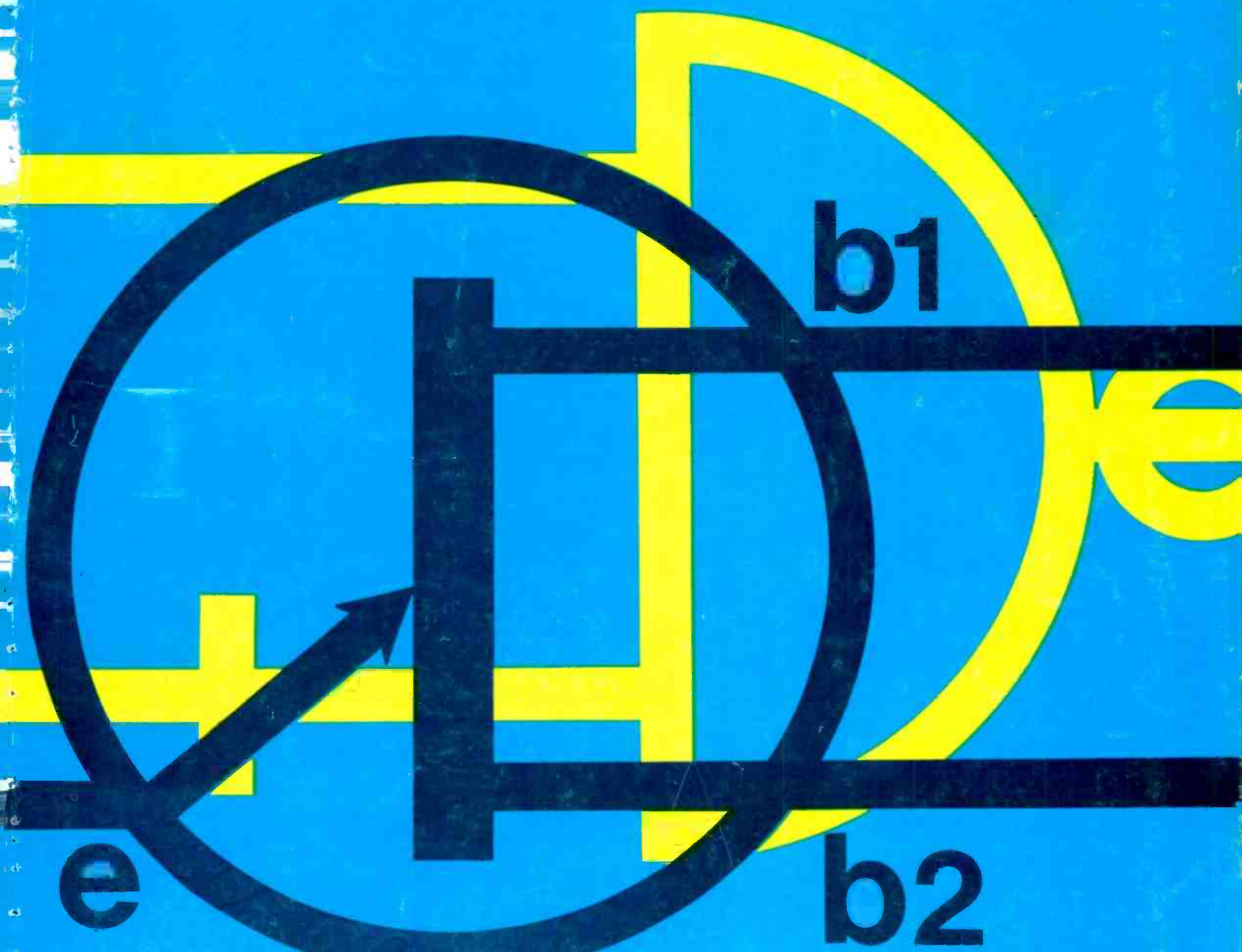
Wireless World

February 1970 Three Shillings

Speakers: horn or direct radiator?

Symbols in electronics



Wireless World

Electronics, Television, Radio, Audio

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This month's cover symbolizes the subject discussed by S. W. Amos on page 63.

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Constructional details of an **ultra-low distortion class A amplifier** with a frequency response of 15Hz to 92kHz (—3dB).
80-metre s.s.b. receiver. Full details for building this amateur band receiver.

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Wireless World

Is there a doctor in the house?

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It was reported some time ago that because so many of the residents in the neighbourhood of one of the NASA research establishments had doctorates it had been decided to call only the medico "doc". (For most G.Ps in this country this is, of course, a courtesy title.) The number of doctorates awarded annually in the U.S.A. is said to be about 20,000 in all subjects and this number is expected to double during the present decade. In this country the number of graduates taking Ph.D. courses is about 2,000.

These facts are by way of introduction to the general question of the Ph.D. system in this country which has come under severe criticism from several different sources and was recently highlighted by Lord Blackett, O.M., C.H., in his anniversary address as president of the Royal Society. He suggested that many British industrialists consider that the present system concentrates so much on basic science that it "unfits many able young people from taking up a career in industry. . . . Thus the attractiveness and efficiency of the British Ph.D. system as a training for basic science is viewed by some industrialists as at least a partial cause of the relative technological backwardness of some parts of British industry."

The Ph.D. degree, which to many a young student is seen as "a passport to the laboratories of the world", is seen by some industrialists as "of little or no use for someone who is to go into industry". Despite this criticism industry recruits Ph.Ds whenever possible "because they believe that at the present time a large fraction of the brightest young people take a Ph.D".

Some months ago the Royal Society undertook an extensive investigation into the suitability of a Ph.D. in engineering and technology as a prelude to a career in industry*. Although divergent views were expressed in the report the consensus was that several changes need to be made in postgraduate training given in universities for students studying for a Ph.D. in engineering and technology. Some of the conclusions are that Ph.D. education should be concentrated in a small number of universities with strong research schools; that the research projects undertaken should be fully justified in their own right as pieces of engineering and technological research; higher entry standards for Ph.D. candidates; and that candidates should be allowed to participate during their studies, in the most technically advanced parts of industry.

Lord Blackett considers that it is "vitally important to maintain and, if possible, strengthen the present outstanding position of British basic science. . . . The Ph.D. system is a cheap and efficient way of getting first-rate research done in basic pure and applied science, and lends itself to the building up of creative multi-national research schools."

What are the prospects for an engineer or technologist who, having undertaken three years' postgraduate research, receives his doctorate? Has he any advantage over his contemporaries who, having graduated, went straight into industry but are not "doctors"? According to the managing director of one of our major electronic companies (who is himself a Ph.D.) he cannot pay them a salary commensurate with their age and academic attainment because there are not a sufficient number of senior positions. Some such major companies consider that they could have given the candidate more industrially oriented technological training in their own research establishments. But, of course, the candidate would not have the piece of vellum, now the cachet which the Ph.D. gives.

It would appear that, for those graduates who plan to join the academic staff of a university or undertake pure research in a Government establishment, the Ph.D. is attractive and worth while. But for those planning to go into industry? The mark of interrogation is large.

* "Post-graduate training in the U.K.—engineering and technology."

Loudspeaker Performance

A discussion of power output and distortion levels for direct-radiator and horn-loaded loudspeakers

*By Paul W. Klipsch**

A loudspeaker is a device to reproduce original sounds. It follows that the basic attributes of a speaker are:

- acoustic power output
- distortion
- polar distribution
- frequency response

in that order of importance.

Defining distortion as the generation of frequencies not originally present enables us to distinguish between this fault and that of errors in frequency response.

Harmonic distortion is relatively unimportant because music consists largely of harmonics, and this attribute is negligible compared to modulation distortion which involves the introduction of inharmonic frequencies not originally present.

For purposes of this discussion and for testing, the spectrum is simplified to contain only two frequencies, f_1 and f_2, and the modulation distortion components would consist of new frequencies

$f_2 \pm f_1, f_2 \pm 2f_1$, etc.

Frequency modulation distortion (f.m.d.) results mainly in first order sideband frequencies.

$f_2 \pm f_1$

and the amplitudes of these sideband frequencies expressed as a fraction or percentage of the amplitude of f_2 is the measure used. There are second-order sideband frequencies, $f_2 \pm 2f_1$, but these are usually very small compared with the first order components.

Amplitude modulation distortion (a.m.d.) gives rise to both first and second order sideband frequencies, and usually higher orders in smaller amounts. If the cone compliance and magnetic system of a loudspeaker are nearly symmetrical it can be shown that mainly even-order sideband frequencies are produced

$f_2 \pm 2f_1, f_2 \pm 4f_1$, etc.

usually with the 4th order components of negligible magnitude. Total modulation distortion (t.m.d.) is the root-mean-square sum or effective value of all the sideband components.

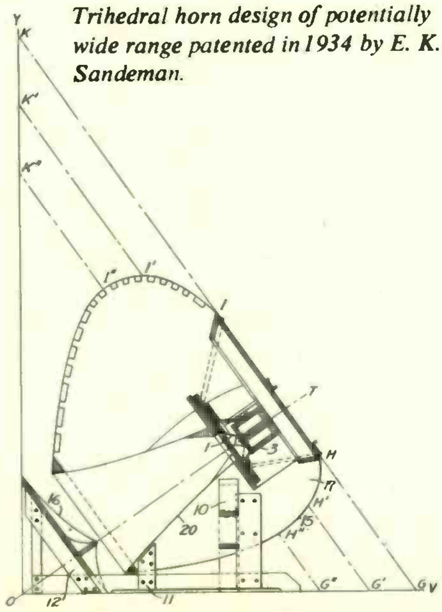
The main purpose of this article is to show the advantages of the horn-loaded loudspeaker over the direct radiator in increasing power output capacity with a reduction in total modulation distortion. Almost always t.m.d. is inversely proportional to efficiency. ("Almost" may be an understatement.) Cost per speaker is somewhat lower for direct radiators than for horns, but the cost per acoustic watt output capacity is vastly higher for the direct radiator.

* Klipsch & Associates, Inc., Hope, Arkansas.

Woofers, squawkers and tweeters

The bass component of a loudspeaker, dubbed the "woofer" in U.S. cinema parlance (the term dating back to the late 20s or early 30s), is the largest and most expensive component. It has to handle the long wavelengths, and to be efficient must have a size comparable to a sixth or even a quarter wavelength. The small "book-shelf" speakers that can handle 25-foot wavelengths must necessarily be inefficient. Also they must be limited in power output. Their t.m.d. is high. To radiate one acoustic watt at 32.7Hz (low C-4) a 10-in cone would have to move 2.2in. To express it another way, if the cone excursion were limited to 0.8in the power output would be only 0.1 acoustic watt. Even this small excursion would produce several per cent total modulation distortion.

Since woofers constitute the most expensive and largest component in a speaker system, and since "more bass" is a popular public demand, the result has been the "long throw" driver unit with excursion capabilities of the order of 0.75in. Practically every "major breakthrough" in new speakers being marketed involves this long-throw aspect, in total disregard of the fact that frequency-modulation distortion is directly proportional to the amplitude of cone motion.



Trihedral horn design of potentially wide range patented in 1934 by E. K. Sandeman.

