCO REFRIGERATION THERMOSTATS

Type A.10. 100-250v. A.C. ½ h.p. 15/-, P. & P. 2/-. Teddington type QJ. 100-250v. A.C. ½ h.p. 15/-, P. & P. 2/-.

W.D. TELEPHONE CABLE

Single D.3. One-third of a mile drums. Ideal for outside telephone systems. Fraction of maker's price. 57/6, carriage 10/-.

NEWMARK SYNCHRONOUS MOTORS

220-240v. 50 cycles, 3 watts 8 r.p.m. Overall size 2 × 2 × 2 ins. 10/6. P. & P. 1/6.

SEND 6d. STAMP FOR LATEST PRICE LIST.

T.C.C. A.C. CAPACITORS

65 mfd 550v. 50 cycles. KVA 6 ± 10%. Amps 9.1. Discharge resistance fitted. Size 13½ × 6 × 4ins. £3.10.0, carriage 8/6. Philips 60 mfd 275v. wkg. A.C. 45/-. P. & P. 5/-.

MAGNETIC DEVICES LTD. RELAYS

6v. D.C. 3 heavy makes. Overall size 2 × 2 × 1 ins. 10/-. P. & P. 1/6.

A WIDE SELECTION OF SERVOMOTORS NOW AVAILABLE INCLUDES THE FOLLOWING TYPES:

Mil size 11-400 Hz versions for 26 and 115v. operation with 10/20. 13/26 and 57.5/115v. control phase windings.

Mil size 08, 10, 11, 15 and 18 motor generators for 400 Hz operation with 26 and 115v. energised tacho generators.

Mil size 08, 10, 15 and 18 two phase servomotors also available with 400 Hz windings and a limited range in 50 Hz types.

Mil Permanent Magnet Field Servomotors Size 08, 11, 15 and 18 with supply voltages from 6 to 50v. D.C.

Mil Tachogenerators Size 08 and 10 for 400 Hz supply.

Mil Size 11 Servomotor **gearheads** available in various ratios from 10:1 to 1000:1.

All items available ex stock and at extremely competitive prices.

Evershed and Vignoles' Servomotors and Servomotor-generators—we hold stocks of this well known manufacturer's items amounting to about 100 different types—an enquiry stating your broad design considerations will bring a reply by return indicating ex stock availability of the motor most nearly meeting your requirements.

Write for our Data Sheets A 131 onwards for details of available **Servomotors.**

MIL SYNCHROS available ex stock in sizes 08, 11, 15, 16, 18 and 23 for 50, 60 and 400 Hz operation.

Synchro Control Transformers
Synchro Control Transmitters
Synchro Control Differential Transmitters
Synchro Torque Transmitters and Receivers
Synchro Resolvers

Equivalent MAGSLIP ELEMENTS more suitable for educational use also in stock.

Write for our Data Sheets A 001 onwards for Synchro and Magslip information.

400 Hz. **MOTOR ALTERNATOR SETS** Input 400/440v. 50 Hz 3 ph. output 115v. 400 Hz 100VA. (coml. rating) for external excitation £15.

PRECISION POTENTIOMETERS

Numerous instrument types, continuous rotation potentiometers for control application and **HELIPOTS** in stock. List on application.

Gertsch **COMPLEX RATIO BRIDGE Model CRB2B.** Six digits in phase, four digits in quadrature. Our Price £200.

DRY REED INSERTS

Overall length 1.85" (Body length 1.1") Diameter 0.14" to switch up to 500 mA at up to 250v D.C. Gold clad contacts. 12/6d. per doz. 75/- per 100; £27.10.0 per 1,000; £250 per 10,000. All carriage paid.

BSX 76 FAST SWITCHING n.p.n. TRANSISTORS (CV8615). For quantities up to 1,000 2/- each; up to 5,000 1/9d.; over 5,000 1/7d. each. Minimum order 10 off. In makers packs.

FAST SWITCHING LOGIC DIODES BAY 38 (CV8617) £24 per 1,000 (post paid).

TANTALUM CAPACITORS We hold large stocks by S.T.C., T.C.C., Dubilier, Kemet, Plessey, G.E., etc., send for stock list with lowest prices for immediate delivery.

SEALED RELAYS by G.E.C., S.T.C., Ericsson, Plessey etc. ex stock.

PLUGS, SOCKETS & CONNECTORS. Over 150,000 items in stock including Plessey Mk 4, 6, 7, 104, U.K.A.N., Painton, Electromethods, Cannon, Belling Lee, Amphenol, Transradio, etc. Enquiries for specific items to Orpington or Lydd.

WEE MEGGERS Evershed in leather case £14.0.0 (Carr. Pd.)

RECORD MINOR INSULATION TESTER 250V 50 M £10.10 (Carr. Pd.)

UNISELECTORS G.E.C. 4 BANK 25 WAY full non-shorting wipers 65/- Carriage Paid.

ETHER-ELECTROMETHODS LOW INERTIA INTEGRATING MOTORS for 1.5, 6, 12 and 24V operation in stock.

PRESSURE TRANSDUCERS G291S up to 350 p.s.i., 100 pF sensitivity 1pF/20 p.s.i. 45/- post paid.

LINEAR ACCELERATION TRANSDUCERS I.T-1-4F± 30g 20/- post paid.

GENUINE VARIACS 0-270v 2Kva excellent condition £15 (30/- carriage).

FULL TRACK (¼" TAPE) ERASE, RECORD REPLAY HEADS set of 3 75/- (post paid).

SINE-COSINE POTENTIOMETERS Types SCP1, SCP4, SCP5. CLR96, CLR66 in stock.

BOURNE TRIMPOTS. Wide range available at attractive prices.

TRANSFORMERS 220/110v Hz 50VA Double wound Redcliffe. In steel case 55/- (post paid).

ETHER-ELECTROMETHODS TEMPERATURE PROGRAMMER AND CONTROLLER 0-1400sC or 0-1200sC (for Pt/Pt/Rh (13%) couples) £45.

CLASS D WAVEMETERS No. 2 1.2-19 Mc with charts. Brand new £15 (carriage 30/-).

BC221T WAVEMETER with charts. £25 (carriage 25/-).

2½" PANEL METERS by reputable British Manufacturers.

Flush	100mA	MC	27/6	Proj	500mA	RF	25/-
,,	500mA	MC	35/-	,,	3A	RF	25/-
Proj	5A	MC	45/-	,,	10A	RF	25/-
,,	10A	MC	37/6				

CAMBRIDGE DYNAMOMETER VOLTMETERS in as new condition. 10 ranges up to 150v. In as new condition £45 each (plus carriage).

GLOSTER DIGITAL VOLTMETERS to 999V D.C. & A.C. send for pamphlet. £92.10.0 (carriage paid).

BRISTOL QUIKSET 7 day 240v 50Hz CHART RECORDER IGS00!16 £25 (+ carriage).

MARCONI VIDEO OSCILLATORS TF885A 50Hz-50MHz sine-square wave outputs 1mV–31.6V in 11 ranges metered output £35 (carriage 30/-) fully serviced.

MARCONI SIGNAL GENERATOR TF801A 10-300 MHz in 4 bands. £45 (carriage 30/-).

MARCONI SIGNAL GENERATOR TF144G £30 (carriage 30/-).

MARCONI Q METER TF329G £60 (carriage 30/-).

MARCONI A.F. WATTMETER TF956 1μ watts to 6 watts into switched loads. £20 (carriage paid).

HIGH SPEED OSCILLOSCOPE TYPE CT90 P.O.A.

Airmec **SIGNAL GENERATOR TYPE 701.** £35 (carriage 30/-).

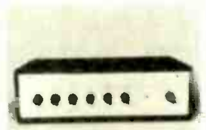
OSCILLOSCOPES SOLARTRON CD71152 D.C.-9 MHz £90 (carriage 30/-).

SOLARTRON CD568 £27.10.0 (Carr. 30/-.)

All instruments are full serviced at our Croydon workshops before sale and customers are invited to attend by appointment final test and inspection. All oscilloscopes are checked on our TEKTRONIX oscilloscope calibrator.

LOW PRICED OSCILLOSCOPES for secondary school use or for production testing.

Cossor 1035	MK I	DB	£25
1049	I	,,	£25
,,	II	,,	£27.10s.
,,	IIIA	,,	£35
339A			£15 (All carr. 30/-)



THE AUDIO EXECUTIVE SIXTY AMPLIFIER gives true 60 Watts R.M.S. output with HI-FI performance and full mixing facilities for 3 inputs. £58.15.0 guaranteed 6 months. Trade supplied.

SANGAMO-WESTON PORTABLE sub-standard **FREQUENCY METERS** S105 1200-2,000 Hz 95-135V. £12.10.0. Post 7/6.

GOODMANS MIDAX 650 mid range horn units 15 ohms special price £9.10.0. (postage 10/-).

1½ WATT NEON INDICATOR LAMPS 2 contact S.B.C. 85V D.C. 30 dozen. £4.12.6. box of 50 (carriage paid).

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T5	8	2G382T	OC82
T6	8	2G344A	OC44
T7	8	2G345A	OC45
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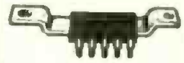

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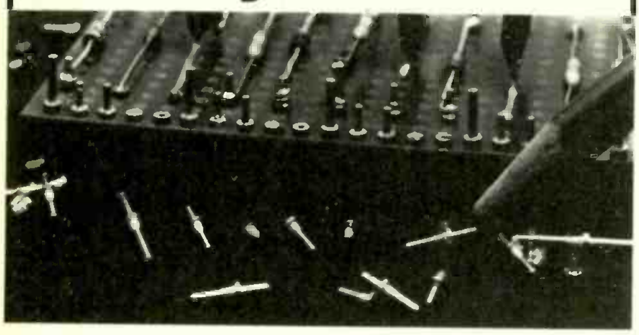

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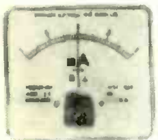

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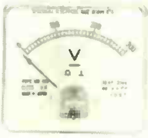

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2mA	27/6	3V. D.C.	27/6
5mA	27/6	10V. D.C.	27/6
10mA	27/6	20V. D.C.	27/6
20mA	27/6	100V. D.C.	27/6
50mA	27/6	150V. D.C.	27/6
100mA	27/6	300V. D.C.	27/6
		500V. D.C.	27/6
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100µA	52/-	50V. D.C.	40/-
100-0-100µA	47/6	300V. D.C.	40/-
500µA	45/-	15V. A.C.	40/-
1mA	40/-	300V. A.C.	40/-
5mA	40/-	8 Meter 1mA	42/-
10mA	40/-	VU Meter	62/-
50mA	40/-	1 amp. A.C.*	40/-
100mA	40/-	5 amp A.C.*	40/-
500mA	40/-	10 amp. A.C.*	40/-
1 amp.	40/-	20 amp. A.C.*	40/-
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50mA	30/-	5 amp. A.C.*	30/-
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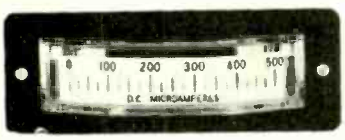

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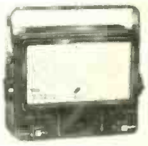

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MODEL MD-120 Features Mirror Scale, Low Loss Switch and Robust Movement. Sensitivity: 20k Ω/Volt D.C. 10k Ω/Volt A.C. D.C. Volts: 30, 60, 300, 600, 3,000V. A.C. Volts: 6, 120, 1,200V. D.C. Current: 60µA, 12, 300mA. Resistance: 60K, 6 MEG Ω. Decibels: —20 to +63db. Rugged High Impact Plastic Case, size 3½in. × 4½in. × 1in. **£4.12.6** p/p 2/6

MODEL PL 436 Features Mirror Scale and Wood Grain Finish Front Panel. Sensitivity: 20K Ω/Volt D.C. 8K Ω/Volt A.C. D.C. Volts: .6, 3, 12, 30, 120, 600V. A.C. Volts: 3, 30, 120, 600. D.C. Current: 50, 600µA, 60, 600mA. Resistance: 10K, 100K, 1MEG, 10MEG Ω. Decibels: —20 to +46db. Rugged High Impact Plastic Case with Handle, size 5⅞in. × 4⅛in. × 2⅛in. **£6.19.6** p/p 2/6

MODEL TW-50K Features 46 ranges, mirror scale. Sensitivity 50k Ω/Volt D.C. 5k Ω/Volt A.C. D.C. Volts: .125, .25, 1.25, 2.5, 5, 10, 25, 50, 125, 250, 500, 1000V. A.C. Volts: 1.5, 3, 5, 10, 25, 50, 125, 250, 500, 1000V. D.C. Current: 25, 50µA, 2.5, 5, 25, 50, 250, 500mA, 5, 10 amp. Resistance 10K, 100K, 1 MEG Ω, 10 MEG Ω. Decibels: —20 to +81.5dB. Plastic case with carrying handle. Size 4¼ in. × 2⅛ in. × 6in. **£8.10.0** p/p 3/6

MODEL 500 Features Mirror Scale and Buzzer Short Circuit Check. Sensitivity: 30k Ω/Volt D.C. 15k Ω/Volt A.C. D.C. Volts: .25, 1, 2.5, 10, 25, 100, 250, 500, 1,000V. A.C. Volts: 2.5, 10, 25, 100, 250, 500, 1,000V. D.C. Current: 50µA, 5, 50, 500mA. 12 amp. Resistance: 60K, 6MEG, 60MEG Ω. Decibels: —20 to +56db. Handsome Dustproof Black Plastic Case, size 3 5/16in. × 6 1/16in. × 2⅜in. **£8.17.6** p/p 2/6

MODEL 5025 Features 57 Ranges, Giant 5¼in. Meter, Polarity Reverse Switch. Sensitivity: 50k Ω/Volt D.C. 5k Ω/Volt A.C. D.C. Volts: .125, .25, 1.25, 5, 10, 25, 50, 125, 250, 500, 1,000V. A.C. Volts: 1.5, 3, 5, 10, 25, 50, 125, 250, 500, 1,000V. D.C. Current: 25, 50µA, 2.5, 5, 25, 50, 250, 500mA. 5, 10amp. Resistance: 2K, 10K, 100K, 1MEG, 10MEG Ω. Decibels: —20 to +85db. Plastic Case with Carrying Handle, size 6¼in. × 2⅞in. × 5¼in. **£12.10.0** p/p 3/6

MODEL 100,000 O.P.V. LAB TESTER Features Unique Range Selector, 6¼in. Scale Buzzer Short Circuit Check. Sensitivity: 100,000 OPV D.C. 5 Ω/Volt A.C. D.C. Volts: .5, 2.5, 10, 50, 250, 1,000V. A.C. Volts: 3, 10, 50, 250, 500, 1,000V. D.C. Current: 10, 100µA. 10, 100, 500mA, 2.5, 10 amp. Resistance: 1K, 10K, 100K, 10MEG, 100MEG Ω. Decibels: —10 to +49db. Plastic Case with Carrying Handle, size 7¼in. × 6⅞in. × 3¼in. **£18.18.0** p/p 5/-

SOLE U.K. AGENTS FOR JAPAN'S PREMIER MANUFACTURER "YAMABISHI" VARIABLE VOLTAGE TRANSFORMERS

● Excellent quality ● Low price
● Immediate delivery

ALL MODELS INPUT 230 VOLTS, 50/60 CYCLES. OUTPUT VARIABLE 0-260 VOLTS

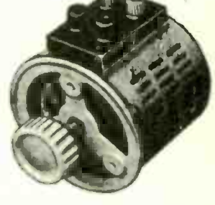
MODEL S-260
General Purpose
Bench Mounting

1 Amp	£5.10.0
2.5 Amp	£6.15.0
5 Amp	£9.15.0
8 Amp	£14.10.0
10 Amp	£18.10.0
12 Amp	£21.0.0
20 Amp	£37.0.0

MODEL S-260 B
Panel Mounting

1 Amp	£5.10.0
2.5 Amp	£6.12.6

Please add postage.
Special discounts for quality

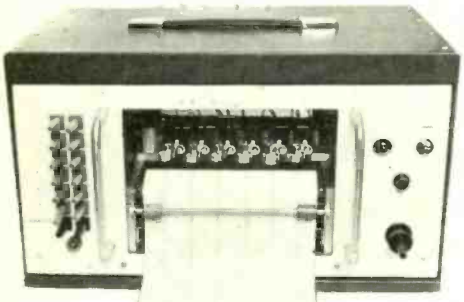


BARNET FACTORS LTD

147 CHURCH STREET, LONDON, W.2
Telephone: 01-723 5328

ELECTRONIC

NEW 6-CHANNEL TIME AND EVENT RECORDER



A self-contained instrument, specifically for recording events without the need for a combined recorder.