Costing several times as much as the long-throw bookshelf speaker, horn woofers may require from 16 cu ft (for a corner type) up to eight times that much for a typical theatre "tub"-type woofer. But the cone motion for a given output is reduced to a small fraction of that required in a small-box speaker. The term "undistorted output" is sometimes used. Personally I try to avoid the term. If a cone moves, it produces distortion, so I prefer to use the term "minimum" distortion as applied to horn speakers. Actually the distortion may be reduced by a factor of 1/10 or even 1/100 by the use of horns.

The midrange, which by itself is apt to sound "squawky" and has thus been dubbed the "squawker", is the part of a loudspeaker that carries a great deal of the intelligence and most of the articulation. Distortion in this range can mask the sounds by which one distinguishes, for example, "key" from "tea".

Tweeters when used in conjunction with bass and midrange speakers normally cover only the range above 4 or 6kHz. In other words the tweeter covers the range containing the upper partials of the piano and the "noise" components of speech.

In every case—woofer, squawker, tweeter—the horn offers "cleaner" sound at all practical levels of sound pressure output. Indeed the horn is about the only means for delivering extremely high sound pressure levels with reasonably low distortion.

The cost difference between horn-type and direct-radiator treble speakers is not as great as for woofers, but the advantages are probably greater. After all, the midrange is "where we live" and distortion in this range even in small amounts can be cumulatively irritating.

In comparing horn type speakers with direct radiators, one may start with the drive system which, in the bass range, will be essentially the same for either type. The driver comprises a voice coil in a magnetic field, with a conical diaphragm attached to the voice coil. In the direct radiator, the driver is mounted in a hole in a baffle; the baffle may be a wall or a box; the box may be a total enclosure or ported. Lord Rayleigh wrote the equations for the function of a "rigid circular plate vibrating in an equal circular aperture cut out of a rigid plane extending to infinity".[1] In other words, he described mathematically the action of a "direct radiator loudspeaker" and the true "infinite baffle" about 46 years before Rice and Kellogg[2] were to invent the loudspeaker of this type.

Loudspeaker analogies

A crude analogy of the direct radiator loudspeaker would be a "baffled" piston on the surface of a lake. It could agitate the waters but it would not be much of a pump. But put a cylinder around the piston, and it becomes capable of lifting the water. This is analogous to the driver unit coupled to a horn. The cone is forced to work at higher pressures with lower velocity.

Another analogy is the gear ratio of the automobile which transforms the "low impedance" engine—low torque, high speed—to the "high impedance" drive wheels—high torque, low speed. The direct radiator speaker is a low impedance device—low pressure, high velocity. The gear box is an impedance transformer. The horn acts as a transformer to increase the pressure and reduce the motion of the driving system.

A direct radiator in a box has a hard time acting directly on the large but imponderable body of air in a room, but horn coupling enables the same drive mechanism to be more effective in actuating the same body of air. The transformation results in better coupling between the driving force exerted by the voice coil and the air in front of the horn. An increase in efficiency of the order of 4 to 10 times usually occurs. This means from 4 to 10 times as much acoustic output for a given amplifier output, or a reduction in amplifier requirement by a factor of 1/4 or 1/10 for a given acoustic output.

Choice of driver

The choice of driver unit characteristics becomes a matter of importance, and often different driver unit parameters are chosen for horns than for direct radiators. For example, an extreme case involves adding weight (mass) to the vibrating system to reduce efficiency and flatten the frequency response curve. Such a driver in a direct radiator system might exhibit an efficiency of the order of 0.05%. It would be unsuited to drive a horn system. More efficient direct radiator systems might achieve 1% efficiency. The purpose of the weighted cone is to permit a flat response down to, say, 50Hz in a small box of the order of 1.5 cu ft. Without the extra weight on the cone the box would need to be about 4 to 6 cu ft for the same frequency response but at about 10 times the efficiency. An optimum driver unit matched to a horn would afford the same frequency response (low-end cut-off) with 5 to 10% efficiency.

Modulation distortion

Modulation distortion is directly affected by the amplitude of diaphragm motion, and would thus be greatly reduced by horn loading.

As stated in the introduction, this distortion consists of amplitude modulation distortion and frequency modulation distortion, the r.m.s. sum of which is the total modulation distortion.

It has been shown that f.m.d. is directly proportional to the amplitude of diaphragm motion[3]:

$$\text{f.m.d.} = 0.033\ A_1 f_2 \qquad (1)$$

where A_1 is the amplitude of diaphragm motion in inches at the lower or modulating frequency f_1, and f_2 is the frequency being modulated. The f.m.d. is expressed as a percentage of the signal amplitude of f_2.

This writer applied the audio spectrum analyser to evaluate actual amounts of f.m.d. in typical loudspeakers.[4] Amplitude modulation distortion can also be shown to be proportional to the amplitude of diaphragm motion.*

The fact that both forms of distortion are proportional to the amplitude of diaphragm motion shows the importance of reducing this motion. Recall the example of the 10-in cone radiating 0.1W and performing an excursion (peak) of 0.7in (0.25in r.m.s. amplitude). Suppose f_2 were 700Hz, then

$$\text{f.m.d.} = 0.033 \times 0.25 \times 700$$
$$= 6\%\ \text{approximately.}$$

The t.m.d. might well be twice that amount. Experiments with "long throw" direct-radiator speakers have shown t.m.d. of this and higher order of magnitude.

A horn-loaded driver of comparable size might deliver 1.0W output with 0.07in excursion, the f.m.d. would be about 0.6% and the a.m.d. would be insignificant. A bonus would be that the efficiency would have been multiplied by a factor of about 10, and the demands on the power amplifier reduced.

So far it is not known how much modulation distortion is "objectionable", "barely audible", "marginal" or "tolerable". We do know that listeners describe good horn speakers as "clean" and "transparent", and the smaller direct radiators as "veiled" and "muddy". In between are the better and larger direct radiators, and the descriptive terminology varies with whether such speakers are compared to inferior direct radiators or superior horns.

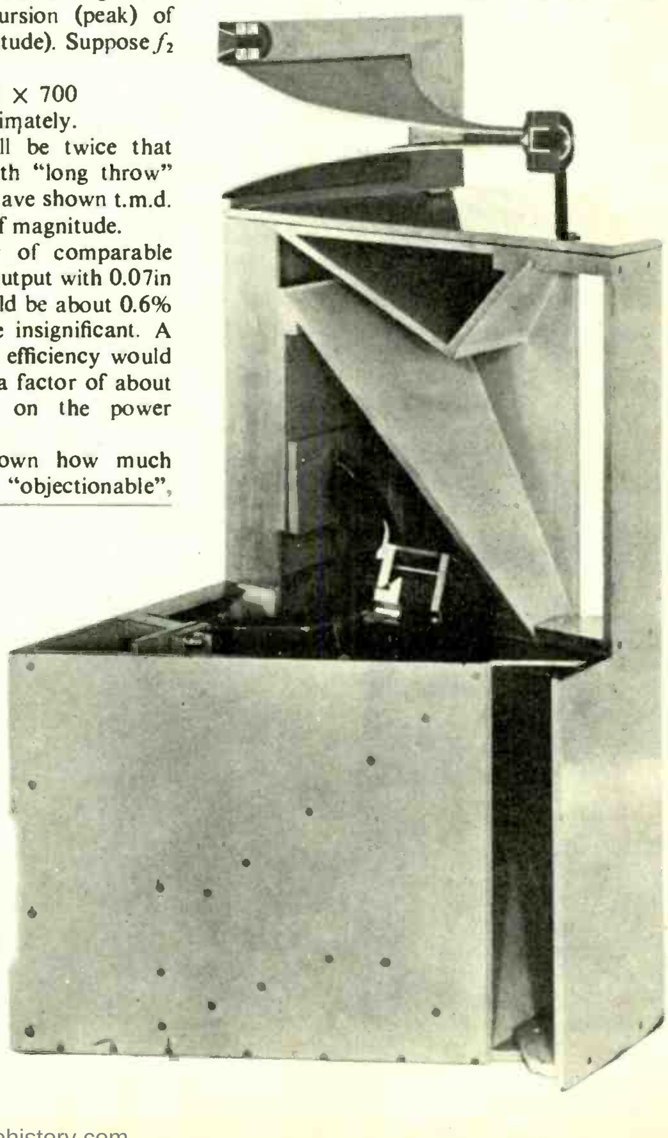
We know too that the shellac disc was the marvel of the age in 1909 and that words were barely intelligible; by 1919 things had improved, and by 1939 had improved some more. But now we realize that the response errors and distortion on these old records preclude pleasurable listening. By 1989 perhaps current 15 i.p.s. tapes will be scorned to the same degree. Surely our tolerance of distortion is decreasing.

Size and cost

A speaker of only 1.5 cu ft having a reasonably flat response down to 50Hz is an accomplished fact. A horn system with comparable response would entail 20 cubic feet. There is a vast difference in the power output capacity. The small direct radiator might handle 90dB sound pressure level (s.p.l.) at 2 feet with 10% total modulation distortion, and the horn 100 times as much power (110dB s.p.l.) at less than 1%.

The cost is always a factor. A typical 1.5

* Unpublished paper



Cutaway model of Klipschorn showing exponential sound passages and back air chambers of bass horn, and section of mid-range horn. The high-frequency horn and driver can be seen over or on top of the mid-range horn.

cubic foot direct radiator might typically cost $150 to $250 (£62 to £104) and a high quality horn system would cost $600 to $1000 (£250 to £410). Expressed in terms of cost per watt output, the horn wins by a wide margin—see Table 1.

If one includes the cost of amplifier power the advantage is still further in favour of the horn system.

Upper frequencies

Much of the foregoing text has been written with bass loudspeakers specifically in mind. The bass part of a 2- or 3-unit loudspeaker is the most bulky, massive and expensive part.

But the facts relating to distortion and power output are at least equally applicable to treble speakers. Perhaps more so; the midrange, from 400 to 6000Hz is the region where the ear is most sensitive. It is in this range where distortion can be detected by ear in quantities that would defy instrumental detection except with highly sophisticated devices such as a spectrum analyser with a 60dB range. The midrange is where we live. A recent article[5] describes a "Jecklin" horn bass-range loudspeaker (which appears to be based on my paper of 1941[6] but the author employs small direct-radiators for the upper frequencies). Our experience with such a top-end speaker showed that it displays over 5% sideband amplitudes and over 10% total modulation distortion at only 90dB s.p.l. output. A good horn system displayed less than 1% t.m.d. at 100dB s.p.l. at 2 feet. To repeat, the midrange is "where we live" it is the range that costs the least in money to be right and costs the most in listener displeasure when it is wrong.

Tests

To illustrate, Fig. 1 shows the spectrum analysis of two speakers; top, a high quality horn-loaded midrange[7], and bottom, an 8-in direct-radiator midrange. (This was by no measure a "cheap" speaker!)