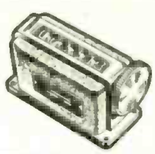
There is a separate and independent paper drive, with a monitor lamp indicating when it is in operation. The pens are displaced 1/16″, activated by a close contact system. Each of the 6 channels works independently of each other, with the pens writing at 72 hours per filling at a maximum speed of 10 pulses per second.

The recorder is supplied either in a portable cabinet or with rack mounting adaptions and the size is 15″ × 9″ × 9½″ deep. It weighs 10 lb. and is available in 220-240 volt A.C. (50 cycles) or 110-115 volt A.C. (60 cycles). The 6-channel time and event recorder is available at the following speeds: 30, 20, 10, 5, 1 per minute. 18, 12, 9, 6 per hour. Width of paper roll is 6″, maximum diameter of roll is 3″, length on standard 3″ diameter paper roll is 200′. Price of the event marker is £79-10-0, plus £5-0-0 for the special vinyl-treated portable case.

The instrument is guaranteed for one year, and is available with a complete range of accessories, including teledotos paper, graphic paper, plain paper, pens, pen containers and time bases. Prices of these items are available on application.

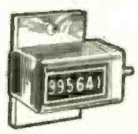
COUNTERS

VEEDER ROOT 6 DIGIT COUNTER



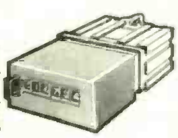
Suitable for counting all kinds of production runs, business machine operation. Mechanically driven Type KA1337. Reset manual knob. Ex-equipment but new condition. Special price 25/- plus 5/- P. & P.

MINIATURE SQUARE COUNTER 6 DIGIT



By Veeder Root. Rotary ratchet type, adds 1 count for each 36° movement of shaft. 9/6 plus 2/6 P. & P.

6 DIGIT ELECTRICAL IMPULSE COUNTER



With electrical and mechanical reset. Counter driven by a 110 v. D.C. 4,400 ohms coil. Reset 110 v. D.C. 800 ohm coil. Housed in plastic-alloy case. The units can be interlocked with each other to give vertical or horizontal displays. Ex. equipment. Price 59/6 plus 5/- P. & P.

EAC DIGIVISOR Mk. II DIGITAL READ-OUT DISPLAY

Ideally suitable for use in conjunction with transistorised decade counting devices. No need for amplifiers or relays as only a few milliwatts of power are required to charge the digits. The DIGIVISOR incorporates a moving coil movement which moves a translucent scale through an optical system and the resultant single plane image is projected on a screen. The translucent scale is made to represent digits 0-9 Specification: 6.3 volt, 250 microamp. Image. height ½ in. Size 4 9/16 × 2 39/64 × 1½ in. Our price £3/13/6. List price 8½ gns.

BERKELEY DECIMAL COUNTING UNIT 0-9

4 valves double triode type 5965 special quality Unit plugs into standard octal base, Modular construction with 10 miniature neon lamps on display panel. Power supplies 6.3v. A.C. 150v D.C. Cut-on or Cut-off—15v. Size 5½ × 5½ in. × ½ in. Price 65/- p. & p. 5/-.

MINIATURE DIGITAL DISPLAY

Operates on a rear projection 6.3 pilot lamp. The lamp projects the corresponding digit on the condensing lens through a projector lens, on to the viewing screen at the front of the unit. 1 in. width, 3 1/16 in. deep, 1 1/16 in. high. Weight 3½ oz. Character size ½ in. high, 0.9 with 8 right hand decimal point and degree. Available to special order, words and other characters or colour, at cost of artwork or plates. List price 6 gns. Our price 49/6. 1 in. display 55/-. P. & P. 5/-.

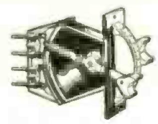
5 DIGIT COUNTER

A very sturdy counter. Coil resistance 100 ohms. Minimum operational voltage 5v. Counting speed 13 counts per sec. Suitable for continuous counting with sine wave drive. Coincidence, recording and frequency meter 35/- p. & p. 5/-.

ALL ORDERS ACCEPTED SUBJECT TO OUR TRADING CONDITIONS A COPY OF WHICH MAY BE INSPECTED AT OUR PREMISES DURING TRADING HOURS OR WILL BE SENT ON APPLICATION THROUGH THE POST.

HIGH GRADE COMPONENTS

DOUBLE AUDIO FADERS 1W



1000 plus 1000 ohms. Each resistive dimmer is adjustable and independent of each other. Ex-equipment but in an almost new condition. Price £3/19/6. P. & P. 7/6.

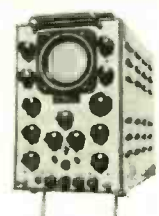
DIMMERS

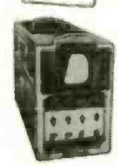
SCR Type. 600W. F.W. Bridge circuit suitable speed control A.C./D.C. commutator motors, lights, etc. Fits standard 2 inch conduit box. 59/6. P. & P. 5/-.

VOLSTATS

VOLSTATS and constant voltage transformers. Large range in stock Prices from £8/10/0.

OSCILLOSCOPES





Solartron CD513	£49.10
Solartron CD 513/2	£49.10
Solartron AD 557	£55. 0
Solartron CD 711	£65. 0
Solartron CD 7118-2	£80. 0
Solartron QD 910	£275. 0
Solartron 5238-2	£52.10
Furzehill 0.100	£25. 0
Airmec 249	£25. 0
Airmec 723	£19.10
Philips PM 3230	£85. 0
Mullard L101 Double Beam	£96.10
Cossor 1035	£25. 0
Cossor 1049 MkIII	£40. 0
Cossor 1049	£35. 0

MOTORS

HYSTERESIS REVERSIBLE MOTOR

Incorporating two coils. Each coil when energised will produce opposite rotation of output shaft. 240V 50 Hz. ½ r.p.m., ¼ r.p.m., 1/6 r.p.m., 120V 60 Hz, 1/10 r.p.m., 30/- each. P. & P. 3/-.

HIGH TORQUE INDUCTION MOTOR

3-30 oz/inch. Available in the following speeds only 240V 50 Hz ½ r.p.m., 1 r.p.m., 2 r.p.m. 120 V 50 Hz. 20 r.p.m 30/- each. P. & P. 3/-.

LOW TORQUE HYSTERESIS MOTOR MA23

Ideal for instrument chart drives. Extremely quiet, useful in areas where ambient noise levels are low. High starting torque enable relative high inertia loads to be driven up to 6-oz/in. Available in the following speeds and ranges: 240V 50 Hz 4 r.p.m., 2 r.p.m., 1½ r.p.m., 1 r.p.m., ½ r.p.m., 1/3 r.p.m., 1/5 r.p.m., 1/10 r.p.m., 1/12 r.p.m., 1/20 r.p.m., 1/40 r.p.m., 1/60 r.p.m., 1/75 r.p.m., 1/120 r.p.m., 1/360 r.p.m., 1/720 r.p.m., ½, 1/20, 1/45 r.p.m.; 120V 50 Hz 1/6 r.p.m., 1/15 r.p.m., 1/16 r.p.m., 1/20 r.p.m., 1/24 r.p.m., 1/30 r.p.m., 1/60 r.p.m., 1/120 r.p.m., 1/240 r.p.m., 1/300 r.p.m., 1/720 r.p.m., 1/440 r.p.m. 25/- each. P. & P. 3/-.

HYSTERESIS CLUTCH MOTOR

With integral clutch allowing the motor to drop out of engagement with the gear train, thereby facilitating easy resetting when used in timers or in conjunction with a light spring. 6 oz. torque at 1 r.p.m. 240 v., 50 c/s. L=left, R=right. 15 r.p.m. L. 4 r.p.m., ½, ¼ r.p.m. L, 1/5 r.p.m., 1/6 r.p.m., R & L, 1/10 r.p.m., 1/12, 1/15 r.p.m. L. Also 120 v. 50 c/s 2, 1/6, 1/12, 5/12, 4/11, 1/10 r.p.m. 25/-. P. & P. 3/-.

HIGH PRECISION MAINS MOTOR

230V 50 Hz 1/8 h.p. continuously rated. 3000 r.p.m. Made by Croydon Engineering. Model KA 60 JFB. Suitable for capstan motor. Size 8 in. long, 4½ in. diameter with 6 in. diameter flange and 4 fixing holes. £4/10/0 each. P. & P. 25/-.

SYNCHRONOUS MOTORS

Model S 71 r.p.h. and 1/60 r.p.h. Self starting complete with gearing shaft ¼ in. dia. ½ in. long, 200/250V 50 Hz. New condition Ex. Equipment. 40/-. P. & P. 3/-.

DATA TRANSMISSION—SYNCHROS

	Type	Maker	Voltage	Hz	Price £	s.	d.
Torque Receiver	11TR4a	Sperry	90/115v	400	7	10	0
Torque Receiver	ACN 1550C	Smith	26/12.3	400	7	10	0
Torque Receiver	11TR4a	Pullin	90/115v	400	7	10	0
Control Transformer	11CT4RT	Muirhead	26v	400	6	10	0
Control Transformer	26v08CT4c	Muirhead	11/8v	400	10	10	0
Control Transformer	11CT4b	Sperry	1/90/deg	400	6	10	0
Control Transformer	11CX4a	Pullin	11.8/26v	400	6	10	0
Control Transformer	11CX4b	Ketay	90/115v	400	6	10	0
Torque Transmitter	ACS/AE	Smith	90/115v	400	6	10	0
Torque Transmitter	11CX4a	Elliott	90/115v	400	6	10	0
Torque Transmitter	15M1B1	Muirhead	90/115v	400	10	10	0

CARRIAGE EXTRA

A.C. MOTOR GENERATOR

Type G1005 Motor Spec. 6000 r.p.m. Torque 25gm/cm. Control winding 20v., 400Hz. Ref. Winding 26v., 400Hz. Generator Spec. Ref. Winding 26v., 400Hz. O/PO 1v/1000 r.p.m. Length 2 in., dia. 1 in. Price £7/10/0 p. & p. 5/-.

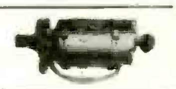
D.C. TACHOGENERATOR

Type 9c/106 16v. at 1000 r.p.m. Drive shaft dia. 3/16 in., 3/8 in. long. Price £16/10/0.

SYNCHRONOUS MOTOR WITH GEARBOX

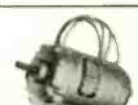
Motor 11M83 gearbox type 11H21. This unit is an 8000 r.p.m., 115v., 400Hz motor fitted with concentric epicycle reduction gearbox of 9.92/1. Motor torque 6 oz./in. length c/w gearbox 2 5/8 in. × 1 in. diameter.

RAGONOT MOTOR



220v., 50Hz single phase. 1/20 h.p., 1500 r.p.m. Price 45/-.

FRACMO



240/250v., 50Hz single phase. 1/20 h.p., 2800 r.p.m., shaft dia. 3/16 in. Price 45/-.

EVERSHED & VIGNOLES SPLIT FIELD SERVO MOTOR

Type FB6A—A1/B ¼ in. keyed shaft. Price £12/10/0 each.

GENERATORS

SIGNAL GENERATOR

T.F. 801A Sine Wave, Square Wave Generator. Frequency Range: 10-310 Mc/s. Output Voltage (maximum) 200 milli-volts ± 2db. Output impedance 75 ohms.

Mark/Space Ratio 50/50 on square wave. Price £79/10/0. Packing and carriage £2.

T.F. 517F/1 Sine Wave, Square Wave Generator. Frequency Range: 120-300 M. C/s Auxiliary 18-58 Meg. c/s. Output Voltage 0.2 Volts. Output impedance 75 ohms. £85.

MARCONI T.F.144G

Frequency Range 85kc/s 25Mc/s. Output voltage 1 micro-volt to 1 volt. Output impedance 1 micro-volt, 100 milli-volt, 10 ohms. 100 milli-volts to 1 volt, 52.5 ohms. £59/10/0 + £2 carriage.

PULSE GENERATORS

Model 101 Repetition rate 10 Hz-10MHz. Delay 30 n-10 m. secs. Output 10V into 50 ohms. £95.

SQUARE WAVE GENERATOR

Frequencies: 1M 100kc/s 10kc/s 50c/s. Load impedance 75 ohms. Output Voltage 10V 75 ohms. 0-18 volts into 2000 ohms. Rise time from 30-50 Milli micro seconds at 1 meg. Cycle. £59/10/0.

BROKERS

MEASURING INSTRUMENTS AND RECORDERS

PORTABLE AC/DC PEN RECORDER

A most versatile pen recorder. Produces a trace on a curvi-linear 3½ in. strip chart. Two speeds 1 in. and 6 in./hr. Limiting contacts to give alarm, and limits the current when it exceeds the high and/or low preset values. Range: 0 - 1MA D.C. Meter Resistance 400 ohms; 0 - 1MA A.C. Meter Resistance 1800 at 50 Hz; —10 to +5 dB into 600 ohm Impedance Source. Chart speed: 1 in. and 6 in./hr. Chart width: 3½ in. curvi-linear. Power supply: 230V 50 Hz driving Synchronous Motor.
Price: **£52.10.0.** P. & P. £1.5.0.