The figures were traced from spectrograms photographed on a Tektronix 564 oscilloscope with a 3L5 spectrum-analyser plug-in unit. The left edge is $f = 0$. The two solid bars are the acoustic outputs resulting from inputs of $f_1 = 510$Hz and $f_2 = 4400$Hz. The dashed bars are distortion components; in the top figure (a) there are two sideband frequencies of $f_2 \pm f_1$. The grid represents 10dB intervals, so the sideband components are more than 40dB below the amplitude of f_2. The t.m.d. is less than 1%.

In the lower figure (b), one sees harmonics of f_1 out to the 4th harmonic, and both first and second order sideband components of significant amplitudes, the t.m.d. amounting to a little over 10%.

The sound pressure level output of the horn system was 100dB s.p.l. at 2 feet; for the direct radiator the output was only 90dB.

In my Audio Engineering Society[4] paper I proposed to call the percentage of

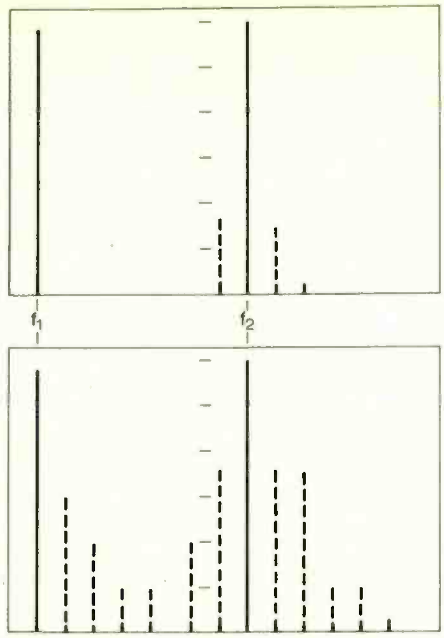


Fig. 1. Spectrum analysis of the output of a high quality horn-loaded midrange speaker (top) and an 8-in direct-radiator midrange (bottom).

t.m.d. the "mud index". Since the t.m.d. is dependent on power output it might seem desirable to employ a "mud/power" index where the t.m.d. is divided by the power output with 100dB s.p.l. chosen arbitrarily as unity. Thus the mud/power index for the horn would remain at less than 1% or simply one, and the index for the direct radiator would be 10%/0.1 or 100% or 100. (0.1 being the power ratio of 90dB relative to 100dB).

The £400 horn is not going to replace the £4 cone in a cheap radio. There is a lot of sense in replacing some of the high-distortion cones with small horns at a small cost increase where intelligibility is important, and there is a lot to recommend the £400 horn over a £50 direct radiator for entertainment. One just doesn't have to filter the music from so much mud.

In the specific example of the Jecklin version of my 1941 woofer, the major cost has already been incurred; the bass system has cost £100 or 200 hours labour or some such near equivalent, and to put a direct radiator tweeter on it gives it the overall performance of a cheap direct radiator speaker. At our plant we spent vastly more man-hours and man-years developing a "top end" (midrange and tweeter system) than we did on the woofer. To say again, the midrange is where we live.

Corner speakers

Take any loudspeaker of any size, make, type or price and compare its operation in a corner with its operation in some other location. You may reasonably expect 3 to 6dB more power output for a given input,

Table 1

	Watts output	Cost £	£ per watt output
Small DR	0.05	100	2000
Large DR	1.0	200	200
Large Horn	10	400	40

a slight reduction in total distortion and beneficial response characteristics over the entire audio spectrum. We tested a small direct radiator and found corner operation extended the bass range 1/4 octave, improved response at 16kHz and averaged 5dB increased sound pressure level for a given input.

The principle is that of "mirror images". A speaker in close proximity to a wall has, in effect, a mirror image behind the wall, doubling the effective radiating area. The three walls at a corner double the effect three times.

If my 1941 bass horn (and the "Jecklin" version) were not in a corner it would have to be eight times as large. Its actual mouth area is only 780sq in but its effective area is eight times that value. All speakers (I have found no exceptions) work better in a corner. This applies to the "audio" function; it also applies to the "stereo" function. But stereo is another story. Take my word for it, that every experiment we have conducted in stereo bears out the advantage of using corners for speaker placement. As for the audio function, try it, preferably with a small enough speaker to be lifted easily. While it is playing have someone walk it into a corner. Listen.

This is one way to double or quadruple the sound pressure level without increasing distortion.

Combining corner operation with horn loading affords the ultimate in low distortion at whatever power level desired.

Conclusion

Horn loading and corner operation offers the lowest distortion per unit of power output. The combined effect offers an improvement in performance per unit cost by a factor of 100 or more. Of importance also is the reduced power amplifier requirement for a given acoustic power output.

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Time

. . . . like an ever rolling stream bears all the charge away

Thomas Roddam discourses on time constants

One of the results of the electronics explosion has been to convert a good deal of design work into ritual. We substitute numbers in expressions for the component values in standard circuits. If we are lucky the expressions are already safely lodged in the computer and we really need not know what they are: if we are unlucky we must look them up in a book and drive our own slide-rule. A good many young engineers do not even need to know what the final object of the performance will be.

I believe that there may be some spiritual or philosophical virtue in inventing the mantra *Om mani padme hūm*. I cannot see any merit in copying it down and spinning it on the shaft of an electric motor. Ritual in fact becomes even more than a substitute for thought: it becomes an excuse for avoiding thought. One way of making sure that you still can think is to consider the first principles of your art.

The first problem in attempting this is the rather unexpected one of deciding what we are talking about in discussing electronics. An obvious answer is quite simply electrons in action. This does not really suit my purpose, because in order to keep my thoughts related to experience I need to deal with things which I can measure. Individual electrons are not the stuff on which our circuits are based. Nor, in general, is the electromagnetic field. Circuit design, at bottom, is an affair of amps and volts.

Amps, volts and seconds. The changes which take place in the currents and voltages with the passage of time are the business of the circuit designer. The digital circuit engineer may think that he has avoided this, that he is concerned only with states of a system. If this is true for him, he is a lucky man who has managed to let someone else have his hang-over. Someone, somewhere, has worried about what happens during the time, which may be only nanoseconds, when the system is changing state.

If we are to start at the beginning it seems reasonable to take our old friend Ohm's Law. Although we regard this as pretty commonplace, we must remember that in any real situation,

$$V = IR$$

implies really a term which we should write

$$R(V, I, t).$$

So long as there are supplies of nickel we can get components for which the ratio (V/I) is so nearly constant, at our sort of voltage and current level, that R can be regarded as independent of voltage, current and time. The constancy of R is, of course, vital in ensuring circuit linearity and the low distortion of the best feedback amplifier is an indication of how R can be regarded as completely independent of V and I. In practice we do not need to take elaborate precautions to obtain resistance elements which can be treated as pure Ohm's Law components. There will be parasitic inductance and capacitance, there will be aging effects, the cheap may well be nasty, but on balance we find that the modern resistor is a very close approximation to the ideal.

Just as well, perhaps, because few laboratories have any way of checking this. It is a long time since I was at school, but my guess is that your first introduction to Ohm's Law was to draw a graph of V against I for some sort of resistor, using, to measure V, a moving-coil meter which measured the current through another resistor. This is just one of those traps which are waiting for us when we look back at the foundations on which we have built.

The ideal resistor is a physical component which has a characteristic, resistance, which is independent of time. It is, now, and the past is wholly irrelevant. The other two simple passive elements are, in a way, pure memories. Throbbing between two lives they have foresuffered all.

The capacitor is also a physical component which is very nearly ideal in its commercial form. What is the essential characteristic of capacitance? The physicist might say that it is energy storage. If we put an amount of charge Q into a capacitance C we shall have bottled up (Leyden, not Kilner) an amount of energy equal to $(Q^2/2C)$. Very nice too, but all I have is an Avo and a stop-watch. I can't measure Q and I can't measure the energy. Another way of defining capacitance is by the equation $C = Q/V$. Capacitance is the charge stored per volt. Again there is this wretched charge, but here we have quite a useful equation. Suppose that we have two capacitors, C_1 and C_2 (and their capacitances are the same as their names), each charged to some voltage V. We have, in fact, just applied the same battery in turn to their terminals. Now we join the terminals by ideal conductors in the way shown in Fig. 1. No current will flow when the switch is closed. We had

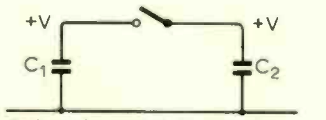


Fig. 1. When the switch is closed no current will flow.

$$Q_1 = C_1V \quad \text{and} \quad Q_2 = C_2V.$$

V is unchanged, the total charge is unchanged, so we now have

$$(Q_1 + Q_2) = Q = (C_1 + C_2)V.$$

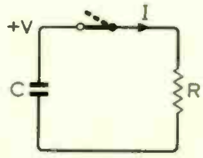
This definition is thus the obvious one for establishing the rule for paralleling capacitances, and it is easy to use it (if we use equal charges) for establishing the rule for series connection.

Simple stuff, you may say. Not to all readers. I met recently, in a small company, a senior man who designed, if that is the word, relay circuits, for production, but who was baffled by the currents in a series. parallel combination of three resistors.

For practical purposes we are still a little far from practicality. We know that a capacitor will store charge or energy. The classic experiment using a group of monks is not easy to perform, but electricity shocks layman and cleric alike. And why think of this energy simply when stored and static, like a bar of gold under a French peasant's bed? Let us shift it from store to store, like marks and dollars hunting the most profitable home, or spend it, dissipate it in a resistance.

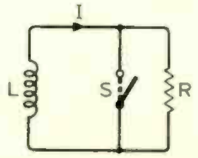
The hot coulomb will come later. Now we can get towards the first kernel of our story by considering the circuit shown in Fig. 2, a circuit so simple that it does not even need a caption. At the instant when the stopwatch is started, current begins to flow and, at this moment, when $t = 0$, the current must be given by

$$I = V/R.$$



S closed at t = 0

Fig. 2.



S opened at t = 0

Fig. 3.

Notice that we can measure all these things, even though, if the time-scale of the whole experiment is very short, we may need something a bit more sophisticated than a moving-coil meter.

We have this idea of charge and capacitance, with $Q = CV$. The current, I, represents the flowing away of charge. Flow is often a measure which makes more subjective appeal than quantity: the speed and depth of a river are the quantities which we think about as natural man; the volume and height of a lake we only consider as engineers.

In this simple circuit Q is not constant, because we have charge flowing away as current. At any time $t = t$ we have

$$\frac{dQ}{dt} = -I$$

There are several different ways of proceeding from here and we want the one which looks easiest. If we write

$$I = V/R = Q/CR \quad \text{we get}$$

$$\frac{dQ}{dt} = -\frac{1}{CR}.Q$$

and thus $$\frac{dV}{dt} = -\frac{1}{CR}.V$$

or $$\int_1^V \frac{dV}{V} = -\int_0^t \frac{dt}{CR}$$

The limits are put in for $V = 1$ at $t = 0$, because then we use the definition (Hardy, *Pure Mathematics*, p. 358 of 5th ed.)

$$\log V = \int_1^V \frac{dV}{V}$$

and so $$\log V = -t/CR$$

Notice that this is a function theory definition of log. The properties are proved from this definition, and then you start carving your slide rule. Another definition gives us

$$V = e^{-t/CR}$$

or, if we started with $V = V_0$ instead of $V = 1$

$$V = V_0 e^{-t/CR}$$

In the most general way, we can arrange this as:

$$\frac{V}{V_0} = e^{-t/t_0}$$

I have written $CR = t_0$, because the term t/CR must be dimensionless, a number.

Quite formally then we introduce a characteristic time, $t_0 = CR$, associated with the resistance-capacitance circuit. Quite naturally we call this the time constant. Very often you will find references to ohm-farads, or megohm-microfarads: can you run 100 yards, or metres, in 10 ohm-farads. We should think more often of our capacitors in terms of their (seconds/ohm) capacitance. The audio engineer, nowadays, is concerned largely with milliseconds/ohm and milliseconds/kilohm sizes. For example, smoothing the power supply to a transistor amplifier his characteristic time is 10 milliseconds (100 Hz) and the resistance may be 20 ohms (20 V, 1 A). The capacitance which just starts to smooth the ripple will be 0·5 millisec/ohm. In fast switching circuits capacitances measured in nanosecs/ohm will begin to interfere with operations. Of

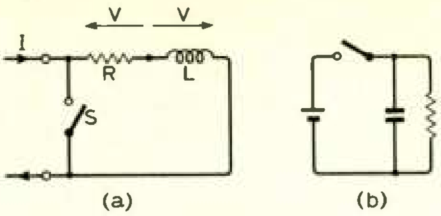


Fig. 4.

course we shall go on talking about microfarads and pFs. The fact that we are also thinking of seconds per ohm, or amp seconds per volt, enables us to keep the feeling for magnitude which picks up stupid errors. And if you don't think stupid errors can happen, ask anyone who bought Poseidon shares when borehole No. 4 reported 9·38% nickel, only to learn, 15 minutes later, that the figure was really 0·38.

One aspect of this analysis I find particularly interesting is that if the mathematicians had not caused the exponential function to exist, we should have had to invent it. It is the description of observed behaviour. And it all depends on the fact that both C and R are constants, because if C were not constant we should have had

$$\frac{dQ}{dt} = C\frac{dV}{dt} + V\frac{dC}{dt}$$

and the second term would not have been thrown away.

Let us turn away from the RC circuit to consider inductance. Exclude from your mind, for the moment, your views on inductors and consider only the abstraction of pure inductance. What is its basic property? We saw that capacitance, left alone, open-circuited, remembered voltage. Inductance, left alone, short-circuited, remembers current. Generally it is necessary to carry out this experiment with superconductors to obtain the sort of time scale we can get very easily with a commercial capacitor, although one practical exception is the reversal of power flow in international submarine cable energy links.

How do we deal with inductance? We had to mention charge in discussing capacitance, even though the charge concept carries the odour of pith balls, cat's skin and glass rods. I don't know when real cat skin was last used in school physics although I have heard a lecturer describe how his early magnetic research was thrown into confusion by a lady (what else?) assistant's stay bones. Charge, however, is simply the amp second storage of a capacitor in a particular state, that is capacitance C charged to voltage V. An equivalent situation for an inductor will be the volt second storage with an inductance L carrying a current I. The object of this is to keep our mathematics in similar form to the previous batch. We write

$$M = LI$$

and instead of the usual $V = L dI/dt$ we say

$$\frac{dM}{dt} = +V$$

This equation agrees with the volt second storage concept, the fact that

$$M = \int_0^t V dt$$

The rules of procedure which I have adopted lead to some confusion of signs. Drawing the circuit in the form shown in Fig. 4(a), with a constant current source, makes things clearer. The source is removed effectively by closing the switch, just as we could have studied the RC circuit by working with Fig. 4(b), in which the start, at $t = 0$, is when the switch is opened. Conditions for negative values of t are slightly different, but that does not matter.

With the arrangement shown in Fig. 4(a) we see how the senses of the voltage across the inductance and the voltage across the resistance appear. After $t = 0$ we have, of course,

$$V = IR = MR/L$$

The induced voltage is in the opposite direction and is $-dM/dt$, so that

$$\frac{dM}{dt} = -M\frac{R}{L}$$

giving $$\frac{dI}{dt} = -I\frac{R}{L}.$$

and $$\frac{I}{I_0} = e^{-t/t_0}$$

where $$t_0 = L/R$$

Again we see the natural appearance of a time constant, the natural appearance of the exponential. Now, however, the unit of inductance is the second-ohm. In the smoothing application, with $t = 10$ milliseconds and a 20-ohm circuit we see that smoothing begins at around 200 millisec-ohm, or 0·2 H. At the other extreme, 20 nanoseconds times 50 ohms gives us one microhenry, the inductance of two or three feet of wire. Of course, if the wire forms part of a transmission line, 20 nanoseconds is the order of magnitude of the propagation of energy along it.

One of the difficulties the practical engineer experiences is the imperfection of real inductors. He may avoid this problem throughout his career; he may, at the other extreme, base his career upon it. Those who are engaged in work on low-level selective circuits, for example, do not consider inductance to be a really awkward element. One must account for the inevitable resistance, but it is a relatively small term so long as you do not let ambition outrun performance. The order of magnitude of the LI product is, however, only around 10^{-4} henry-amps, or 10^{-4} volt-seconds.

We move into quite a different world when the inductor must support, say, 200 volts for 1/100 second. Now we have 2 volt-seconds to consider. Whether one considers energy density or "charge" density as the criterion is an interesting question, but even with charge density the ratio is $(27)^3$:1. Inductors for power system working are designed to be of reasonable size, while inductors for low-level filters are designed to be of convenient size, to use wire which will not break in handling.

The capacitor designer, at one time, had the same problem. Fifty years ago the Carnarvon transmitter incorporated a capacitor which filled a room, its air-spaced plates hanging down like the week's washing in a Spanish slum. On one occasion,

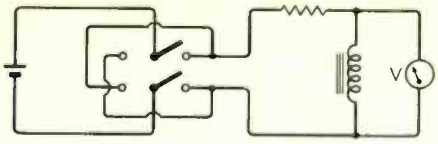


Fig. 5. Basic circuit for examining saturation time constant.

indeed, a dog walked into the capacitor. Steady progress from waxed paper to polywhatsit film has brought the factor CV/inch^3 down without any loss of linearity. No such luck for the inductor designer. He is stuck with iron, or, more precisely in inductor design, a combination of a selected iron alloy and air.

I do not think this is the point at which I want to discuss inductor design. There is, however, another time constant which appears when we talk about iron-cored inductors which may, conveniently, be mentioned.

Suppose that we take such an inductor, which we believe to have an inductance L. We apply a voltage to this, and watch the behaviour of the current. It follows the simple law

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

or

$$I = \frac{V}{L}.t,$$

growing linearly as time passes. Grows linearly, that is, until quite sharply, it starts to increase at a much higher rate. If the equations above have any meaning, the inductance L must have fallen to a much lower value. The sharpness of the change depends very largely on the core material, and in practical use of this phenomenon any air-gap and any eddy-current effects must be taken into account. This is, of course, the phenomenon of saturation.

We have been adopting the modern "discovery" method of learning in our approach to the CR and LR circuits. This is also known as Squeer's Way (W.I.N.D.E.R, winder = now go and clean them). The basic experiment is a simple one. If we connect a battery, a reversing switch, a resistor, and a voltmeter to our inductor, in the way shown in Fig. 5, we can carry our core from saturation in one direction to saturation in the other. The resistor is only there to protect the battery and should be relatively small (whatever that means). When we flip the switch the voltmeter will read nearly the full battery voltage and will fall steadily as the product IR increases, until I jumps up. We want this drop to be quite a lot less than V for our experiment to be meaningful.

The first experiments will show that a particular inductor has a particular volts-seconds product. This time constant is not a constant at all, but is inversely proportional to the applied voltage. Further experiments reveal that it is in fact proportional to the turns per volt for a fixed core area. It is also proportional to the core area. The overall picture leads us to a property of the core material, the saturation flux density, with the defining equation

$$Vt = 2NAB.10^{-8}.$$

The units are cm^2 and gauss, because those are the units adopted by the core material makers in their tables.

This kind of time constant is quite different theoretically from the CR and L/R constants discussed at the beginning. It is interesting to notice, therefore, that both kinds are used in otherwise similar circuits, in inverter circuits. The CR type is used mainly at frequencies in the kilohertz range, while the switching core type is commoner at low frequencies. There are other, minor, differences which relate to the detailed design. And certainly frequency is not fundamental, for to get time constants measured in terms of seconds we should certainly use the CR circuit.

After this diversion it seems appropriate to refresh the reader's memory. With resistance and one kind of reactance we can generate, by a switching operation, a waveform which turns out to be the exponential function of the mathematicians. The scale of this is defined by the product CR, or the ratio L/R.

Books Received

The Semiconductor Data Book from Motorola is now available in its fourth edition. Instead of a number of product categories, discrete device specifications are presented in alpha-numeric sequence in three major sections: '1N' numbered devices; '2N' and '3N' numbered devices; and devices with Motorola "house" numbers. It is thus easier to obtain data. Also a 50-page section of selection guides enable application requirements to be related directly to semiconductor device numbers. Furthermore, the book lists all '1N', '2N' and '3N' devices registered by the U.S. Electron Industries Association along with their short-form specifications. In all, more than 12,700 types are listed together with details of their characteristics. Pp.2160. Price £3 (plus 6s postage). Available from the Modern Book Co., 19 Praed Street, London W.2.

Tape Recorders: A-Z is essentially a catalogue of magnetic tape recorders available in the U.K. Also included are lists of mixers, headphones, tape, and accessories. The video tape recording section is divided into two parts—machines using ½-in or 1-in tape, and those using 2-in tape. Essential technical specifications are supplied for each model along with a photograph, the price, and the address of the manufacturer or agent. This presentation is used for the recorder sections which are: professional (scientific and industrial) audio tape recorders; domestic and hi-fi tape recorders (including car tape recorders/players); tape teaching machines (domestic type); and background tape players. Pp.164 including an index. Price £1. APA Publishing (Catalogues) Ltd, Quality House, Quality Court, Chancery Lane, London W.C.2.

New Ceramic Control Device

Using the principles of both piezoelectricity and ferroelectricity, a new ceramic element invented at RCA Laboratories, U.S.A., has possibilities for remote and near control of domestic and other electrical appliances. It enables supply currents to be switched on, turned off or varied continuously. Being completely electronic it seems to offer longer life and higher reliability than the electro-mechanical devices often used for remote control. A particular feature of the new element is that it will "remember" its last control setting indefinitely, even if its supply power is cut off.

The device is constructed as a "sandwich" consisting of two ceramic wafers, each with piezoelectric and ferroelectric properties, bonded together by epoxy resin. The principle of operation is that when a material has both these properties a change made in the ferroelectric polarization alters the efficiency of the material's piezoelectric effect. When an a.c. signal is applied to one wafer, this wafer vibrates because of its piezoelectric property. The vibrations are transmitted through the epoxy bonding resin to the other wafer, which converts them back into an electrical output signal. The amplitude of the piezoelectric output signal can be varied by subjecting either wafer to an electrical pulse, which changes the ferroelectric polarization in the wafer and thereby its piezoelectric efficiency. Since the wafers are made of a stable ferroelectric material, the output signal is stable and changes only when the polarization is changed.