STRIP-CHART INDICATING RECORDER

Chart width 9¾ in. 10 mV. Sensitivity ±0.17 of full scale. Source impedance 100 ohms. Speed of operation 33 sec. for full-scale travel. Chart speed ½ in., 3 in., 6 in. per hour. Single point. **£49.10.0.** P. & P. 30/-. 12 Multi-point recorder available.

NEW PORTABLE RECORDING AMMETER

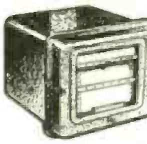
Specification. Type: Moving Coil, D.C. Range: 0-5 amp. D.C. Chart Width: 100 mm. Scale Length: 127 mm. Chart Speeds: 20, 60, 180, 600, 1800 and 5400 mm/hr. Dimensions: 180h × 163w × 245 mm. Weight: 5.5kg. List price £65. Our price **£35.** P. & P. 30/-.

PEN RECORDER

Portable 1, 2 and 4 channel pen recorders by Kelvin Hughes. General purpose recorders providing clear instantaneous and permanent records of phenomena with comparatively high rates of change. The torsion-strip suspension of the moving-coil renders the instrument immune to the effects of vibration and acceleration.

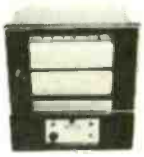
Six possible chart speeds, chart width 55 mm., length 150 ft., linearity 8 v. at 3 m.A. response D.C. to 100 c/s. Single pen with amplifier **£99**; 2 pen recorder **£85**, 4 pen with amplifier **£149**. Also 5 pen recorder complete with amplifiers, specification as above but housed in cabinet **£225**. P. & P. extra.

POTENTIOMETRIC 6 POINT STRIP CHART RECORDER BRAND NEW



For use with thermocouplers, pyrometers and other e.m.f. sources. 6 point. Range (−100)—0—(+100) mV; 0—1,600 deg. C. 6¼ in. chart width; pen speed 8 secs. Accuracy ±0.5%; 10 chart speeds 20-720 mm/hr. Tropicalised. Including tools and spares. Listed at over £200. Our price **£79.10.0.** Also available 0-100 mW F.S.D. **£89.10.0.**

SERVORITER Model FWS



By well-known American manufacturer. Power supply 120 v 50 Hz. Response time 24 secs. Resistance source 10 K ohms max. Chart width 11 in. This is a slow-speed recorder that can be used for measuring any quantity with a comparatively slow rate of change such as temperature, humidity etc. Supplied with electrovolt controller that enables the sensitivity, reset, proportional band and rate to be adjusted. This unit enables the demanded temperature to be controlled and the actual temperature recorded. Size: 16½in. wide, 17½ in. high, 13½ in. deep. Price **£175**. Carriage extra.

METERS

DIGITAL VOLTMETERS

DM2022 digital voltmeter and ratiometer, accurate to 0.0025% offering exceptional linearity.
Reading rate of 50 per second. Outputs: Parallel B.C.D. Scale 39999. Inputs: 25000MΩ CMR 160dB on d.c. Range 10μV to 1KV. This is a rare opportunity to obtain such an instrument at such a low price of **£350**. Carriage free.
DM2006. An all solid state D.V.M. having a wide application. Scale 9999. D.C. accuracy 0.017f.s.d. with a D.C. range of 10μV to 1KV. Input impedance 10000MΩ. C.M.R. 154dB. Outputs parallel B.C.D. **£245**. Carriage free.
DM2023. This D.V.M. is suitable for data-logging due to the high C.M.R. 175dB. It has six operating modes. Accurate to 0.001% and complete with plug in units to give either manual or automatic ranging from 10μV to 1KV with a 10MΩ input impedance. **£460.** Carriage free.
Type **LM902-2.** 4 digit **£75**. **LM902-2R.** 4 digit **£75**. **LM1010.** 4 digit **£75**. All the above units have been calibrated.
Digital Voltmeters 2003 A.C./D.C. D.C. range 1mV.-1KV. 4 digits. **£135.**
2 in. dia. mounting A.C. voltmeter 0-300 V. A.C. **£1/15/0.** Carriage 6/-.

A.C. CALIBRATION UNIT TYPE 2126

L.F. amplifier module A3 and mean detector module B3. Both units housed in one cabinet. Price **£110/0/0.**
Precision A.C. & D.C. Wattmeter. Model 8.67 certificated. Accuracy to ½% up to 133 c/s. Range 250/450 V. and 0.5 to 1 A. **£29/10/0.** Carriage 30/-.

MULTI-RANGE TRANSISTORISED VOLTMETER 1063

Employing silicon planar F.E.T., this instrument gives long-term stability and negligible drift over a wide temperature range. Wide frequency band 0-300 MHz. using HPV 1063. Voltage range 0-30KV. Centre zero on DC ranges for differential circuit application. Input resistance 1 M.ohm/Volt on all DC ranges. Accuracy ± 3% F.S.D. Meter scale 5in. with IM different colour for different scales. Special price **£42/10/0** each. Carriage £1/10/0.

PRECISION POTENTIOMETERS

TEN TURN 3600° ROTATION BRAND NEW

Res. Ohms	Linearity Per cent	Manufacturer	Model	Price
100/100/100		Beckman	A	160/-
100	0.5	Beckman	A.S.	60/-
200	0.5	Beckman	A	60/-
500	0.1	Beckman	S	70/
500		Colvern	2501	45/-
500		Foxes	PX4	40/-
500		Colvern	2610	50/-
500		Colvern	26/1000/11	60/-
500	1.0	Relcon	HEL107-10	45/-
1K		Relcon	HEL0710	45/-
2K	0.5	Beckman	SA1101	60/-
2K	0.25	Beckman	7216	60/-
2K		Reliance	GPM15	40/-
2K		General Controls	GPA15/4	40/-
5K		Relcon	07-10	50/-
5K		Colvern	CLR2503	60/-
10K	0.5	Beckman	A	60/-
10K	0.1	Beckman X	A	70/-
10K	0.1	Colvern	CLR26/1001	70/-
15K		Colvern	CLR2402	60/-
18K		Beckman	A	60/-
25K	0.5	Helipot	SAJ337	60/-
29K	0.05	Beckman	SA1244	90/-
30K		Colvern	2402	30/-
30K		Beckman	SA95C	60/-
30K	0.1	Beckman	A.SS	70/-
30K	0.5	Beckman	SA1692	60/-
30K	0.25	Beckman	SA1679	65/-
30K	1.0	Colvern	2402/1	30/-
50K		Reliance	07.10	45/-
50K			07.5	45/-
50K		Colvern	2503	45/-
50K	X	Foxes	PX4	45/-
50K	0.5	Beckman	A	60/-
50K	0.1	Beckman	A	70/-
100K/100K		Ford	A	100/-
100K	0.1	Beckman	A	70/-
100K	0.5	Beckman	A	60/-
100K		Colvern	2501	45/-
100K		Colvern	2610	50/-
298K	0.1	Beckman	SA3902	70/-
300K	0.1	Beckman	A	70/-

THREE TURN 780° ROTATION

Res. Ohms	Linearity Per cent	Manufacturer	Model	Price
100/100	0.5	Beckman	C	60/-
100/100		Beckman	Type C	60/-
300		Beckman	9303	45/-
1K		Fox	PX2/H3	45/-
10K	0.5	Beckman	C.ss	45/-
20K/20K	0.1	Beckman	C.S	60/-
10K/10K	0.1	Beckman	C	60/-
50K	0.5	Beckman	C.S	35/-

FIFTEEN TURN 5400° ROTATION

Res. Ohms	Manufacturer	Model	Price
25K/25K	Beckman B	10 watts	£6.10/-
46/K/46K	Beckman B	10 watts	£6/10/-

TWENTY TURN 7200° ROTATION

Res. Ohms	Manufacturer	Model	Price
1 Meg	General Controls	PXM130	80/-
50K	Reliance		40/-

156 TURN 56 160° ROTATION

Res. Ohms	Manufacturer	Model	Price
460	Kelvin Hughes	KTP0701	£9/10/-

FIVE TURN 1800° ROTATION

Res. Ohms	Manufacturer	Model	Price
200	Relcon	HEL07.05-F/11	45/-
500	Colvern	CLR2505	40/-
U1.5K	Colvern	CLR2605	40/-

FIVE-&-A-HALF TURN

Res. Ohms	Manufacturer	Model	Price
500	Colvern	2405	40/-

SINE COSINE

Values	Type	Maker	Price
5 Kohms	CLR 8601	Colvern	£17/10/0
14 Kohms	SCP 5	Smith	£22/10/0
15 Kohms	CLR 8601	Colvern	£17/10/0
20 5 Kohms	CLR 8602	Colvern	£22/10/0
25 Kohms	CLR 9602	Colvern	£17/10/0
30 Kohms	CLR 8601	Colvern	£17/10/0
32 Kohms	SCP 4	Kelvin-Hughes	£17/10/0
35 Kohms	SCP 1	Smiths	£17/10/0

P. & P. EXTRA

INDUCTION POTENTIOMETER No. 1 Mk. 1

Can be used for multiplication, division, and reciprocal calculations. 60 ohms, 15Hz, 2kHz. Supply voltage 50v. 2-3 MA at 50Hz. Accuracy 0.1%. Octagonal in shape 6½ in. across the flats. Price **£15/10/0.** P. & P. 15/-.

COLVERN 10-TURN INSTRUMENT DIALS

19/6 p. & p. 3/6.

BOURNS KNOB POT

New 10-turn precision potentiometers consisting of potentiometer, knob and readout dial in one extremely compact assembly. A very attractive unit finished in black plastic with white dial. Available in 100K, 20K and 1K. 1½W. Resistance tolerance 5%. Accuracy correlation of dial reading to O/P 0.5%. Weight 0.6 oz., overall length 1 11/16 in., diameter ⅞ in. New price £7.15.0 each. Our price **£4/10/0.** P. & P. 2/6.

NUMICATORS

Cold cathode gas-filled, in-line 0-9 digital display tubes. Long life expectancy. Minimum striking voltage 180v. Side reading type XN 13. Price **18/6** each. P. & P. 2/6.
Type NI 1. End reading. Price **£1** each. P. & P. 2/6.

MERCURY WETTED RELAYS

Type (new) HG4B1007 relay is capable of an operating time as short as 5 milliseconds. A BILLION OPERATIONS! Small chassis space required. Convenient mounting. Environment-free. Tamper-proof. High sensitivity. Maintenance-free. No contact wear. Performance is made possible by the presence of a film of mercury which at one and the same time cushions the contacts and provides an unbroken metallic path for the electrical circuit. This mercury film, constantly renewed by capillary action, prevents wear, dissipates heat and thus avoids contact erosion and eliminates bounce or chatter in the electrical circuit. Hermetic sealing of the switch and mercury pool in a glass capsule eliminates dirt and assures constant adjustment.

Type	Coil Resistance	Voltage	Contacts
HG2B 1004	5000 ohm	24	2SPST
HG2b 1006	1300 ohm	24	2SPST
HG2b 1010	1300 ohm	24	2SPST
HG4B 1005	1300 ohm	24	4SPST
HG4B 1007	1300 ohm	24	4SPST

BOTH NEW AND EX-EQUIPMENT AVAILABLE
New Relays **£2/10/0.** Ex-equip. **£1/10/0.** P. & P. 5/-.

PHOTOMULTIPLIER VMP11/44 (CV 2317) by 20th Century Electronics

Cathode sensitivity 40μA/L. Operating volts for 10 A/L 1100 volts. DARK current 0.004μA. **£9/10/0.**
E.M.I. 6097 and 20th Century CV 2317 **£9/10/0.** P. & P. 5/-.

ANIMAL SONARY Type 1803B by Dawes Brand New

An instrument for measuring the thickness of fat on an animal by the use of ultrasonics using the pulse echo principal. The animal sonary was specifically designed for the measure of back fat thickness for use under field conditions. Fully portable weighing only 26 lb. Complete with handbook. price: **£149/10/0.**

CRYSTAL OVENS

Redifon 6v./12v. A.C. Fitted bi-metal strip. 0.78A-0.39A. Marconi Type F. 3006-01. Price on application.

VARIABLE VOLTAGE TRANSFORMERS

Various types available, including single- and three-phase manual or motor drive. Contact us by phone or letter for stock appraisal and delivery.

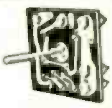
SYNCHRONOUS CHOPPERS

Base B-9. Coil 6.3 v., 50-60 Hz. Proportion of time contacts are closed 45%. Price **£6/10/0.** P. & P. 5/-.

NEW COMPLETE TELEPHONE DIAL ASSEMBLIES

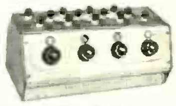
Clear Perspex dials—no markings. **20/-** each. P. & P. 5/-.

LINEAR THYRISTER CONTROLLED LIGHT DIMMER



600w. module. Ideally suitable for photoflood or speed controller, etc. Will mount into standard socket boxes. Our price **49/6.** P. & P. 3/-.

HIGH VALUE RESISTANCE BOX TYPE R.7003



Specification. Range: 0.01-111 Meg. in 0.01 Megohm divisions. Accuracy: 0.05%. Maximum power rating: 0.1w. per step. Case: Hammer finish stove enamel. List price £60. Our price **£22/10/0.**

PORTABLE WHEATSTONE BRIDGE

Specification. Type: Moving coil galvanometer. Ranges: 1. 0.05 to 5 ohms. 2. 0.5 to 50 ohms. 3. 5 to 500 ohms. 4. 50 to 5,000 ohms. 5. 500 to 50,000 ohms. Scales: Switched. Slidewire: 0.5 to 50. Galvanometer scale: 10-0-10. Case: Moulded plastic. Internal Source: V. Dry battery. Dimensions: 200 × 110 × 65mm. Weight: 0.9 kg. List price £25. Our price **£9/19/6.**

MUTUAL INDUCTANCE COIL TYPE R.7006

Specification. Value: 0.001H. Accuracy: ±0.3%. Operating Frequency: 5 Kc/s. 10 Kc/s. Maximum current: 1A, 3A. Resistance of coils: 4 ohm, 1 ohm. Case: Moulded plastic. List price 8 gns. Our price **50/-.**

MUTUAL INDUCTANCE BOX TYPE R.7005

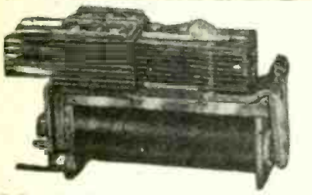
Specification Range: 0-11.100 mH in 0.002 mH divisions. Accuracy: $\pm(0.3 \times \frac{0.012}{M})\%$ where M = value of mutual inductance in mH set on the box. Frequency range: 0-2.5 Kc/s for all decades except X1 = 0-15 Kc/s. Maximum current: 0.5A for decades 1A for variometer (both primary and secondary wingings). Case: Polished teak. List price £65. Our price **£26/10/0.**

ELECTRONIC BROKERS LTD., 49-53 PANCRAS ROAD, LONDON, N.W.1. Tel: 01-837 7781/2. Cables: SELELECTRO

Wilkinsons FOR RELAYS

P.O. TYPE 3000 AND 600

BUILT TO YOUR REQUIREMENTS—QUICK DELIVERY



COMPETITIVE PRICES—VARIOUS CONTACTS
DUST COVERS—QUOTATIONS BY RETURN
LARGE STOCKS HELD OF G.E.C. MINIATURE SEALED RELAYS

P.O. STANDARD EQUIPMENT RACKS 6ft. U channel sides drilled for 19in. panels heavy angle base, 150/-, cge 20/-.

MINIATURE BUZZERS. 12 volts with tone adjuster, 7/6 each as illustrated. Quantity Rates.

EQUIPMENT WIRE P.V.C. covered 80/- per 1000 yds. 7/.0076, 1/.024, 14/.0048 type 1 and 2, all colours. 14/.0076 type 11 Red and Natural £14 per 1,000 yds.

HEADPHONES. 1600 Ohms type DHR 17/6 ea.

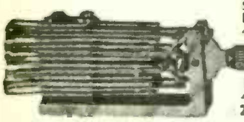
LEDEX ROTARY SOLENOIDS AND CIRCUIT SELECTORS. SIZE 5s. 4 pole, 11 way and off 110/-, 4 pole, 12 way 110/-, 24 pole, 11 way and off 210/-, 54 pole On/Off 150/-. **SOLENOIDS** type 3E in stock at 17/6 each.

CERAMIC AND PAXOLIN WAFER SWITCHES available from stock at keen prices, send for list. 24 way Double Pole Pax Wafer Switches 12/6 each, post 2/6.

Single Pole Change Over Roller Type **MICRO SWITCHES** 15 amp 125/460 volts A.C. Honeywell 10/6 ea.

ONE HOLE FIXING SWITCHES. Single Pole On/Off 3 amp. 250 volt Ball Dolly, Bulgin 2/- ea. Pear Dolly, NSF 3/6 ea. Ball Dolly Biased Off, Bulgin 3/6 ea. Pear Dolly Biased Off, NSF 3/6 ea. Ball Dolly Biased On, Bulgin 3/6 ea. Single Pole Change Over 1 amp. 250 volt, Arrow 2/- ea. Single Pole Double Throw 1 amp. 250 volt Ball Dolly, Arrow 2/6 ea. Pear Dolly, Arrow 2/6 ea. Double Pole On/Off 1 amp. 250 volt Ball Dolly, Arrow 2/6 ea. 3 amp. 250 volt Ball Dolly, Bulgin 3/- ea. Double Pole Change Over 1 amp. 250 volt, Arrow 3/- ea. Pear Dolly, Arrow 3/- ea. 3 amp. 250 volt Pear Dolly, NSF 3/6 ea. **BANK OF FIVE SWITCHES ON/OFF** 6 hole fixing flush bakelite case 14/- ea.

TEMPERATURE CONTROL SWITCHES. Casing 1" × 1" square Gravinette 3 types 17 degrees C. or 18 degrees C. or 21 degrees C. 5/- ea.



STANDARD LEVER KEYS, 3 POSITION 4C lock/4C lock 17/6 each. Stop/6C 15/6 each. 2C 2M non-lock/2C 2M non-lock 14/6 each. 4C non-lock/6C lock 20/- each.

ONE HOLE FIXING. Stop/4 C.O. non-locking 2 position 10/6. 6 C.O. lock/2 lock 2 position 17/6.

VACUUM GAUGES. 2in. scaled. 0/30 inches of mercury, 20/- each, post 2/6.

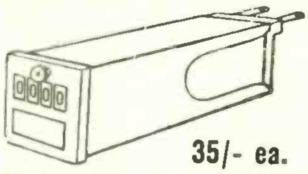
DIRECT ON LINE STARTERS. Crabtree B15 Coil 240/265 v. 50 cycles max. motor load 15 A. 440 v., overload adjustable between 5-10 amps. 70/- ea.

AMAZING VALUE. 1/6th hp G.E.C. Fractional hp **MOTOR** 230/250v A.C., fitted with thermal protector with push button reset. ensures complete protection against overheating or burn-out, 1440 r.p.m. ½in. shaft 1⅞ins. long. Fully guaranteed 97/6, carriage 15/-.

GEARED MOTORS. 1 r.p.m. or 3 r.p.m. 4 watts very powerful, reversible 24v. A.C. 35/-, post 2/6, can be operated from 230v. with our 20/- Transformer. Post 5/-.

AIR BLOWERS. 200/250v. A.C. cylindrical 7in.—7in. suitable for intake or extraction. 1/50th h.p. £10. 1/15th h.p. £11. 1/10th h.p. £14. Stockists of Stuart Turner Centrifugal Pumps. Nos. 9, 10 and 12, Details available.

HIGH SPEED COUNTERS
3½ × 1in., 10 counts per second with 4 figures. The following D.C. voltages are available, 6v., 12v., 24v., 50v. or 100v.



35/- ea.

SUB-MINIATURE Microswitch Honeywell S.P.D.T. type 11 SM1 TN 13 size ¾in. × ⅜in. × ¼in. 6/6 each, or mounted in fives for 22/6 post free.

JACK PLUGS. 2 Point with screw-on cover, 2/6, post 9d. PO 201 on headphone cord 3/-, post 1/6.

PLUG-IN RELAYS. Londex 4 change-over HD contacts 28v. D.C. with base and cover, 35/- each.

UNISELECTORS. 8 bank, 25 way, full wipers, £7.10 each.

VARLEY Miniature Relays. 700 ohms 4 CO, 15/6 ea.

BELL SETS. No. 25 Twin Gong Bell Induction coil and condenser with cover 17/6 ea. post 6/-.

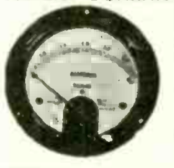
SINGLE FUSE HOLDERS. Belling & Lee L356. 1 hole fixing. 3/6 each.

TERMINAL BLOCKS. 2 way 5C/430 or 3 way 5C/432 50/- per 100 or £20 per 1,000. (As illustrated.)

MAGNETIC COUNTERS. Veeder Root with zero reset. 800 counts per minute, counting to 999,999. 110 volts A.C. or 110 volts D.C. 65/- each, post 3/-.

PRECISION GERMAN MADE **MAGNETIC COUNTERS.** 2¼in. × 1¼in. × 1in. with push button zero reset. 3 digits, 12 volts D.C., 25 imp/sec., 50/- ea.

METERS GUARANTEED. Complete list available.



Microamps 0/500 2in. MC	25/-
Microamps 0/500 2½in. MC	37/6
Milliamps 0/50 2½in. MC	35/-
Milliamps 0/500 3½in. MC	54/-
Amps 50-0-50 2in. MC	17/6
Amps 0/5 2in. MC	42/6
Volts 5/0/5 2½in. MC	25/-
Volts 0/20 2in. MC	42/6
Volts 0-40 2in. MC	42/6
Volts 0/10 A.C. 3½in. MCR	70/-

"VISCONOL-CATHODRAY" CONDENSERS. .002 mfd. 15 kV, 9/-; .02 mfd. 10 kV, 10/-; .025 mfd. 2.5 kV, 5/-; .05 mfd. 5 kV, 9/-; 0.1 mfd 4 kV, 9/-; 6 kV, 17/6; 0.5 mfd. 2.5 kV. 17/6; 1 mfd. 2kV. 17/6.

PORTABLE VOLTMETERS 30v moving coil DC precision sub standard grade 5in. mirror scale, in polished wood case £8.17.6, post 8/6.; 160v moving iron AC/DC 8in. mirror scale in p. wood case £4.19.6, post 7/6; 250v moving iron AC/DC 6in. scale in p. wood case £8.10.0, post 7/6.

CELL TESTING VOLTMETERS 3-0-3 v moving coil DC with leads and prods. in leather case 3in. scale 35/- ea., post 4/6

CAMBRIDGE PORTABLE MILLIAMMETER precision grade AC moving iron 7in. scale ranges—50, 100, 200, 500 and 1,000 mA. enclosed case £25, post 10/6.

PORTABLE AMMETERS 0-3 A. moving iron AC/DC 3in. scale in case, 35/- ea., post 4/-.

MEGGERS, SERIES 2. 500 volts, range 0/100 Meg ohms-infinity. Metal case. Complete with test leads in leather case with strap £37.10. cge 12/6.

ELLIOTT CENTURY TEST SETS. First-grade, reading Absolute. D.C. volts .075, 3, 30, 150, 300 and 750 (FSD 20mA) and Absolute D.C. amps 1.5, 15, 150 and 600 (75 mV) on 5in. Mirror scale. Wood case, with shunts in fitted compartment, £25, cge 15/-.

L. WILKINSON (CROYDON) LTD.
LONGLEY HOUSE LONGLEY RD. CROYDON SURREY
Phone: 01-684-0236 Grams: WILCO CROYDON

LATEST RELEASE OF

RCA COMMUNICATION RECEIVERS AR88

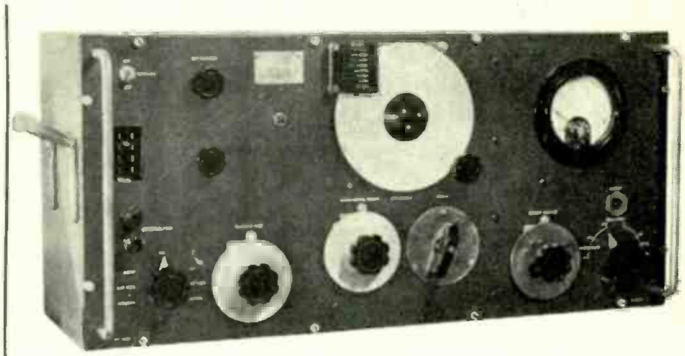
BRAND NEW and in original cases—A.C. mains input. 110V or 250V. Freq. in 6 bands 535 Kc/s-32 Mc/s. Output impedance 2.5-600 ohms. Complete with crystal filter, noise limiter, B.F.O., H.F. tone control, R.F. & A.F. variable controls. Price £87/10/- each, carr. £2.

Same model as above in secondhand cond. (guaranteed working order), from £45 to £60, carr. £2.

***SET OF VALVES:** new, £3/10/- a set, post 7/6; **SPEAKERS:** new, £3 each, post 10/-. ***HEADPHONES:** new, £1/5/- a pair, 600 ohms impedance. Post 5/-.

AR88 SPARES. Antenna Coils L5 and 6 and L7 and 8. Oscillator coil L55. Price 10/- each, post 2/6. RF Coils 13 & 14; 17 & 18; 23 & 24; and 27 and 28. Price 12/6 each. 2/6 post. By-pass Capacitor K.98034-1, 3×0.05 mfd. and M.980344, 3×0.01 mfd., 3 for 10/-, post 2/6. Trimmers 95534-502, 2-20 p.f. Box of 3, 10/-, post 2/6. Block Condenser, 3×4 mfd., 600 v., £2 each, 4/- post. Output transformers 901666-501 27/6 each, 4/- post.

** Available with Receiver only.*



MARCONI SIGNAL GENERATORS

TYPE TF-144G

Freq. 85Kc/s-25Mc/s in 8 ranges. Incremental: +/— 1% at 1Mc/s. Output: continuously variable 1 microvolt to 1 volt. Output Impedance: 1 microvolt to 100 millivolts, 10 ohms 100mV-1 volt-52.5 ohms. Internal Modulation: 400 c/s sinewave 75% depth. External Modulation: Direct or via internal amplifier. A.C. mains 200/250V, 40-100 c/s. Consumption approx. 40 watts. Measurements: 19½ × 12½ × 10 in. The above come complete with Mains Leads, Dummy Aerial with screened lead, and plugs. As New, in Manufacturer's cases, £40 each. Carr. 30/-. DISCOUNT OF 10% FOR SCHOOLS, TECHNICAL COLLEGES, etc.

S.A.E. for all enquiries. If wishing to call at Stores, please telephone for appointment.

W. MILLS 3-B TRULOCK ROAD, TOTTENHAM, N.17
Phone: 01-808-9213

SUPER-BARGAIN STOCKTAKING SALE!!

Use form below for your order. CONDENSERS MUST BE ORDERED BY STOCK NUMBER ONLY.
If any sale item is 'sold-out' when order received we shall substitute items of equal value.

ELECTROLYTIC CAPACITORS

Capacity	Voltage	No. required	Stock No.	Price s.	Price d.	£ s. d.
1 uf	6		1		4	
20 uf	6		7		4	
8 uf	6		11		4	
32 uf	150		9		9	
100/200/200/50	275		18	7	6	
50/80	300		19	3	0	
24	275		21	1	0	
16/32	350		25	2	6	
32	275		26	1	6	
3,000	35		32	7	6	
3,000	15		33	3	0	
2,500	9		36	2	0	
750	12		38	1	9	
100	275		39	2	6	
30	10		40		3	
16	50 REV		42	2	0	
16/16	275		43	2	0	
16	275		44	1	0	
350	12		45		9	
20/4	275		46	1	0	
64	275		51	1	9	
32/32	350		52	2	6	
8/8/8	275		53	1	9	
500	6		54		6	
500	4		60		3	
64/32/8	275		62	2	6	
30	6		67		3	
50/50/50	350		69	4	0	
40/40/20	275		70	2	0	
400	6.4		71		3	
320	10		72		3	
32/32	275					
+25	25		73	2	6	
250	150		G4/3	2	6	
50/50	200		G4/4	2	6	
16	300		G4/5	1	6	
60	350		G4/5A	2	6	
60/200	275		G4/6	5	6	

Capacity	Voltage	No. required	Stock No.	Price s.	Price d.	£ s. d.
32/300/70	275		G4/6A	6	6	
40/40	275		G4/7	3	0	
40/40	300		G4/8	3	0	
8/8	350		G4/9	3	0	
350	25		G4/10	2	6	
60/100	350		G5/4	5	0	
400	275		G5/5	3	6	
60/100	275		G5/6	4	6	
100/400/32	275		G5/6A	7	6	
100/400	275		G5/7	7	6	
100/64	500		G5/7A	7	6	
4/4	250		G5/8	1	6	
100/65	250		G5/8A	4	0	
8/8	450		G5/9	4	0	
100/100/50	350		G5/10	7	6	
100/380/16	275		G5/10A	7	6	
100/100	25		G5/11	2	6	
100/20/10 }	350					
20 }	50		G5/12	5	6	
1,000/1,500	25		G5/12A	6	0	
40/100	350		G5/13	3	6	
40/40/40	350		G5/13A	3	6	
8/8/8	275		G5/14	2	6	
12,500	15		G6/1	15	0	
800	6		G6/2	1	6	
1,600	80		G6/5	7	6	
1,000	60		G6/6	7	6	
100	275		G6/7	2	6	
200	250		G6/8	3	0	
200	150		G6/9	2	6	
8	200		G6/10	1	6	
200	25		G6/10A	2	0	
40	350		G6/11	2	6	
400	300		G6/11A	3	6	
250	25		G6/12	2	6	
1,000	12		G6/12A	2	0	
40	450		G6/13	4	0	

Total:

RESISTORS. Mainly 5 per cent. **7/6** per 100 of any one value. **2/-** per dozen of any one value.
Smaller quantities **3d. each**. Most values in stock.
Mixed bags (our selection) **6/6** per 100.
Mixed bags (our selection) ½ to 3 watt **7/6** per 100.
MAINS DROPPER TYPE. Hundreds of values from .7 ohm upwards. 1 watt to 50 watts. A large percentage of these are multi-tapped droppers for radio/television. Owing to the huge variety these can only be offered "assorted". **10/-** per dozen.