Two versions have been developed. One responds only to input signals in a narrow frequency range, while the other responds to input signals covering a broad frequency spectrum. Both versions use wafers made of ceramic lead zirconate/lead titanate material, often used in gramophone pick-ups. A wafer's polarization can be altered by any desired amount by applying voltage pulses to produce an electric field typically 10 to 45 volts per thou' of wafer thickness. In this way, the output signal can be varied continuously over a dynamic range of approximately 60dB, in a period as short as one millisecond or as long as 1,000 seconds.

At present the device is purely experimental: no commercial exploitation is envisaged for the moment. Also it has not yet emerged what advantages this component might have over semiconductor control devices such as the thyristor and triac.

Ceramic Pickups and Transistor Pre-amplifiers

Are they incompatible?

by B. J. C. Burrows, B.Sc.(Eng.)

Of the pre-amplifier designs published in *Wireless World* over the past eight years or so, Mr. Linsley Hood's[1] is the first to provide proper equalization for ceramic pickups. This article explains in greater detail how he derived his pre-amplifier replay characteristics and gives a new simple circuit for correct—yet adjustable—equalization.

Ceramic pickups work on the piezo-electric principle, as do crystal pickups, and thus they are basically alike. The likeness extends further since historically crystal pickups were the first to be developed and marketed on a commercial scale, and they were followed by ceramic pickups (which are more reliable than their elder brethren, being less affected by temperature and humidity extremes). Many of the traditions of crystal pickup manufacture were carried over to ceramic cartridges, such as built-in mechanical compensation, and perhaps ceramic pickup manufacturers assumed that their products would be used generally into a high-impedance amplifier as in the "crystal pickup plus valve amplifier" days. It is apparent that many people experienced difficulty in using ceramic pickups (which usually need an input impedance of twice that for crystal pickups) with transistor pre-amplifiers and this has resulted in a wealth of designs for high input impedance converters using f.e.ts etc. to overcome the problems. The author thinks that this is an unsatisfactory method and that better results will be obtained by re-thinking the problem from scratch. By looking at the basic operating principles of the pickup and comparing these with the requirements, a simple design may readily be evolved.

Piezo-electric pickups

Let us first have a close look at the important characteristics of piezo-electric pickups and contrast them with a typical magnetic pickup. As the name implies, the piezo-electric pickup depends upon the piezo-electric effect—that is, when certain crystals like Rochelle salt and barium titanate are strained (i.e. bent, twisted etc.) an e.m.f. is developed across the faces of the crystal. Conducting layers deposited on the opposite faces of the crystal with wires attached complete the piezo-electric transducer. The piezo-electric e.m.f. is proportional to the strain in the crystal element, so the e.m.f.

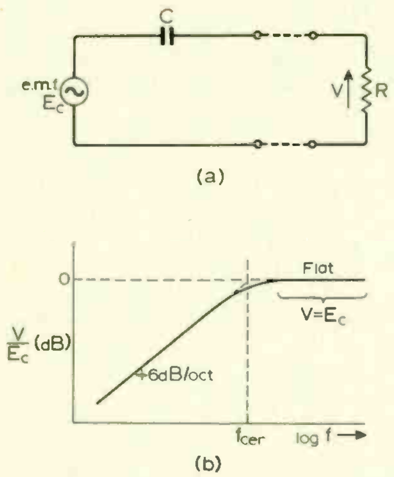


Fig. 1. (a) Equivalent circuit and (b) frequency response of piezo-electric pickup. $f_{cer} = \dfrac{1}{2\pi CR}$ (C in farads, R in ohms, f in Hz).

depends upon the amplitude of movement of the device transmitting the force to the crystal. Thus, in the case of a ceramic pickup the e.m.f. produced by stylus movements is proportional to the instantaneous deviation of the groove from the unmodulated position, or as is commonly said, the e.m.f. is proportional to the amplitude of the groove. This is the first fundamental difference between ceramic and magnetic pickups.

The second important feature is that the piezo-electric crystals are dielectrics and hence the conducting layers together with the crystal form a capacitor—typically 700 pF to 1500 pF which appears in series with the piezo e.m.f.*

We can draw an equivalent circuit for the pickup feeding into a resistive input impedance and this is shown in Fig. 1(a). The pick-up consists of a zero impedance

*Sometimes the impedance of a pickup is quoted as, say, 2 MΩ. This practice is misleading, because owing to its capacitance the impedance is inversely proportional to frequency, and almost purely reactive. Obviously the pickup will have a reactance of 2 MΩ at only one frequency (~50 Hz). I think, too, that an impression exists that one has to "match" a pickup to an amplifier like matching a loudspeaker to the amplifier output stage. Perhaps matching is an appropriate expression for the pickup case, but the reasons that govern the choice of "matching" impedances are quite different in the two cases. [See p. 66—Ed.]

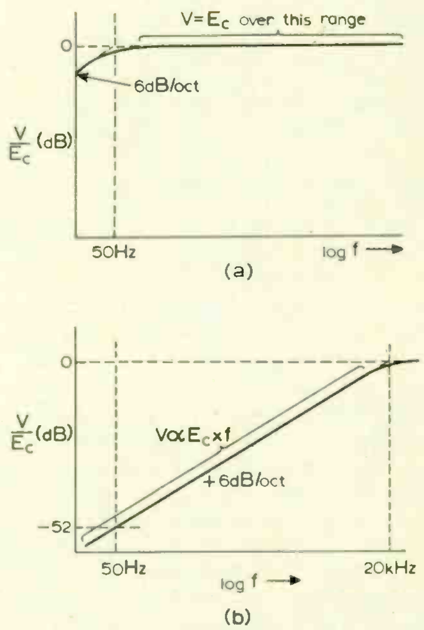


Fig. 2. (a) High-resistance loading, R = 4 MΩ and (b) low-resistance, "velocity" loading, R = 10 kΩ.

generator in series with a capacitor. Fig. 1(a) will be immediately recognized as a differentiation circuit, that is, a high-pass filter whose cut-off frequency, called f_{cer}, separates a region of slope 6 dB/octave from a region of zero slope, as shown in Fig. 1(b).

For example, if $C = 800$pF and $R = 4$MΩ, then f_{cer} occurs at 50 Hz. This will be termed high-impedance loading because the voltage developed across the load is substantially independent of R and is equal to E, the pickup e.m.f. over the whole audio frequency range. That is to say, the voltage at the amplifier terminals equals the pickup voltage. So, *if* records were recorded with a constant amplitude characteristic† a perfect piezo-electric pickup would require no further equalization.

An alternative method of operating the pickup is the "low-impedance loading" or "velocity loading" method. Here we choose R to place f_{cer} at the highest end of the frequency spectrum—say 20 kHz—where

†"Constant amplitude characteristic" means here that the records will have been recorded in such a way that a perfect zero impedance amplitude-sensitive pickup would produce a signal requiring no further correction before being amplified and fed to the loudspeaker.

R would equal 10 kΩ for a pickup capacitance of 800 pF as before. Referring to Fig. 1(b) again it can be noticed that if f_{cer} lies at 20 kHz, the whole of the audio spectrum lies on that part of the curve with a rising frequency response of 6 dB/octave. Only above 20 kHz is V equal to E, so at 50 Hz V is very low (approximately −52 dB). The name "velocity loading" has been given to this mode of operation because the output shows a rising response with frequency as obtained from a magnetic pickup under appropriate conditions (see below). One frequently comes across this recommendation: to give approximate "velocity loading" load a ceramic pickup with 68 kΩ! This recommendation is unjustifiable since the "velocity loading" will be effective only up to 2·5 kHz, and at 12 kHz, for example, 68 kΩ loading gives 12·6 dB less than true velocity loading.

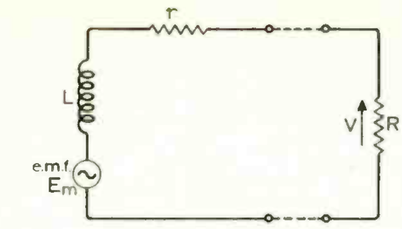
Figs. 2(a) and (b) summarize the above ideas for a ceramic pickup of 800 pF operating into a load of (a) 4 MΩ and (b) 10 kΩ, while playing a constant amplitude recording.

Magnetic pickups

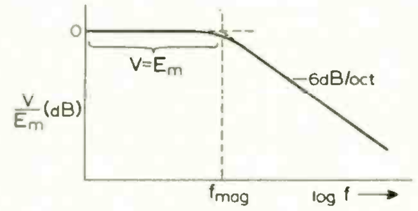
I hope the reader will forgive the rather lengthy discussion on piezo-electric pickups—a few quick words will sum up the essential features of magnetic pickups. A similar type of equivalent circuit may be drawn except that, first, the e.m.f. is proportional to the velocity of the stylus at any instant and, secondly, this e.m.f. can be thought of as a zero impedance generator in series with an inductance, typically 500 mH. Fig. 3(a) shows the equivalent circuit and Fig. 3(b) the frequency response of this circuit when stray capacitance is ignored. It is seen that up to f_{mag} the voltage V across the amplifier input equals E, the pickup e.m.f. Now, if we assume that such a magnetic pickup is used to reproduce from a constant amplitude record, E (the pickup e.m.f.) is directly proportional to the frequency f. E is rising at a rate of 6 dB/octave over the whole frequency range and therefore V will also rise at the same rate up to f_{mag} and then turn "flat" above it. This is shown in Fig. 4 for the case when R = 65 kΩ. By analogy with piezo-electric pickups, 65 kΩ loading would be termed high-impedance loading, because the audio range lies entirely in that region of the curve where the amplifier input voltage is equal to the pickup e.m.f. (which is proportional to frequency). Low-impedance loading is of no practical interest*, but intermediate impedance loading is practicable[2] and in this case f_{mag} is made 2100 Hz.

If Fig. 2(b) is now compared with Fig. 4 it is seen that they are identical in most respects, particularly in having the response $V \propto f$ over the whole audio spectrum. Both curves apply only to pickups on constant amplitude recordings. This means therefore

*This is true because low-impedance loading would produce a very small output voltage although giving a flat frequency response in principle. A smaller output voltage would aggravate the noise problem, and in any case the value of R required to make f_{mag} = 50 Hz is 160 Ω which is already less than the actual a.c. resistance of the pickup coil! Intermediate loading is practicable though with many magnetic pickups.



(a)



(b)

Fig. 3(a). Equivalent circuit and (b) frequency response of magnetic pickup. $f_{mag} = \frac{(R+r)}{2\pi L}$ *H. (R in ohms, L in henries).*

that an ideal ceramic pickup when velocity loaded (C = 800 pF, R = 10 kΩ) will require exactly the same frequency correction as an ideal magnetic pickup (L = 500 mH, R = 65 kΩ). This should make clear the use of the term "velocity loading" as applied to a ceramic pickup.