SILVER MICA/CERAMIC/POLYSTYRENE CONDENSERS
10/- per 100 of any one value. **3/-** per dozen of any one value. Smaller quantities **6d.** each. As available.

COMPARE THESE PRICES!!

MULLARD POLYESTER CONDENSERS

			No.	Price
1,000 pf	**3d.** each	400V		
1,500 pf	**3d.** each			
1,800 pf	**3d.** each			
2,200 pf	**3d.** each			
.15 uf	**6d.** each	160V		
.22 uf	**6d.** each	160V		
.27 uf	**6d.** each	160V		
1 uf	**1/-** each	125V		

Total:

25% discount lots of 100 per type.

TRANSISTOR BARGAIN! THEY CAN'T GET ANY CHEAPER!!!
OC 44. First-grade Mullard. **4/-** each.
OC 45. Mullard. Boxed. **4/-** each.
P.N.P. Audio. Untested, unmarked. MAINLY O.K. **10/-** per 100.
N.P.N. Silicon. R.F. types, unmarked. ALL USUABLE. **10/-** per 50.
Power Output (Similar OC 35). ALL TESTED. **4/-** each; **£2** doz.
ZTX 300. Transistors similar to, tested in P.E. organ circuit and approved for use in same by designer. **1/-** each.
OCP 71 (similar to). Light-sensitive. **2/-** each.
Light-sensitive Diodes. Can be used to control any transistorised device. **1/-** each. **75/-** per 100. **£25** per 1,000.

RECTIFIERS. Latest type. All marked. 800 volt peak, 1 amp mean current type 1N4006. **2/6** each, **24/-** dozen, **£7/10/-** 100. S.T.C. 3/4 (400 volt) **2/6** each, **24/-** dozen, **£7/10/-** 100. BYZ 13 or 19 (6 amp) **2/6 each, 24/-** dozen, **£7/10/-** 100.
BY 127 2/6d. each. **24/-** dozen. **£7/10/-** per 100. **£50** per 1,000.

RECORDING TAPE GIVE-AWAY! ALL BRITISH MADE, BEST QUALITY!
5" Standard .. .. **7/6d.**
5¾" Standard .. .. .. **9/-** 5¾" Long-play **12/-**
7" Standard .. .. .. **12/-** 7" Long-play **16/3**
3" "Oddends" Minimum 150 **2/3d.**

GIANT SELENIUM SOLAR CELLS. Last few to clear at half price! Circular, 67 mm. diameter **5/-** each. 50 mm. × 37 mm. 3 for **10/-**.

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3¾" × 3¾" × .15	**3/11**	3¾" × 3¾" × .1	**4/9**
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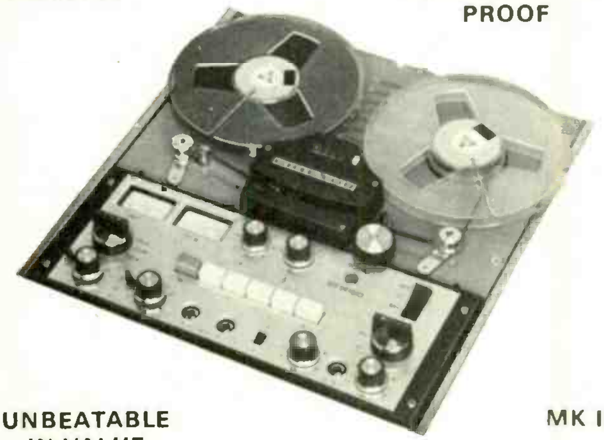

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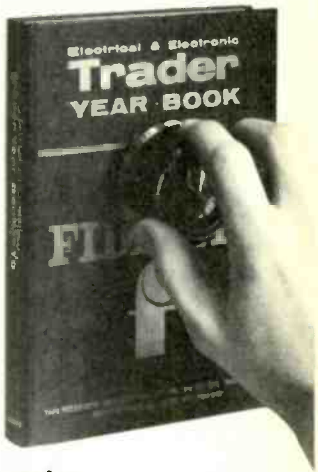

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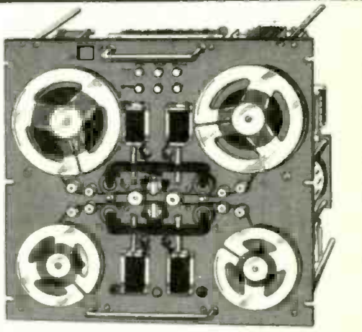
UNIQUE TWIN TAPE DECK UNITS



These superb twin tape deck units were originally designed for installations requiring the continuous replay of music or speech when connected to suitable amplifiers. Consisting of two completely self-contained tape decks operating at either $3\frac{3}{4}$" (3 button $\frac{1}{4}$ track model) or $7\frac{1}{2}$" (6 button $\frac{1}{2}$ track model). Each tape drive unit is fitted with a unique automatic solenoid operated tape drive reversal mechanism actuated by metallic stop foil at end of tape or inserted where reversal is desired. Constructed to the highest specification with the finest components available to ensure the utmost reliability. Nothing has been spared in the construction and the superb heavy duty capstan motors (2 off) and rewind motors (4 off), top grade relays, solenoids, etc., all bear witness to the high standards set.

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TECHNICAL SPECIFICATION

Power requirements 230/250V A.C. 50 c/s. Vertical or Horizontal operation. Overall dimensions: 19" x 19" x 8" deep. Weight 54 lbs. 3 Button model operates at $3\frac{3}{4}$ I.P.S. 6 Button model operates at $7\frac{1}{2}$ I.P.S. **TAPE REEL SIZES:** Upper deck $5\frac{3}{4}$". Lower deck 5". Capstan drive motors: 2 AEI A.C. motors continuous rating Type BC1504-B. 230/250 Volts A/C 50 c/s 1/75th H.P. 1500 R.P.M. **REWIND & TAPE UP MOTORS:** 4 Garrard A.C. Motors continuous rating Type DHP5C 100-130/200-250 Volts 50/60 c/s 0.3A-0.15A 24W. **RELAY SUPPLY TRANSFORMER:** Primary 210-230-240 Volts A/C 50 c/s. Secondary 24-26-32 V. **RECTIFIER.** Sentercel selenium rectifier type 460 SC 218I **5. CONDENSERS:** 1 Plessey 2,000 uf 50v D.C. 2 AEI 2uf 400V. **SOLENOIDS:** 8 Magnetic Devices Ltd Type 42766 120 Ohms. **RELAYS:** 2 Double coil relays type 593EII/TS 5668 590 Ohms. 2 Type 569E14/590/AEF2/24. 2 Type 596/E9/890/G2/24. 2 Type 596E8/590/E2/24 (3 Button unit only I). **RECORD/REPLAY HEADS.** 3 Button Unit fitted 2 Ferrograph 350 Ohms impedance half track stereo heads. 6 Button model fitted 2 Marriott 4 track heads 500 Ohms impedance.

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BC214L	4/–	BFY52	5/–	2N2924	4/4	2N3826	5/11
BCY70	5/4	BSY95A	3/11	2N2925	5/3	2N4058	4/6
BCY71	10/4	MJ481	27/3	2N2926	3/–	2N4059	3/5
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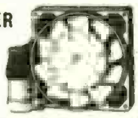

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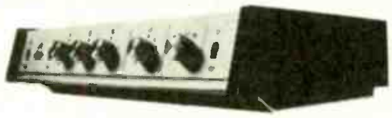

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C	1/2W	5%	4·7Ω–10MΩ	E24	3	2·5	2·25
MO	1/2W	2%	10Ω–1MΩ	E24	9	8	7
C	1W	10%	4·7Ω–10MΩ	E12	6	5	4·5
WW	1W	10%±1/20Ω	0·22Ω–3·3Ω	E12		15d. all quantities	
WW	3W	5%	12Ω–10KΩ	E12		15d. all quantities	
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CARBON SKELETON PRE-SETS
Small high quality, type PR: Linear only: 100Ω, 220Ω, 470Ω, 1KΩ, 2K2, 4K7, 10K, 22K, 47K, 100K, 220K, 470K, 1MΩ, 2M2, 5M, 10MΩ vertical or horizontal mounting .. 1/- each

S-DeCs PUT AN END TO "BIRDS-NESTING". Components just plug in.
Saves valuable time. Use components again and again.
S-DeC .. .. .. Only 30/6 post free
Compact T-DeC, increased capacity, may be temperature-cycled.
T-DeC .. .. .. only 50/- post free

WAVECHANGE SWITCHES
1P 12W; 2P 6W; 3P 4W; 4P 3W—long spindles .. .. 4/9 each
SLIDER SWITCHES
Double pole, double throw .. .. 3/- each

MULLARD SUB-MIN ELECTROLYTICS C426 RANGE .. .. .. **Price 1/3 each**
Axial leads. Values (μF/V): 0·64/64; 1/40; 1·6/25; 2·5/16; 2·5/64; 4/10; 4/40; 5/64; 6·4/6·4; 6·4/25; 8/4; 8/40; 10/2·5; 10/16; 10/64; 12·5/25; 16/40; 20/16; 20/64; 25/6·4; 25/25; 32/4; 32/10; 32/40; 32/64; 40/16; 40/2·5; 50/6·4; 50/25; 50/40; 64/4; 64/10; 80/2·5; 80/16; 80/25; 100/6·4; 125/4; 125/10; 125/16; 160/2·5; 200/6·4; 200/10; 250/4; 320/2·5; 320/6·4; 400/4; 500/2·5.

LARGE CAPACITORS. ALL NEW STOCK
High ripple current types: 2000μF 25V 7/4; 2000μF 50V 11/4; 5000μF 25V 12/6; 5000μF 50V 21/11; 1000μF 100V 16/3; 2000μF 100V 28/9; 5000μF 70V 36/-; 5000μF 100V 58/3; 1000μF 50V 8/2; 2500μF 64V 15/5; 2500μF 70V 19/6.

MEDIUM RANGE ELECTROLYTICS
Axial leads, Values (μF/V): 50/50 2/-; 100/25 2/-; 100/50 2/6; 250/25 2/6; 250/50 3/9; 500/25 3/9; 1000/10 3/3; 500/50 4/6; 1000/25 4/-; 1000/50 6/-; 2000/25 6/-; 330/25 2/6.

SMALL ELECTROLYTICS
Axial leads: 5/10, 10/10, 25/10, 50/10 1/- each
25/25, 47/25, 100/10, 220/10 .. .. 1/3 each

COMPONENT DISCOUNTS
10% on orders for components for £5 or more.
15% on orders for components for £15 or more.
(No discount on nett items)

POSTAGE AND PACKING
Free on orders over £2.
Please add 1/6 if order is under £2.
Overseas orders welcome: carriage charged at cost.

ZENER DIODES: Full range of 5% 400 mV available in E24 series, 2.7 V to 30 V .. .. **4/6 each**

COLVERN 3 WATT WIRE-WOUND POTENTIOMETERS: 10Ω, 15Ω, 25Ω, 50Ω, 100Ω, 150Ω, 250Ω, 500Ω, 1KΩ, 1·5KΩ, 2·5KΩ, 5KΩ, 10KΩ, 15KΩ, 25KΩ, 50KΩ.
Price .. .. **only 5/6 each**

CARBON TRACK POTENTIOMETERS
Double wiper ensures minimum noise level. Long plastic spindles.

Single gang linear ..	220Ω, 470Ω, 1K, etc. to 2M2Ω	2/6
Single gang log. ..	4K7, 10K, 22K, etc. to 2M2Ω ..	2/6
Dual gang linear ..	4K7, 10K, 22K, etc. to 2M2Ω ..	8/6
Dual gang log. ..	4K7, 10K, 22K, etc. to 2M2Ω ..	8/6
Log/Anti-log. ..	10K, 47K, 1MΩ only	8/6
Dual anti-log ..	10K only	8/6

Any type with ½ amp double pole mains switch .. extra 2/3
Please Note—only decades of 10, 22 and 47 are available with range quoted.

FETS n-channel
Low cost general purpose 2N5163, 25 volt .. only 5/- each
Audio/r.f. Texas 2N3819 .. .. **8/6 each**
Motorola 2N5457 (MPF103) .. .. **9/9 each**
Motorola 2N5459 (MPF105) .. .. **9/9 each**

30 WATT BAILEY AMPLIFIER COMPONENTS:
Transistors for one channel £7/5/6 list, with 10% discount .. .. only **£6/11/-**
Transistors for two channels £14/11/- list, with 15% discount .. .. only **£12/7/5**
Capacitors and resistors for one channel, Nov. '68 circuit list £2.
Printed circuit board free with each transistor set.
Complete unregulated power supply kit **£4/17/6** mono or stereo, subject to discount.
Complete regulated power supply kit Nov. '68 circuit £9/5/- subject to discount.
Further details on application.

MAIN LINE AMPLIFIER KITS AS ADVERTISED. PRICES NET AUTHORISED DEALER

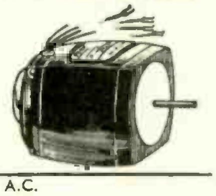
SINCLAIR IC.10 INTEGRATED CIRCUIT AMPLIFIER AND PRE-AMPLIFIER
This remarkable monolithic integrated circuit amplifier and pre-amplifier is now available for despatch from stock. It is the equivalent of 13 transistor/18 resistor circuit plus 3 diodes and the first of its kind ever. It is d.c. coupled and applicable to an unusually wide range of uses all of which are detailed in the manual provided with it. **59/6 NETT**
Sinclair products as advertised **post free**

ELECTROVALUE

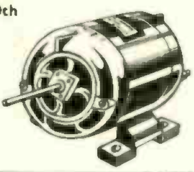
DEPT. WW.704, 28 ST. JUDES ROAD, ENGLEFIELD GREEN, EGHAM, SURREY,
Hours: 9-5.30 daily; 1.0 p.m. Saturdays. ***Telephone: Egham 5533 (STD 0784-3)***

Electro-Tech Sales

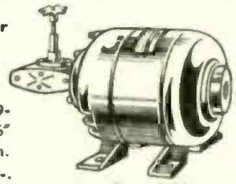
NEW HYSTERESIS MOTORS BY WALTER JONES. Type 14050/12. 240v. 50 c/s 1500 RPM cont. rating, output 2.0 oz./in. Size: Length (less spindle) 3¼". Width 2¼"×2¼". Spindle 1"×3/16". Weight 3 lb. Maker's price in region of £22.10.0. Our price **£6.10.0.** each.



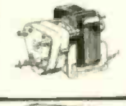
NEW "CROYDON" 240v. A.C. reversible motors. Choice of 1/50th HP, 1,500 RPM, or 1/100th HP, 750 RPM (identical in appearance). Size 3⅜" high × 5" long plus spindle 1⅜"×¼" dia. A beautiful motor at less than half maker's original price. **£6.10.0 each.**



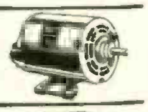
"Parvalux" Reversible 100 RPM Geared Motor
Type S.D.14, 230/250v. A.C. 22 lb./in. Standard foot mounted, variable angle final drive. Removable 9-tooth chain spiggot on 3/16" spindle. 1st class condition. **£7.10.0** each. P. & P. 10/-.
Also limited number only as above. But Brand New. **£12.10.0** each. P. & P. 10/-.



NEW "CARTER ELECTRIC" 12 r.p.m. MOTOR.—Non-reversible, ¼" spindle. 240v. A.C. Open frame with cast aluminium cased gearbox. Stoutly constructed. Approx. 25 lbs./in. Overall size (approx.) 3"×3"×4" plus spindle. 45/-. P. & P. 5/-.



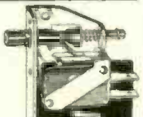
English Electric ⅓ h.p. Motors. 240v. single-phase, standard foot mounted, 1,425 r.p.m., continuous rating. £4.15.0. Carriage 20/-.



Isolation Transformers. By Majestic Winding Co. 1 to 1 ratio. 240v. input, 240v. centre tapped out, at 2K.V.A., mounted in metal case measuring 8¾"×8½"×11" high. Weight 65lb. £16.10.0. Plus £1.10.0 carriage.

GENERAL ELECTRIC "TELETYPE". 115v. 50 cps. Synchronous motor, 3,000 RPM, double ended 5/16" spindle. These motors are precision built to a very high standard, silent running, continuous running, drawing 70 watt on run. Original cost is believed to be in region of £25 each. We are offering these Brand New at 45/- each.

"HONEYWELL" TYPE 23AC-NE—15 amp. change-over switch is fitted on angled metal mount with spring loaded plastic rod operating cam. 10/- each.



"HONEYWELL" V3 SERIES.—Flush micro-switch 10 amp. c/o. The side panel is insulated. End-plate size: 2"×⅜". 36/- per doz.

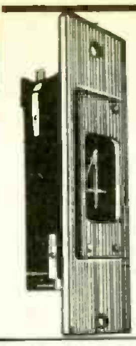
OMRON MICRO SWITCH. Type VV—15—1A. Single c/o 10 amp. at 250v. 1⅛"×⅜"×⅜". 30/- per dozen.

"HONEYWELL" MICROSWITCH.—Single and double bank, manual-push. Ideal for vending machines, etc. Each bank comprises a change-over rated 15 amps. 240v. A.C. The through-panel mounting assembly is in heavy polythene surmounted by black knob. Neck dia. ⅜". Single 10/- each. Double 15/- each. Also few only 3 bank. 20/- each.

"GOYEN" PRESSURE SWITCH.—Incorporating differential adjustment between 2" and 12" water gauge (a max. of approx. ½ p.s.i.). A single pole change-over switch rated 15 amps. 250v. is actuated. Air inlet tube 5/16" dia. Projection 11/16". Overall size: dia. 3¼", depth 2" plus 11/16" (air tube). 25/-.

"BONNELLA" 15 AMP. 240v. TOGGLE SWITCHES.—Single pole change-over, ¾" Long Dolly. Standard single hole mounting. 30/- per doz. (minimum ½ doz.).

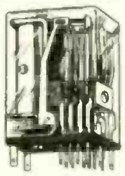
THORN DIGITAL INDICATOR. A modular unit easily read through a wide angle of view even under bright lighting. 12 characters, 0 to 9, decimal point and minus sign. Characters 13/16" high on acrylic, edge-lit by 1 watt midget lamp. Front panel 4⅞"×1⅛", depth overall 1", matt black finish. Supplied with 12 lamps. Choice of the following ratings—6v. .1A. or 12-14v. .08A. £4.0.0 each, spare lamps 24/- per dozen.



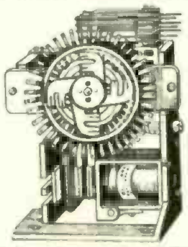
Welwyn high value Resistors Type GA 36501. Values between 9.4 and 10.9 kilo-meg ± 1%, glass encapsulated 15/-.

"WELWYN" RESISTORS.—Type H12. One value only. 1 kilo-meg ±20%. 5/- each. (Minimum order 2.)

SPECIAL OFFER. Enclosed Relay, complete with base. Brand New. Type MQ308 600 Ω 24v. 4 c/o. Size 1⅞"×1½"×2". £5 per dozen. 12/- each.
Type MQ508 10,000 Ω 100v. 4 c/o. £5 per dozen. 12/- each.
Type MQ108 40 Ω 6v. 4 c/o. £6 per dozen, 13/6 each.
Type MQ208 150 Ω 12v. 4 c/o. £6 per dozen. 13/6 each.



SCHRACK ROTARY STEPPING RELAY RT304 48v. (28 ohm). 48 step in bank of 4 (4 pole 12 position). There are 2 secondary switches: (1) one c/o H/Duty contact set which changes over and back with each step; (2) two H/Duty changeovers which change over on each 12th step and return on the following pulse. Size: Base 3¼"×1⅞"×4¼" high. New in maker's packing, also, as above, but 110v. (1,290 ohm coil), £4.15.0 each.

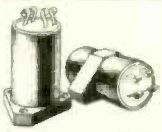


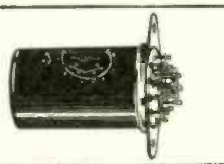
NEW "F.I.R.E." PLUG-IN RELAY.—115v. Coil 50/60 c.p.s. 3 heavy duty silver change-over contacts. Very robust. 17/6.

NEW DIAMOND "H" 240v. A.C. RELAY.—3 heavy duty silver change-over contacts. 17/6.

SEIMENS HIGH SPEED RELAY, Type 89L. 1,700 Ω + 1,700 Ω coil. New 15/- each.

MINIATURE "LATCH-MASTER" RELAY 6, 12, or 24v. D.C. operation. One make one break, contacts rated 5 amps. at 30v. Once current is applied, relay remains latched until input polarity is reversed. Manufactured for high acceleration requirements by Sperry Gyroscope Co. Size: Length ⅞" dia. 9/16" (including mount). Please state vertical or horizontal mount and voltage. £2.5.0 each.





DIAMOND "H" SEALED RELAY Type. BR 115 C.I.T.—1C 26v. 150 Ω 4 P.D.T. Completely encapsulated in heavy gauge brass case, glass sealed terminals, very robust. 17/6 each.

K.L.G. Sealed Terminals. Type TLS1 AA, overall length 11/16", box of 100, 25s. Type TLS1 BB, overall length 1", box of 100, 35s.

CENTRIFUGAL BLOWER BY AIR CONTROL LTD. 240v. AC. 9" dia. 2,850 RPM. 1/10th HP. Ideal for organ blowing, powerful, low noise level. 1st class condition. Photo on request. £12.10.0. Carriage £1.

GARDENERS AUTO-TRANSFORMERS. 110/115/200/250v. 1500 watts. Weight 23lb. Few only. £10.10.0. P. & P.

WE WELCOME OFFICIAL ORDERS FROM ESTABLISHED COMPANIES, EDUCATIONAL DEPTS., ETC.

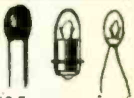
BRAND NEW "KLAXON" GEARED MOTORS. 230/250v. 250 r.p.m. Cont. 45lb./in. Few only. **£25.0.0.** Carriage £1.10.0.

POWER SUPPLY UNIT. 240v. A.C. To 112 or 125 D.C. at 3 amps. Ripple at 3 amps less than 500 millivolts. Output resistance 5 Ω. Size 15"×9¾"×7" high. Weight 44lb. £8.10.0. C. & P. £1.10.0.

SYLVANIA MAGNETIC SWITCH—a magnetically activated switch operating in a vacuum. Switch speed—4ms. temperature −54 to +200° C. Silver contacts normally closed rated 3 amps. at 120v. 1.5 amp. at 240v. 10/- each. 80/- per dozen. Special quotations for 100 or over. Reference Magnets available 1/6 each.

SYLVANIA CIRCUIT BREAKERS gas filled providing a fast thermal response between 80° and 180°C. Will withstand pressures up to 2,000 lb. sq./in. rated 10 amp. at 240v. continuous. Fault currents of 28 amps. at 120v. or 13 amp. at 240v. silver contacts. Supplied in any of the following opening temperatures (degs. cent.) 80, 85, 95, 100, 105, 110, 120, 125, 130, 135, 140, 145, 150, 155, 160, 170, 175, 180. 10/- each or 80/- per dozen.

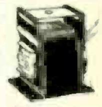
ATLAS SUB-MINIATURE LAMPS type L1122 and L1123—a high efficient light-source with excellent light-output and low power demand. Ratings 5v. 60 ma. .35 ± 25% lumens. Life expectancy 60,000 hours or at 6 v. 70 ma. .75 ± 25% lumens 5,000 hours. Dimensions: Uncapped 6.3 × 3.1 mm. leads 12.7 mm: capped 9.1 × 3.1 mm. Ideal for instrument lighting normally sold in excess of 12/- each, our price 30/- per dozen or boxes of 50 at £5 per box.



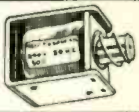
ATLAS MIDGET PANEL LAMPS unrivalled for indication purposes requiring a brilliant but tiny light source. Available with flange cap or wire ended in the following ratings: Capped: 6v. .1A and 12-14v. .08A. Uncapped: 4v. .25A., 6v. .1A., 6v. .2A. 24/- per dozen or boxes of 50 at £4 per box.

INDICATOR LAMP HOLDERS AND CAPS for MIDGET PANEL LAMPS (as above) available red, green, blue, 2/6 each (complete) minimum order 4 units.

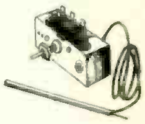
"DECCO" MAINS SOLENOID.—Compact and very powerful. 16 lb. pull. ⅜" travel which can be increased to 1" by removing captive-end-plate. Overall size 2"×2½"×2⅜" high. 35/-. P. & P. 5/-.



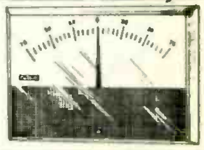
New "Magnetic Devices" solenoid 240v. A.C. Type 42117, 1 to 3 lb. pull, frame size 1½"×1½"×1". 20/- each.



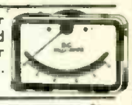
"TEDDINGTON" CONTROLS THERMOSTAT.—Adjustable between 75° and 100°C. A further internal adjuster takes the maximum up to 120°C. Circuit cuts in again at 3° below cut-out setting. 42" capillary and sensor probe. The thermostat actuates a 15 amp. 250v. c/o switch. A second single pole on/off switch is incorporated in the adjustment mechanism. 17/6.



New 75-0-75 Micro-ammeter by Sifam. 750 ohm movement, clear reading, 5μa divisions × ⅛"; plastic front, projection ½" (tapering forward). Size: 4¾"×3¾", 57/6 each.



Ernest Turner 5"×4", 0-1 Ma. meter calibrated 0-10 in 50 divisions mirrored scale, handsome chrome escutcheon for flush mounting. A quality instrument. £6.10.0.



MINIATURE B.P.L. 500-0-500 Micro-Ammeter. 13/16" Diam. scale. Through-Panel mounting, 45/-.

TRIMPOTS. "Painton" Types: 200S-1-502 5K Ω; 200S-1-103 10K Ω; 200S-1-501 500K Ω; 200S-1-503 50K Ω; 224P-1-202 2K Ω; 224S-1-102 1K Ω; 200S-1-203 20K Ω; 275-1-252 2.5K Ω. "Rll" Type: 321 10K Ω. "Morganite" Type: 80 1K Ω. "Mec" Type: 025 (tubular) 200 Ω; T20P 50 Ω. All types 12/- each.

GARDNERS CHOKES. Type C237: 20H 180MA 30/- P. & P. 5/-. Type C570: 0.05H 3.5A 35/- P. & P. 5/-. Type C549: 0.1H 2.5A 20/- P. & P. 5/-. Type C271: 5H 500MA 37/6 P. & P. 7/6. Type C576: 0.05H 7.5A 50/- P. & P. 10/-. Type C527: 0.5H 4A 50/- P. & P. 10/-. Type SK7486: 35 MH 3A D.C. 30/- P. & P. 5/-. Type F9719: 25H 60MA 8/6 P. & P. 3/6.

"KNOWLE" (U.S.A.) MINIATURE MICROPHONE CAPSULES. Impedance 2000 Ω. Output about 100dB at 1 KC (Type A). As above, but output 60dB (Types B & C), as used in miniature hearing-aids, bugging devices, etc. All tested. 20/- each.
Also **"KNOWLE" M/C SUB-MINIATURE EAR TRANSDUCERS.** Type 1530. Size 7/16"×7/32"×⅛" thick. 15/- each.

WHERE NO CARRIAGE CHARGE IS INDICATED PRICE IS INCLUSIVE. PERSONAL CALLERS WELCOME.

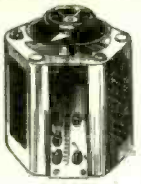
ELECTRO-TECH SALES

BUSINESS HOURS: 9.30-6 (1 p.m. Sats.)

264 PENTONVILLE ROAD, LONDON, N.1
(ONE MIN. FROM KINGS X STATION) Tel. 01-837 7401

SERVICE TRADING CO

Postage and Carriage shown below are inland only. For Overseas please ask for quotation. We do not issue a catalogue or list.


8 AMP


1 AMP

INPUT 230 v. A.C. 50/60
OUTPUT VARIABLE 0/260 v. A.C.

BRAND NEW. Keenest prices in the country. All types (and spares) from ½ to 50 amp. available from stock.

0-260 v. at 1 amp	£5	10	0
0-260 v. at 2·5 amps	£6	15	0
0-260 v. at 5 amps	£9	15	0
0-260 v. at 8 amps	£14	10	0
0-260 v. at 10 amps	£18	10	0
0-260 v. at 12 amps	£21	0	0
0-260 v. at 15 amps	£25	0	0
0-260 v. at 20 amps	£37	0	0
0-260 v. at 37·5 amps	£72	0	0
0-260 v. at 50 amps	£92	0	0

20 Different types available for immediate delivery.

OPEN TYPE (Panel mounting). ½ amp. £3.10 1 amp £5.10. 2½ amp. £6.12.6. P. & P.7/6.