If we now wish to specify the gain/frequency characteristic of amplifiers for reproducing constant amplitude records using the pickup configurations shown in Figs. 2 and 4, we find that a "flat" amplifier characteristic is required for Fig. 2(a) and this is shown in Fig. 5(a). Both 2(b) and 4 require a gain falling at a slope of −6 dB/octave over the whole audio spectrum as shown in Fig. 5(b). (See last section for note about bass lift below 50 Hz.)

R.I.A.A. Recordings

Up to now we have considered constant amplitude recordings only and this is now a convenient point to introduce the complications caused by the real R.I.A.A. recording characteristic. The R.I.A.A. characteristic is usually given as a gain/frequency curve required to correct a *perfect magnetic pickup with a high-Z load.* Fig. 6(b) shows this curve. The author's preference, when considering ceramic pickups, is the replay characteristic for a high-Z loaded ceramic pickup which is given in Fig. 6(a). This form of the curve emphasizes the close approximation of the R.I.A.A. characteristic to constant amplitude recording apart from the 12·5 dB "coggle" in the curve between 500 and 2121 Hz. Thus it might be loosely assumed that an amplifier to replay from a ceramic pickup would require a gain/frequency curve like Figs. 6(a) or 6(b) depending on the loading employed. However, the historical development of piezo-electric pickups comes into play here, and as mentioned above the tradition of expecting piezo-electric pickups to be played into a high impedance load dies hard so we have the situation that almost all piezo-electric pickups have built-in compensation.

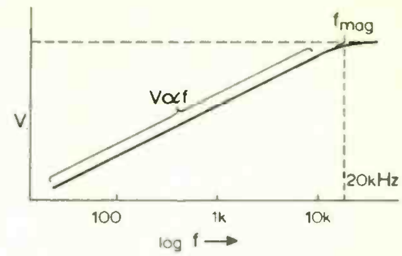
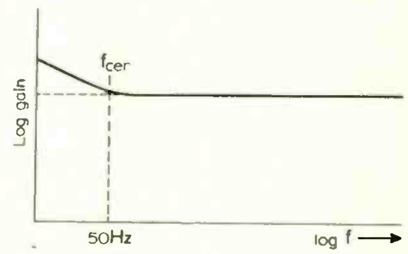
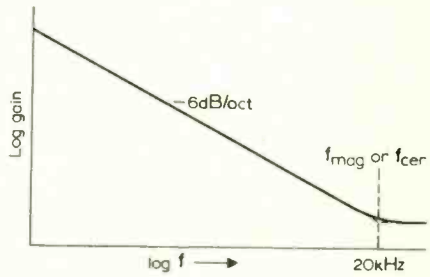


Fig. 4. High-resistance loading for magnetic pickup playing a constant amplitude recording. (R = 65 kΩ, L = 500 mH, f_{mag} = 20 kHz, E ∝ f over audio range.)

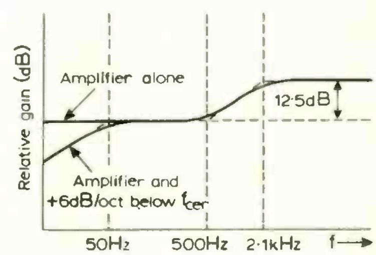


(a)

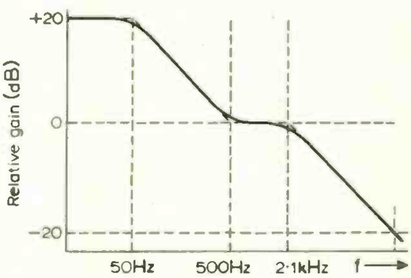


(b)

Fig. 5. Amplifier gain characteristics; (a) for high-Z piezo pickup (Fig. 2(a)) and (b) for low-Z piezo (Fig. 2(b)) and high-Z magnetic (Fig. 4) pickups. Note: These characteristics refer to ideal piezo and magnetic pickups playing constant amplitude recordings.



(a)



(b)

Fig. 6(a). R.I.A.A. replay characteristic (ideal ceramic pickup with high-Z load) and (b) standard R.I.A.A. replay characteristic (magnetic pickup into high-Z load).

The 12·5 dB lift in the higher frequencies is provided by built-in mechanical compensation and this means that the pickup can be played directly into a high-impedance "flat" amplifier and give acceptable results. On the other hand, no magnetic pickups incorporate mechanical equalization and so always need the full R.I.A.A. equalization as given by the curve in Fig. 6(b). But as practically all ceramic cartridges have the mechanical compensation the amplifier gain/frequency characteristic would have to be like Fig. 5(a) or 5(b), depending on the loading employed, *not* 6(a) or 6(b).

As nothing can be done about the built-in mechanical compensation, additional electrical equalization must be added to an existing amplifier if an attempt is made to "velocity load" the pickup and then play it through an amplifier with full R.I.A.A. magnetic equalization. Despite the mechanical compensation, no basic change in the equivalent circuit of the pickup is needed, the only difference is that the e.m.f. E is a function of frequency, but the pickup is still basically an amplitude sensitive device. I think there is a good case for marketing high-quality ceramic pickups with no built-in equalization, specifically designed to operate into the "magnetic" input socket of pre-amplifiers, whose input impedance is of the order of 50 kΩ.

This should have explained fully the derivation of the three curves in Fig. 5 of ref. 1 where circuits and curves are given for varying degrees of built-in mechanical compensation.

Curve 1—Full mechanical
Curve 2—50% effective mechanical
Curve 3—Zero mechanical

In this respect Mr. Linsley Hood's Fig. 5 arrangement is more flexible than his Fig. 4 circuit which assumes full mechanical equalization.

Medium-Z loading of magnetic and ceramic pickups

In the original version of the Tobey-Dinsdale pre-amplifier[2], an ingenious form of equalization was suggested for magnetic pickups with an inductance of the order of 500 mH. This depended on the concept of splitting the equalization into two separate sections, one providing the treble equalization above 2121 Hz and the other providing the bass equalization below 500 Hz. Treble equalization was obtained by setting f_{mag} = 2121 Hz and reference to Fig. 5(b) will show that a flat amplifier characteristic is required above f_{mag} for proper overall equalization. Below 500 Hz amplifier bass lift is required and this was achieved by frequency selective feedback using a virtual earth amplifier (see Appendix 1) where Z_2 consisted of a resistor and capacitor in series with a time constant of 300 μs.

This provides a gain/frequency characteristic as shown in Fig. 7, assuming Z_1 is resistive. Thus the combination of the two systems provides correct equalization. Pickups with inductances much smaller than 500 mH and/or with high a.c. resistances at 2 kHz cause difficulty with this method.

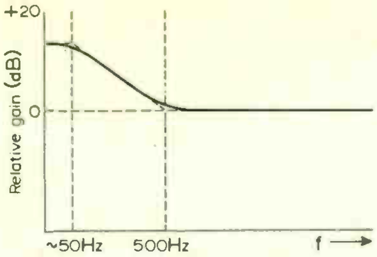
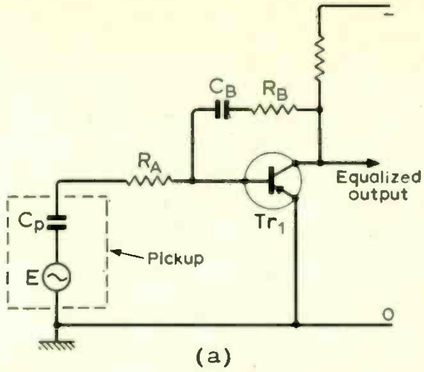
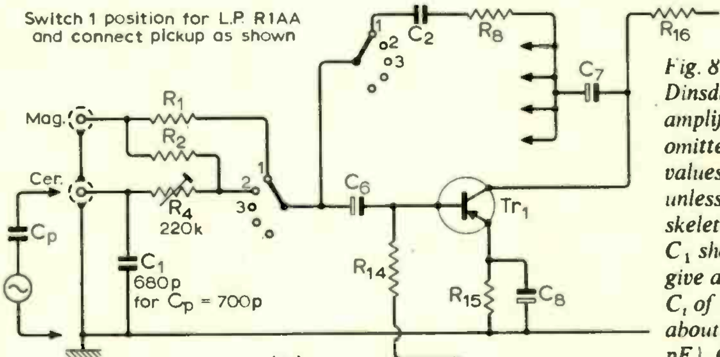


Fig. 7. Gain/frequency curve of pickup equalization feedback circuit of Ref. 2.



(a)

Fig. 8(a). Principle of equalization for virtual earth amplifier (see Appendix 1). No biasing components are shown.



(b)

Fig. 8(b). Modified Dinsdale Mk. I pre-amplifier. Notes: R_3 is omitted. Component values as in original unless shown. R_4 is a skeleton pot. The value of C_1 should be chosen to give a total capacitance C_t of $C_p + C_1 + C_{leads}$ ... about 1500 pF (±150 pF). C_{leads} is about 100 pF.

However, the critics of this system were unduly harsh and it is probable that the majority of stereo magnetic pickups will work satisfactorily with this form of equalization. Tests on the Neat V-70 and the B. & O. SP2 pickups, which are typical of the moving magnet and variable reluctance type respectively, have shown no decrease at all in channel separation using the E.M.I. stereo test disc TCS 101 when first one channel, then the other, is shorted. In a recent article in *Wireless World*[8] it was pointed out that magnetic imbalance of these types of pickup is very low, resulting in a separation of better than 40 dB from this cause alone. Thus any transformer effect (i.e. the current in one coil inducing a voltage in the other) would be of negligible proportions compared to the other causes of crosstalk—which are principally mechanical. Obviously the Decca *ffss* pickup is an exception since it has a sum and difference coil system, where the common coil would carry appreciable current through a common impedance.

When ceramic stereo pickups are operated into low-Z loads there is no risk at all of worsening the channel separation—indeed, some authors believe that low impedance loading improves the damping and hence the transient performance. This idea originated a long time ago[3], and as yet no evidence is forthcoming in support of this claim. Reference 3 contains many misleading and contentious remarks, and it is possible that pen was put to paper rather too hastily! Well, low-impedance loading is probably neither much worse nor much better than high-impedance loading, other things being equal, and if the reader will accept the idea of a 100 kΩ load, or thereabouts, it is very simple to design a circuit providing the necessary equalization. No doubt many readers have reverted to high-impedance loading after being dissatisfied with results from their pickup when operated into a magnetic input and the reasons for this should be clear from the above discussion.

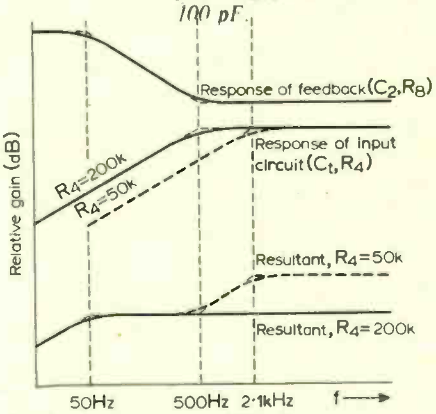


Fig. 9. Performance of Fig. 8.

However, theoretically perfect equalization with medium-Z loading is possible by adapting the Tobey-Dinsdale system for equalizing magnetic pickups.