RING TRANSFORMER

Functional Versatile Educational

This multi-purpose Auto Transformer, with large centre aperture, can be used as a Double wound current Transformer, Auto Transformer, H.T. or L.T. Transformer, by simply hand winding the required number of turns through the centre opening. E.g. Using the RT.100 V.A. Model the output could be wound to give 8V. @ 12½Amp., 4V. @ 25Amp. or 2V. @ 50Amp., etc.

Price: RT.100VA 3.18 turns per volt, £2 5 0 + 3/6 p. and p.
RT.300VA 2.27 turns per volt, £4 4 0 + 5/6 p. and p.
RT. 1KVA 1.82 turns per volt, £6 10 0 + 6/6 p. and p.
RT.2KVA 1.5 turns per volt, £10 10 0 + 9/6 p. and p.
RT.3KVA 1.5 turns per volt. £14 0 0 + 10/- p. & p.

L.T. TRANSFORMERS

All primaries 220-240 volts.

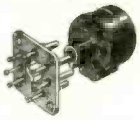
Type No.	Sec. Taps	Price			Carr.
1	12 v. at 5A	£1	17	6	5/6
2	30, 32, 34, 36 v. at 5 amps.	£4	13	6	6/–
3	30, 40, 50 v. at 5 amps.	£6	17	6	6/6
4	10, 17, 18 v. at 10 amps.	£4	19	0	4/6
5	6, 12 v. at 20 amps.	£6	8	6	6/6
6	17, 18, 20 v. at 20 amps.	£7	5	6	6/6
7	6, 12, 20 v. at 20 amps.	£6	17	6	7/6
8	24 v. at 10 amps.	£5	4	6	5/6
9	4, 6, 24, 32 v. at 12 amps.	£7	3	0	6/6

AUTO TRANSFORMERS. Step up, step down. 110-200-220-240 v. Fully shrouded. New. 300 watt type £3/12/6 each, P. & P. 4/6. 500 watt type £5/2/6 each, P. & P. 6/6. 1,000 watt type £7/2/6 each, P. & P. 7/6.

SANGAMO WESTON SYNCHRONOUS GEARED MOTOR

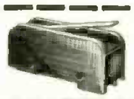
New. Three Types. 1 R.P.M. 1 Rev per hour. 12 Rev per hour. All at 17/6 each, p. & p. 2/6.

MULTI WAY PLUGS AND SOCKETS

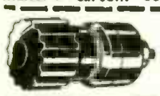


10 way plug and socket. (Socket chassis mounted.)
7 way reversed plug and socket. Plug chassis mounted. (Illustrated.)
Price: either type 3/6 pair. 9d. P.&P.

BURGESS MICRO SWITCH



Lever operated c/o contacts. Price 4/- plus 9d. P. & P. 10in maker's carton. 35/- post paid.



INSULATED TERMINALS

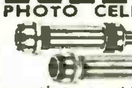
Available in black, red, white, yellow, blue and green. New 2/- each.

LIGHT SENSITIVE SWITCHES

Kit of parts including ORP.12 Cadmium Sulphide Photocell. Relay Transistor and Circuit. Now supplied with new Siemens High Speed Relay for 6 or 12 volt operations. Price 25/-, plus 2/6 P. & P. ORP. 12 and Circuit 12/6 post paid.

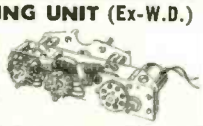
220/240 A.C. MAINS MODEL incorporates mains transformer rectifier and special relay with 2 × 5 amp. mains c/o contacts. Price inc. circuit 47/6, plus 2/6 P. & P.

LIGHT SOURCE AND PHOTO CELL MOUNTING



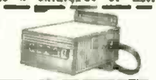
Precision engineered light source with adjustable lens assembly and ventilated lamp housing to take MBC bulb. Separate photo cell mounting assembly for ORP.12 or similar cell with optic window. Both units are single hole fixing. Price per pair £2/15/0 plus 3/6 P. & P.

MOTORISED SWITCHING UNIT (Ex-W.D.)

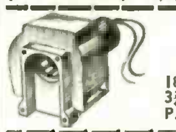


Powerful, precision-made, ex-W.D., 12 v. D.C., reversible motor, drives multiple gear train with outputs approx. 4 r.p.m. and 5 r.p.m. Price 25/- P. & P. 4/6.

VEEDER ROOT COUNTER



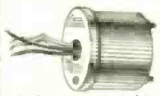
230 v. A.C. 50 cycle 5 figure counter (non resetable). 18/6, P. & P. 1/6.



Ex. W.D. MINIATURE BLOWER UNIT

18-24 v. D.C. operation, overall length 3⅞ in. Blower 2⅞ × 2⅛ in., 20/-. P. & P. 2/6.

SOLID STATE INTERVAL TIMER



24-30v. D.C. operation. Stabilised uni-junction Timer and S.C.R. (30v. 1Amp.), encapsulated in metal core. Timing interval adjustable from a fraction of a second to several minutes by means of external resistor or pot. By adding a 24v. Relay many other complex timing Functions are possible. Price: 16/6 incl. circuit, p. & p. 2/6. Suitable relay 9/6. P. & P. 1/6.

A.C. CONTACTOR

2 make and 2 break (or 2 c/o) 15 amp. contacts. 230/240 v. A.C. operation. Brand new. 22/6 plus 1/- P. & P.

POWER RHEOSTATS

(NEW) Ceramic construction, winding embedded in Vitreous Enamel, heavy duty brush assembly designed for continuous duty. **AVAILABLE FROM STOCK IN THE FOLLOWING 11 VALUES: 100 WATT 1 ohm 10a., 5 ohm 4.7a., 10 ohm 3a., 25 ohm 2a., 50 ohm 1.4a., 100 ohm 1a., 250 ohm ·7a., 500 ohm ·45a., 1k ohm 280mA., 1·5k ohm 230mA., 2·5k ohm ·2a., 5k ohm 140mA.,** Diameter 3¼in. Shaft length ⅜in. dia. ⁵⁄₁₆in., 27/6. P. & P. 1/6.
50 WATT 1/5/10/25/50/100/250/500/1K/1·5K/2·5K/5K ohm. All at 21/-, P. & P. 1/6.
25 WATT 10/25/50/100/250/500/1K/1·5K/2·5K ohm. All at 14/6, P. & P. 1/6.

Black Silver Skirted knob calibrated in Nos. 1-9. 1½ in. dia. brass bush. Ideal for above Rheostats, 3/6 each.

STROBE! STROBE! STROBE!

THREE EASY TO BUILD KITS USING XENON WHITE LIGHT FLASH TUBES. SOLID STATE TIMING + TRIGGERING CIRCUITS. PROVISION FOR EXTERNAL TRIGGERING. 230-250v. A.C. OPERATION. The Strobe is one of the most useful and interesting instruments in the laboratory or workshop. It is invaluable for the study of movement and checking of speeds. Many uses can be found in the psychiatric and photographic fields, also in the entertainment business. It is used a great deal in the motor industry and is a real tool as well as an interesting scientific device.

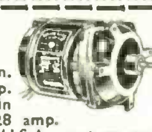
EXPERIMENTERS "ECONOMY" KIT
Adjustable 1 to 36 Flash per sec. All electronic components including Veroboard S.C.R. Unijunction Xenon Tube + instructions £5.5.0 plus 5/- P. & P.

NEW INDUSTRIAL KIT
Ideally suitable for schools, laboratories etc. Roller tin printed circuit. New trigger coil, plastic thyristor Adjustable 1-80 f.p.s. Price 9 gns. 7/6 P. & P.

HY-LYGHT STROBE
This strobe has been designed for use in large rooms, halls and the photographic field, and utilizes a silica tube for longer life expectancy, printed circuit for easy assembly, also a special trigger coil and output capacitor. Speed adjustable 1-30 f.p.s. Light output approx. 4 joules. Price £10.17.6. P. & P. 7/6.

7-INCH POLISHED REFLECTOR. Ideally suited for above Strobe Kits. Price 10/6 and 2/6 P. & P. or post paid with kits.

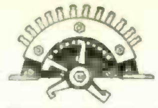
BODINE TYPE N.C.1 GEARED MOTOR



(Type 1) 71 r.p.m. torque 10 lb. in. Reversible 1/70th h.p. 50 cycle .38 amp.
(Type 2) 28 r.p.m. torque 20 lb. in reversible 1/80th h.p. 50 cycle .28 amp.
The above two precision made U.S.A. motors are offered in 'as new' condition. Input voltage of motor 115v A.C. Supplied complete with transformer for **230/240v A.C. input**
Price, either type £3.3.0 plus 6/6 P. & P. or less transformer £2.2.6 plus 4/6. P. & P.
These motors are ideal for rotating aerials, drawing curtains, display stands, vending machines etc. etc.

INSULATION TESTERS (NEW)

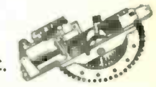
Test to I.E.E. Spec. Rugged metal construction, suitable for bench or field work, constant speed clutch. Size L.8 in.. W.4 in. H.6in., weight 6lb., **500 VOLTS,** 500 megohms **£28** carriage paid.
1,000 VOLTS, 1,000 megohms, **£34** carriage paid.



MINIATURE UNISELECTOR

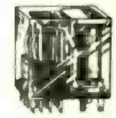
3 banks of 11 positions, plus homing bank. 40 ohm coil. 24-36 v. D.C. operation. Carefully removed from equipment and tested. 22/6, plus 2/6 P. & P.

UNISELECTOR SWITCHES *NEW*
4 BANK 25 WAY FULL WIPER
25 ohm coil, 24 v. D.C. operation. £5.17.6, plus 2/6 P. & P.



6 BANK 25 WAY FULL WIPER 25 ohm coil, 24 v. D.C. operation. £6.10.0, plus 2/6 P. & P.

RELAYS



NEW **SIEMENS PLESSEY**, etc. MINIATURE RELAYS AT A HIGHLY COMPETITIVE PRICE.

COIL Ω	WORKING D.C. VOLT	CONTACTS	PRICE
170	9—12	4 c/o H.D.	14/6
170	9—12	3 c/o + 1 H.D. c/o	12/6
230	6—12	2 c/o	12/6
280	6—12	2 c/o incl. base	14/6
700	12—24	2 c/o incl. base	12/6
700	16—24	4 c/o incl. base	15/6
700	16—24	4M 2B incl. base	12/6
9000	40—70	2 c/o incl. base	10/-

H.D. = Heavy Duty *POST PAID*

MINIATURE RELAYS

9—12 volt D.C. operation. 2 c/o 500 M.A. contacts. Size only 1in. × ⅞ × ½in. Price 11/6 Post paid.
30-36 v. D.C. operation. 2 c/o 500 M.A. contacts. 3.200 ohm coil. Size only 1 × ⁷⁄₁₆ × 1½in. 8/6 post paid.

SPECIAL OFFER

Relay 12/24 v. D.C. 2 c/o 3 Amp contacts. 400 ohm coil. NEW. 9/6 P. & P. 1/6 or 4 for 30/- post paid.

230 VOLT AC RELAY LONDEX four c/o 3 amp contacts. 18/6, Incl. base. Post Paid.

SANWA MULTI RANGE TESTERS

NEW MODEL U-50D MULTI TESTER, 20,000 O.P.V. MIRROR SCALED WITH OVERLOAD PROTECTION. Ranges: D.C. volts: 100mV., 0.5 v., 5 v., 250 v., 1,000 v. A.C. volts. 2.5 v., 10 v., 50 v., 250 v., 1,000 v. D.C. current: 50μA., 0.5 mA., 5 mA., 50 mA., 250 mA. Size: 5¼ × 3½ × 1⅜ in. Complete with batteries and test prods. **£7.5.0** Post paid

PANEL METERS AT BARGAIN PRICES

A.C. AMMETERS 0-1, 0-5, 0-10, 0-15, 0-20 amp. F.R. 2½in. dia. **ALL AT 21/- EACH.**
A.C. VOLTMETERS 0-25 v., 0-50 v., 0-150 v. M.I 2½in. Flush round **ALL AT 21/- EACH.** P. & P. extra.
0-300 v. A.C. Rect. M-Coil 2½in. 29/–
0-300 v. A.C. Rect. M-Coil 3½in. Type W23 ...... 45/–

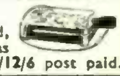
FOOT SWITCH

Suitable for Motors, Drills, Sewing Machines, etc. 5 amp. 250 volts. Price 17/6 plus 2/6 P. & P.

230 v. A.C. SOLENOID. Heavy duty type. Approx 3lb. pull. 17/6 plus 2/6 P. & P. **12 v. D.C. SOLENOID** Approx. 1lb. pull. 10/6, P. & P. 1/6.
50 v. D.C. SOLENOID. Approx. 1lb. pull. 10/6, P. & P. 1/6.
50 v. D.C. SOLENOID. Approx. 2lb. pull. 12/6, P. & P. 1/6.

NEW MODEL **HIGH FREQUENCY TRANSISTORISED MORSE OSCILLATOR**
Adjustable tone control. Fitted with moving coil speaker, also earpiece for personal monitoring. Complete with morse key. 45/- plus 3/6d. p. & p.

SEMI-AUTOMATIC "BUG" SUPER SPEED MORSE KEY

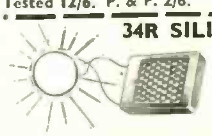


7 adjustments, precision tooled, speed adjustable 10 w.p.m. to as high as desired. Weight 2½lb. £4/12/6 post paid.

NICKEL CADMIUM BATTERY

1.2 v. 35 AH. Size 8¾ high × 3 × 1½. 30/- each, plus 4/- P. & P.
Sintered Cadmium Type 1.2 v. 7AH. Size: height 3½ in., width 2⅛in. × 1⁷⁄₁₆in. Weight: approx. 13 ozs. Ex-R.A.F. Tested 12/6. P. & P. 2/6.

34R SILICON SOLAR CELL



4 × .5 volt unit series connected, output up to 2 v. at 20 mA. in sunlight, 30 times the efficiency of selenium. 45/-. P. & P. 1/6d.

ALL MAIL ORDERS. ALSO CALLERS AT:
57 BRIDGMAN ROAD, LONDON, W.4. Phone: 995 1560
Closed Saturdays.

SERVICE TRADING CO.
SHOWROOMS NOW OPEN
AMPLE PARKING

PERSONAL CALLERS ONLY
9 LITTLE NEWPORT STREET, LONDON, W.C.2.
Tel.: GER 0576

APPOINTMENTS VACANT

DISPLAYED SITUATIONS VACANT AND WANTED: £7 per single col. inch.
LINE advertisements (run-on): 8/- per line (approx. 7 words), minimum two lines.
Where an advertisement includes a box number (count as 2 words) there is an additional charge of 1/-.
SERIES DISCOUNT: 15% is allowed on orders for twelve monthly insertions provided a contract is placed in advance.
BOX NUMBERS: Replies should be addressed to the Box number in the advertisement, c/o Wireless World, Dorset House, Stamford Street, London, S.E.1.
No responsibility accepted for errors.

Advertisements accepted up to THURSDAY, 12 p.m., 4th JUNE for the JULY issue, subject to space being available.

CONTINUOUS EXPANSION

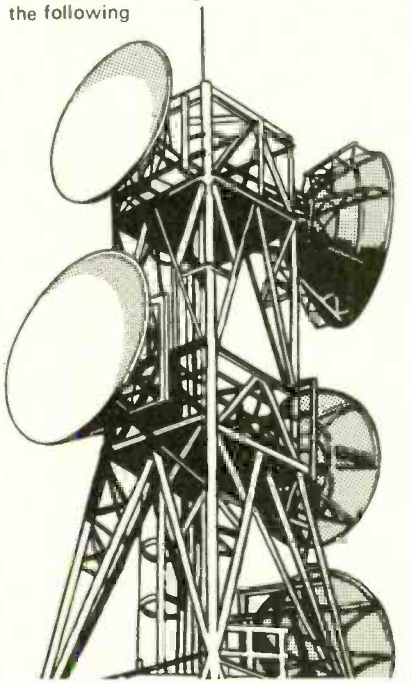
Standard Telephones & Cables, Microwave and Line Division based at Basildon are growing fast. In order to keep pace with this consistent growth rate we require the following

Installation Engineers Technicians & Testers

Ref. 25720

To test and commission Multiplex, Co-axial Line and Microwave Radio Systems.

Ideal candidates will be less than 45 years of age with practical experience on some of the above equipment. These challenging posts call for drive, initiative and common sense. It is necessary for applicants to be prepared to work anywhere in the U.K.



Test Technicians

Ref. 27221

The diversity of products manufactured at the Basildon Plant demands experienced testing staff for work on complex transmission systems.
Candidates should hold an ONC in electrical engineering and be able to offer considerable practical experience in the field of testing and fault clearing all types of land-unit, pcm and microwave equipment.

Applications should be addressed to
The Personnel Officer,
STC Chester Hall Lane,
Basildon, Essex.

STC

91

ELECTRONICS TECHNICIANS

Decimalisation..... the growing use of computers – the business machine explosion is upon us and with it comes a wealth of opportunity and big career prospects for trained Electronics Technicians.
This is the chance to develop your skills with Burroughs – today's pacesetter in the competitive world of electronics. The opportunities are wide open and promotion into computer fields and managerial positions is purely dependent upon your ability. So, if you're aged between 20 and 25 with an electronics background – then let's get to know each other. In return, we offer good salaries and many company benefits including a generous car purchase assistance scheme.

Burroughs

Take a step into today's growth industry and meet the challenge that only an international electronics company can offer – fill in the coupon and send off for one of our application forms. The address is:
Geoff Lewis, Personnel Manager, Burroughs Machines Ltd., (Z). Heathrow House, Cranford, Hounslow, Middx.

Name ____________________

Address ____________________

____

DE/M8

SENIOR ENGINEERS
£2,360 - £2,780

Applications are invited for three posts based at the Regional Engineers' offices at SOUTHAMPTON (Ref. W.W./1385.) BIRMINGHAM (Ref. W.W./1386.) and LEEDS (Ref. W.W./1387). These posts are for Senior Engineers attached to the Regional Engineers' staff.

The duties associated with these posts include:–

* Attendance at the commissioning of new Transmitter Stations and ancillary installations and accepting responsibility (on behalf of the Regional Engineer) for the satisfactory introduction of these Stations and installations into operational service.
* Providing technical assistance to Station Engineering Staff in the day to day operation and maintenance of Station Transmitter equipment.
* Providing some instruction to Station Staff on the design features of new equipment being brought into service.
* Providing technical and administrative assistance to the Regional Engineer.

In each case a good deal of travelling, sometimes at short notice, and mainly within the Region of appointment, will be involved. However, at times there is the possibility of extended periods away from the Regional Office.

Candidates should preferably be Graduate Members of a recognised Institution with substantial experience in the field of VHF and UHF Television Transmitter and Transposer installations. The successful candidates will possess a wide understanding of these installations and ancillary equipment, together with knowledge of the testing and measuring techniques employed. They will be expected to display and develop an active interest in automatic, remote control and computer techniques as related to Television Broadcasting, and to be aware of modern developments in all aspects of their work.

Starting salary will be in the above range according to age and experience.

Candidates interested in the above posts should write for an application form, quoting the appropriate reference and stating clearly which Region they wish to be considered for. Closing date for completed application forms, June 1st, 1970.

ITA

The Personnel Officer,
INDEPENDENT TELEVISION AUTHORITY,
70, Brompton Road,
London, S.W.3.

Tel: 01-584 7011 Extension 482

Vacancies exist in our AYLESBURY and CRAWLEY factories for:

SERVICE ENGINEERS

OUR PRODUCT: **Flight Simulators.**

REQUIREMENTS: A complete theoretical knowledge coupled with at least 2 years' practical experience in one or more of the following: Digital computing techniques, hardware, software and computer peripherals. We are prepared to train suitable applicants who have considerable experience in transistorised and integrated circuits.

A knowledge of analogue computing techniques and principles of hydraulics systems would be advantageous. Service Engineers are also required for service on Visual Flight attachment, which involves closed circuit colour T.V. A thorough knowledge of commercial T.V. is essential. ONC or City & Guilds Electronics.

TRAVEL: Must be prepared to travel anywhere in the U.K. and overseas.

SALARY: Negotiable but we are prepared to go as high as £1,800 for the right persons.

APPLICATIONS TO

**Personnel Manager,
REDIFON AIR TRAINERS LIMITED.
Bicester Road, Aylesbury, Bucks.,**

**Personnel Manager,
REDIFON FLIGHT SIMULATION DIVISION LIMITED.
Gatwick Road, Crawley, Sussex.**

520

ELECTRONIC ENGINEERS

Service Engineers required for Offices, throughout the United Kingdom, of well-known Company manufacturing Electronic Desk Calculating Machines. Applicants should possess a sound knowledge of basic Electronics with experience in Electronics, Radar, Radio and T.V. or similar field. Position is permanent and pensionable. Comprehensive training on full pay will be given to successful applicants. Please send full details of experience to the Service Manager, Sumlock Comptometer Ltd., 102/108 Clerkenwell Road, London, E.C.1. 82

ANTARCTIC EXPEDITION

require

Wireless Operator/Mechanics

With current morse speed of 20 w.p.m. PMG Certificate, teleprinter experience essential. Salary from £1,003 according to qualifications and experience with all living and messing free.

For further details apply to:

BRITISH ANTARCTIC SURVEY
30 Gillingham Street, London, S.W.1

406

RADIOLOGICAL PROTECTION SERVICE
(Department of Health and Social Security and Medical Research Council)
Clifton Avenue, Belmont, Sutton, Surrey

requires

Junior Technician and Technician

POST 1 **Apprentice Technician** required for duties in the Department of Electronics to assist in the construction of nucleonic instruments. Preference will be given to those candidates with aptitude and interest in electronics and mechanical practice. Part-time day release for further studies. Five day week. Three weeks' annual leave. M.R.C. Conditions of employment. Salary according to experience at a point on the scale £467 (–922) plus London Weighting.

Applications with the names and addresses of two referees to the Administrative Officer at the above address, quoting reference 70/4/17.

POST 2 **Technician** required for duties in the Department of Electronics to maintain nucleonic instruments and systems. Previous experience of testing and 'fault-finding' on Electronic equipment is essential. Two 'A' level G.C.E.s desirable but not essential. Salary according to qualifications and experience at a point on the scale £982 (–1255) plus London Weighting. M.R.C. Conditions of employment.

Applications with the names and addresses of two referees to the Administrative Officer at the above address, quoting reference 70/4/9.

552

RADIO OPERATORS

There will be a number of vacancies in the Composite Signals Organisation for experienced Radio Operators in 1971 and in subsequent years.

Specialist training courses lasting approximately nine months, according to the trainee's progress, are held at intervals. Applications are now invited for the course starting in January, 1971.

During training a salary will be paid on the following scale:

Age 21	£848 per annum
„ 22	£906 „
„ 23	£943 „
„ 24	£981 „
„ 25 and over	£1,023 „

Free accommodation will be provided at the Training School.

After successful completion of the course, operators will be paid on the Grade 1 scale:

Age 21	£1,023 per annum
„ 22	£1,087 „
„ 23	£1,150 „
„ 24	£1,214 „
„ 25 (highest age point)	£1,288 „

then by six annual increases to a maximum of £1,749 per annum.

Excellent conditions and good prospects of promotion. Opportunities for service abroad.

Applicants must normally be under 35 years of age at start of training course and must have at least two years' operating experience. Preference given to those who also have GCE or PMG qualifications.

Interviews will be arranged throughout 1970.

Application forms and further particulars from: **Recruitment Officer, Government Communications Headquarters, Oakley, Priors Road, CHELTENHAM, Glos., GL52 5AJ**
Telephone No. Cheltenham 21491, Ext. 2270

OPPORTUNITIES IN TELECOMMUNICATIONS

Men with good telecommunications knowledge are required to be responsible for telephone switching, transmission equipment and cables on London Transport. The work involves shift duties and consists of maintaining, testing and fault finding on the following types of equipment:

(a) Automatic telephone exchange and associated equipment.
(b) Radio and television equipment.
(c) Underground cables and lines.

A sound knowledge of one of these categories of work is required. The possession of City and Guilds Certificates (or equivalent) in telecommunications subjects 49 and 300 would be an added advantage.
The rate of pay including a variable incentive bonus averages £28 for a 5 day, 40 hour week. Additional payments are made for overtime, night work and rostered Saturday and Sunday duties.

These positions offer:—
FREE TRAVEL ON AND OFF DUTY, SICK PAY AND PENSION SCHEMES.
Please apply in writing to:
Superintendent of Recruitment, Griffith House, 280 Old Marylebone Road, London, N.W.1. (Ref. A.T.L).

508

Medical Physics Department
QUEEN ELIZABETH HOSPITAL

Electronics Technician

To work in a group responsible for the care, servicing and development of medical electronic equipment in use throughout the Hospital. Applicants should possess ONC, or equivalent qualification, and at least five years' appropriate experience. Whitley terms and conditions (Medical Physics Technician Grade III). Salary scale £1,180—£1,500. Pleasant working conditions in new laboratory. Five day week. Further information from the Chief Physicist.

Applications, quoting one referee, to
Administrator,
QUEEN ELIZABETH MEDICAL CENTRE,
Birmingham, 15
stating age, qualifications and experience

530

The Government of Zambia

MAINTENANCE ENGINEER

Required by the Government of Zambia, Zambia Broadcasting Services, Ministry of Information, Broadcasting and Tourism on contract for one tour of 36 months in the first instance. Commencing salary Kwacha 3,300 (£Stg. 1,925) rising to Kwacha 3732 (£Stg. 2,177), plus an Inducement Allowance of £Stg. 804 per year, payable direct to the officer's bank in the U.K. Gratuity 25% of total salary drawn. Both Gratuity and Inducement Allowance are normally TAX FREE. Free passages. Accommodation at moderate rental. Education allowances. Liberal leave on full salary or terminal payment in lieu. Contributory pension scheme available in certain circumstances.

Candidates, between 25-55, must have passed City and Guilds final certificate in Telecommunications or equivalent and should have had at least eight years experience with a broadcasting organisation, with particular experience in the installation of recording equipment and studio control equipment.

The officer will be required to maintain and service audio-visual aid equipment and instal and operate public address/recording/film projection equipment when and where required. He will be required to supervise workshops and staff in the absence of the Senior Maintenance Engineer.

Apply to CROWN AGENTS, 'M' Division, 4 Millbank, London, S.W.1, for application form and further particulars stating name, age, brief details of qualifications and experience and quoting reference number M2Z/691029/WF.

THE UNIVERSITY OF LEEDS

Applications are invited for a post in the following Department:

FOOD & LEATHER SCIENCE

SENIOR EXPERIMENTAL OFFICER

Funds have been made available from the Sainsbury Centenary Grant for the Advancement of Research and Education in Food Science for the appointment of an experienced graduate electrical (electronic) engineer or similarly qualified person to join a research group investigating the chemistry of the substances responsible for the flavour of foods, using combined gas chromatography-mass spectrometry. His main duty would be to care for the sophisticated instruments involved and to develop the instrumentation further. He would be available also for consultation by other research groups in the Department.

Closing date. 25th May 1970.

Reference number 40/1/CI.

SALARY SCALES: Senior Experimental Officer £1,460-£1,940.

Applications (three copies) stating age, qualifications and experience and naming three referees should be sent to the **Registrar, The University, Leeds LS2 9JT** from whom further particulars may be obtained.

Electronic Test Engineers

Opportunities exist at our Haverhill Plant for Electronic Test Engineers who are capable of fault finding on VHF/UHF mobile and fixed equipment. Applicants should have either;

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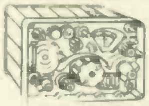

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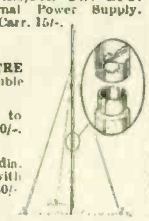

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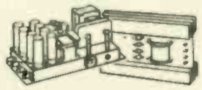

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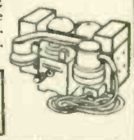

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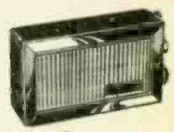

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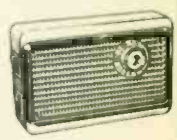

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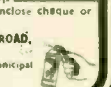

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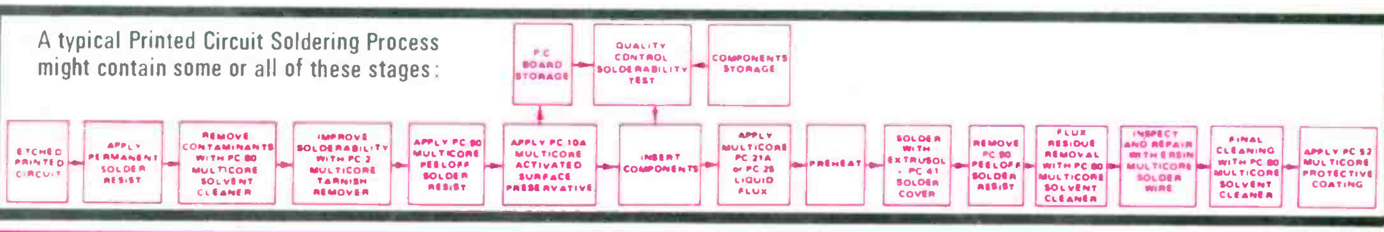

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