Equalization of ceramic pickups—new method

Suppose we load a 1500 pF pickup with 200 kΩ. The formula by Fig. 1(b) tells us that f_{cer} = 500 Hz. Frequencies below 500 Hz suffer an attenuation of 6 dB/octave as shown on Fig. 1(b). Suppose also that we use a feedback circuit providing an amplifier gain curve as shown in Fig. 7, which gives a rising gain below 500 Hz. Combining these two circuits will provide a flat overall frequency response—which is what is required for a fully mechanically compensated ceramic pickup playing R.I.A.A.

recordings. The virtual earth amplifier as used in reference 2 works very satisfactorily when the input circuit is modified as shown in Fig. 8(a) which shows the outline system and (b) giving the detailed modifications. With a Sonotone 9 TAHC C_2 and R_8 were kept as 0·005 μF and 47 kΩ, and the only alteration was to include the preset R_4. The performance of the adapted circuit is shown by the full line in Fig. 9. Should the mechanical compensation not be fully effective the circuit can be arranged to give the full 12 dB lift by reducing the value of R_4 to 50 kΩ, which raises the turn-over frequency f_{cer} from 500 Hz up to 2000 Hz as shown by the dashed curve in Fig. 9. It is obvious that any degree of mechanical compensation can be allowed for by tweaking R_1. This can be done quite easily by ear. If 200 kΩ is inconveniently high, the pickup can be shunted with extra capacitance, say 1000 pF, so allowing R_4 to be reduced, for the same product of $C_t \times R_4$. It is convenient to arrange for the feedback circuit to have its turnover frequency at 500 Hz because then inadequate mechanical compensation can be easily adjusted for. If it is known that the pickup is fully compensated any convenient value for $C_t \times R_4$ may be chosen.

Any feedback type pre-amplifier stage can be easily modified to provide correct ceramic pickup equalization using the basic method just discussed. The type discussed in Appendix 2 has appeared as the Dinsdale Mk. II[4]; this pre-amplifier can be modified to give excellent equalization as shown in Fig. 10. Another popular more recent *Wireless World* pre-amplifier design is the Bailey circuit[5], which also can be improved by greater attention to the equalization requirements. This design can easily be modified by, say, using the "Disc 1" position for a ceramic pickup and "Disc 2" for the magnetic. The circuit for the ceramic pickup will now appear as shown in Fig. 11. The circuits in both Figs. 10 and 11 are capable of the adjustment range as shown in Fig. 9 for the simpler virtual earth circuit. Each has an additional control R_3 of 10 kΩ to preset the overall gain to a suitable level for the particular pickup. Using this form of equalization for pickups, it is doubtful whether the performance of the modified Dinsdale Mk. II is in any way inferior to the modified Bailey because the feedback circuit in the Dinsdale Mk. II does not have a falling impedance with rising frequency any more. Instead, the impedance flattens off at about 9 kΩ and does not shunt the transistor load impedance excessively at high frequencies. The same is true for the other two amplifier circuits, of course.

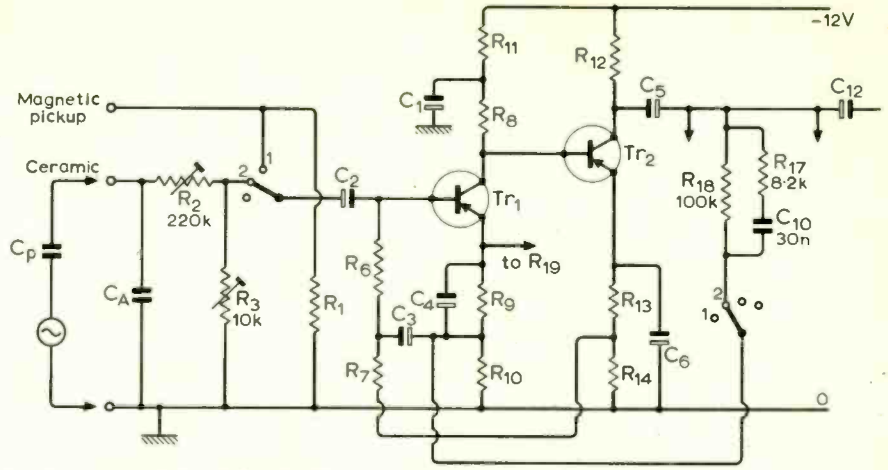


Fig. 10. Modified Dinsdale Mk. II for ceramic pickup equalization. Switch position 2 is now labelled ceramic pickup R.I.A.A. l.p. Note: Do not operate this circuit with C_{10} shorted and R_3 set to less than 3500 Ω or motor boating at 1 Hz might occur. To be safe, raise C_2 to 20 μF or more. $C_t = C_p + C_A + C_{leads}$ etc.; choose C_A to make $C_t \approx 1500$ pF (±150); $R_{18} \cdot C_{10} = 3000$; $R_{18}/R_{17} = 12{\cdot}4$; C in uF; R in Ω; R_2 – set f_{cer}; R_3 – set gain.

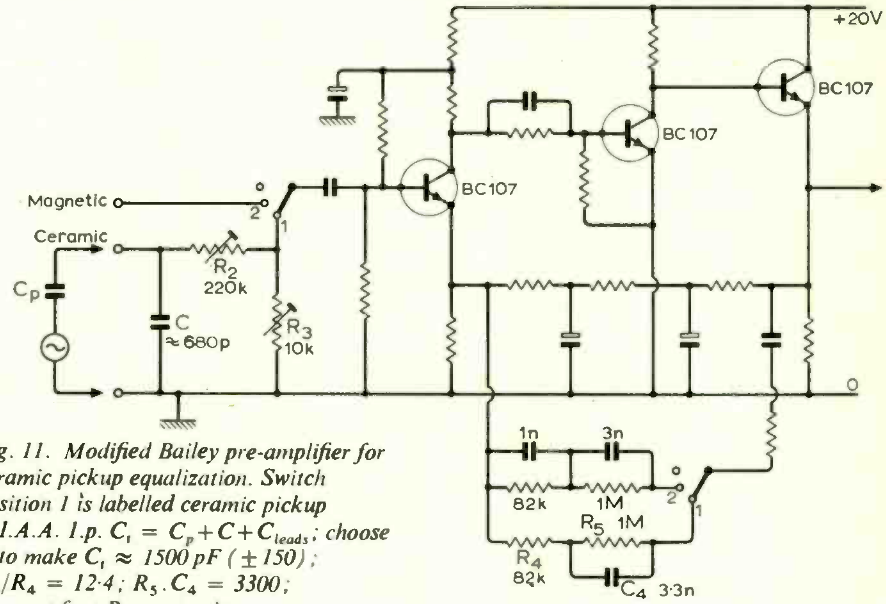


Fig. 11. Modified Bailey pre-amplifier for ceramic pickup equalization. Switch position 1 is labelled ceramic pickup R.I.A.A. l.p. $C_t = C_p + C + C_{leads}$; choose C to make $C_t \approx 1500$ pF (±150); $R_5/R_4 = 12{\cdot}4$; $R_5 . C_4 = 3300$; R_2 – set f_{cer}; R_3 – set gain.

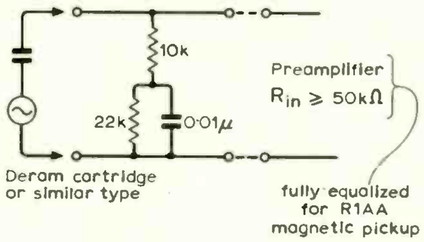


Fig. 12. Circuit for "velocity" loading and decompensating a ceramic pickup.

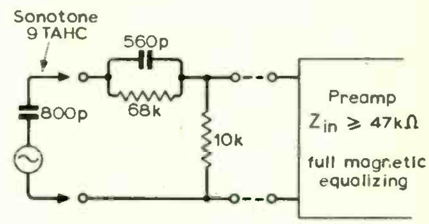


Fig. 13. Circuit for "velocity" loading and decompensating Sonotone 9 TAHC.

Equalization of ceramic pickups: alternative circuits

Circuits requiring no internal modifications to the pre-amplifier fall naturally into two main groups:

(1) add-on high input impedance f.e.t. and boot-strapped circuits

(2) circuits adapting magnetic-cartridge inputs by "velocity loading" the pickup and decompensating for the mechanical compensation.

I shall confine the discussion to the second group since adequate information is already available for the first group.

One of the best known circuits for decompensating the mechanical equalization is due to J. Walton (Fig. 12). This is an ingenious circuit. It provides "velocity loading" of the pickup over the whole audio frequency range but the effective load impedance for the pickup is higher at low frequencies than at higher frequencies, therefore a relatively larger signal is produced at low frequencies than at high. This circuit allows the Decca Deram to be connected successfully to a fully R.I.A.A. compensated magnetic input of R_{in} approximately 47 kΩ or so. An alternative circuit, which was provided in a private communication, for decompensating the Sonotone 9 TAHC pickup is shown in Fig. 13, and although seemingly very different from Mr. Walton's circuit, achieves the same objective.

These circuits probably function quite well, but there is the possibility of a big build-up of errors in the mechanical compensation, the decompensation and the amplifier equalization characteristic. By comparison the circuit of Fig. 8(a) is very simple, gives less risk of accumulated errors, and allows adjustment for degrees of mechanical compensation. The one main shortcoming of this simple circuit is the lack of loop gain to stabilize gain at low frequencies. In this respect the Dinsdale Mk. II and Bailey pre-amplifiers are superior. Rumble filtering is a good feature to include as well. If the Dinsdale design of main amplifier is used, or the Bailey amplifier with the recent modification[6], then rumble filtering is not so necessary since these amplifiers have a built-in high-pass characteristic.

Further notes

(1) It may have occurred to the reader that an even simpler form of equalizer is possible, consisting of a virtual earth amplifier with just a capacitor in the feedback circuit as in Fig. 14. Though superficially very attractive, this circuit is not very satisfactory owing to the shunting effect of C_2 on the transistor load resistor at high frequencies, and the difficulty of adjusting the compensation. Stabilization of low-frequency gain would be desirable, so requiring a resistor shunting C_2 and perhaps C_1, thus making the circuit no simpler than the adjustable circuit of Fig. 8. On the other hand, the simple circuit of the form of Fig. 8 is eminently suitable for a multi-transistor virtual earth amplifier and is a simpler way of achieving proper ceramic pickup equalization than Mr. Linsley Hood's circuit (Fig. 5 of ref. 1).

(2) Pickups of very low or very high outputs may cause difficulty through lack of gain, or overloading and some further notes might help to provide solutions for particular problems.

Circuits in Figs. 10 and 11 are not likely to be troubled in this way owing to the presence of the adjustable R_3. If the pickup output is low, R_3 may be increased up to 50 kΩ max., which might then require $R_2 = 0$. An alternative method to increase the gain is to alter the values of the resistors and capacitors in the feedback circuits (R_{18}, R_{17}, C_{10}) in Fig. 10; or the equivalent ones (R_4, R_5, C_4) in Fig. 11. The ratios between the component values must be maintained, however, as given by the formulae at the side of each diagram. In general, raising the resistor values increases the gain and lowering them reduces it. The equalization will not be affected by such changes.

The circuit in Fig. 8(b) is not quite so simple, as no one component can be varied easily to alter the gain. Shunting the pickup with a capacitor will neither raise nor lower the overall gain, because the attendant alteration of R_4 to preserve the same f_{cer} will exactly neutralize the change. However, if a series capacitor is used and a shunt capacitor as well to keep the same effective source capacitance of 1500 pF, effective gain reduction can be achieved without raising R_4 at all (Fig. 15). For C_{tot} = 1500 pF with $C_p + C_{strays}$ = 800 pF, C_s = 390 pF, C_1 = 1200 pF, gain is reduced by a factor of 3 compared with the gain when C_5 is not used, and the pre-amplifier would not be overloaded by operating from a pickup with an output of 1·25 V max!

An alternative method is to alter the values of the feedback components (C_2 and

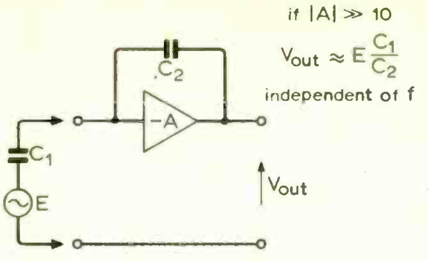


Fig. 14. A simple but impracticable equalization circuit.

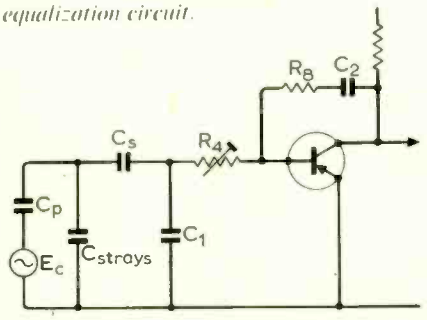


Fig. 15. Curbing high output pickups by including series and shunt capacitance. Effective capacitance value for calculating f_{cer} *is* C_{tot} *which* $= \frac{(C_p + C_{strays}) \times C_s}{C_p + C_{strays} + C_s}$.

R_8 in Fig. 8(b)). In general decreasing R_8 lowers the gain, and increasing R_8 raises it. However, this causes a change in the magnetic pickup gain as well as the ceramic pickup, so it is best avoided.

Finally, the pickup output may be shunted directly with a resistor, R_3, which would be connected between the left side of R_4 in Fig. 8(b) and chassis. To preserve the time constant once more, this resistor would have to be shunted by a capacitor C_1 larger than normal so that

$$(C_p + C_1) \times \frac{R_3 R_4}{R_3 + R_4} = 318\,\mu s$$

That is, if R_3 equals 200 kΩ, and R_4 is 200 kΩ, thus giving a parallel combination of 100 kΩ, $C_p + C_1$ would have to be made equal to 3000 pF or so.

A word of warning, do not attempt to shunt virtual earth amplifiers by putting a resistor between the virtual earth point (see appendix 1) and real earth. The loop gain of the amplifier is reduced, making the circuit more susceptible to transistor gain variations and the gain/frequency curve will be less exact.

(3) Response below 50 Hz. Referring to Fig. 6(a) which shows the replay characteristic for a piezo-electric pickup playing R.I.A.A. recordings, the curve implies that bass lift is recorded below 50 Hz, since, theoretically the replay characteristic should drop off below 50 Hz at 6 dB/octave. This is probably not done by many recording companies because of the allowable maximum recorded amplitude which is less for the lower frequencies.* Thus a flat gain is probably required below 50 Hz, down to say 20 Hz, below which a fall of 18 dB/octave to reduce rumble is beneficial. Too few pre-amplifiers include adequate rumble filtering. The author recently has had to modify a valve stereo amplifier of a very well known make on account of its extended low frequency response—flat to less than 10 Hz!

On balance it is better to dispense with the luxury of "flat to 20 Hz" and allow the theoretical 6 dB/octave below 50 Hz (R.I.A.A.) aid the rumble reduction, leaving only 12 dB/octave to be added elsewhere, say, by a couple of differentiation circuits in series between the pre-amplifier and main amplifier, unless the main amplifier itself has a high pass characteristic.

In principle, the simple equalization circuit of Fig. 8(a) would give a flat response down to zero frequency. This is not true of Fig. 8(b) owing to the limited gain of a one transistor amplifier, and also to the feedback deliberately introduced to give a high pass action. With a high gain amplifier and no anti-rumble feedback, C_2 would need to be shunted by 560 kΩ to give a turnover frequency of 50 Hz.

Bass roll-off would not be achieved by putting a capacitor of 0·01 μF in series with R_4, although it was this method, in effect, that was suggested recently[7]. Since the 0·01 μF is in series with the pickup capacitance and the pickup capacitance is only 700 pF or so, the 0·01 μF capacitor would have only a 7% effect on the turnover frequency of the pickup in conjunction with the amplifier input resistance. (f_{cer} would be about 1·5 kHz, and not 50 Hz.)

(4) Magnetic pickups playing into high resistance loads. Manufacturers of magnetic pickups commonly state that their products should be loaded with not less than 47 kΩ. Many reports on magnetic pickups refer to the problem of the pickup inductance and lead capacitance giving a resonant effect on frequencies about 15 kHz to 20 kHz. In the case of pickups with an inductance of about 500 mH it is advisable to use no more than 50 kΩ since then the Q of the LCR circuit is about 1 which almost entirely suppresses the resonance effect.

(5) The capacitance of the connecting leads to a ceramic pickup are of no consequence since the capacitance simply adds to the source capacitance of the ceramic pickup and does not cause resonance effects.

(Please see p. 80 for Appendix)

*See for example, "Measuring pickup performance", J. Walton, *Wireless World*, December 1967.

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News of the Month

NASA to close electronics centre

The National Aeronautics and Space Administration announced on December 29th the closing of its Electronics Research Centre at Cambridge, Mass. The decision to suspend operations at the centre was made when planning the future course of the U.S.A.'s space programme over the next decade, when it was also decided to reduce the country's manned space flight programme.

Announcing that the phasing down of work in the Electronics Research Centre would begin at once, Dr. Thomas Paine, the administrator, said "we are simply faced with the hard fact that NASA cannot afford to invest broadly in electronics research as we have in the past".

The Electronics Research Centre was opened in September 1964 and has 850 employees engaged in advanced research in electronics, in aeronautics and space.

Stereoscopic television system

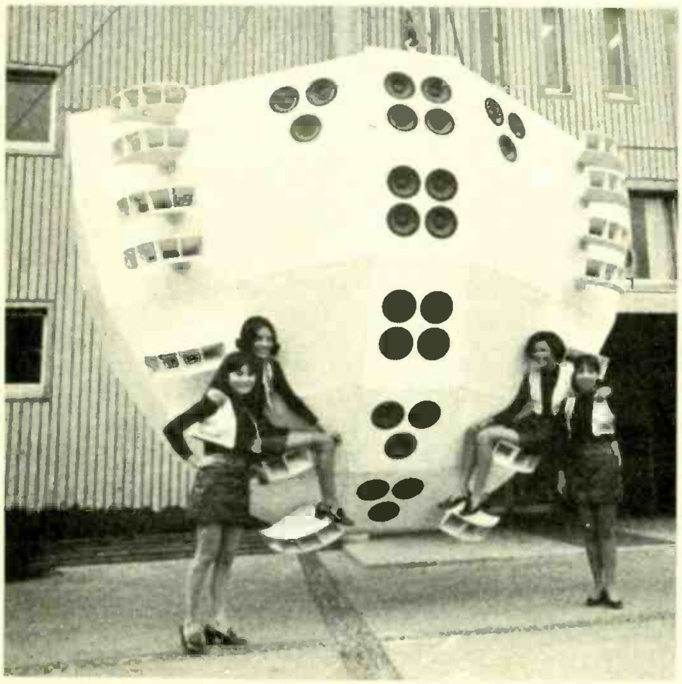
Three-dimensional scenes in motion can be viewed on some closed-circuit television systems with a new live-transmission technique devised at Bell Telephone Laboratories, U.S.A. A 3-D scene is transmitted as a series of slightly different two-dimensional images that convey depth information. At the receiving end, the 2-D images are combined to reconstruct the original 3-D scene. No special glasses are required to see the scene in three-dimensional form.

The basis of the technique is a pair of spherical mirrors, called varifocal mirrors. Because they are constructed of flexible mylar, their centres can be made to move rapidly in and out, from concave to convex shapes, like loosely fitting drum skins.

As the mirror at the transmitting end moves, it reflects portions of the 3-D scene to a short focal length lens. The lens then focuses these different "depth planes" one at a time so that they can be shown on a rear projection screen, recorded by a television camera, and transmitted.

At the receiving end, a television monitor displays the 2-D images. An observer views them reflected from a second moving mirror, which is placed in front of the monitor. The mirror forms an image of each successive view, instantaneously placing it in the correct depth position to reconstruct the original 3-D scene.

Although the technique requires several times more bandwidth than broadcast television it has potential applications for 3-D data transmission in specialized scientific and medical fields. Applications to broadcast or closed-circuit entertainment is limited by a phenomenon called "phantom imaging" associated with the varifocal mirrors. Because of this, objects in the foreground of a 3-D scene do not, as they should, totally obstruct those in the background.



One of two gigantic speaker systems manufactured by the Pioneer Electronic Corporation, of Japan, for installation at the Festival Plaza of Expo '70 now under construction at the Senri Hills, Osaka, and due to be opened to the public on March 15th. Each speaker system weighs two tons, and contains 42 speaker units—four 50cm (20in) diameter 'woofers', twenty-four 20cm (8in) 'squawkers', and fourteen multicellular exponential-horn 'tweeters'. Each system can handle 400W of input power.

Lightweight military navigation system

An airborne i.l.s./v.o.r. equipment, type AD280, which has been introduced by Marconi, provides complete instrument landing facilities and a v.h.f. omnidirectional range in a single unit and is primarily intended for light strike aircraft and helicopters.

All components will be tested comprehensively and 'burned in' both at the supplier's and at the Marconi factory, during manufacture. In addition, the units will all undergo extensive automatic testing, both at the sub-assembly stage, and as completed units.

The complete unit consists of a number of plug-in returnable modules, completely encapsulated and sealed to prevent both contamination and accidental physical damage during their life. These modules are said to have a calculated m.t.b.f. greater than the operational life of most aircraft. The m.t.b.f. for the complete assembly has been calculated conservatively at 4000 hours, but this figure is expected to be exceeded comfortably in service.

The complete AD280 system consists of a chassis unit with six modules, and was designed by the Aircraft Radio Corporation of America and will be manufactured under licence by Marconi.

I.T.A. report

The engineering section of the annual reports and accounts of the Independent Television Authority for 1968-69 records the work undertaken in equipping u.h.f. stations for colour transmission and lists the 26 main stations which are being brought into service between 1969 and 1972. In addition there will be a large number of u.h.f. relay stations. During the year under review the Authority (which supplies and operates the transmitters used by the programme contractors) has completed its plans for 47 v.h.f. stations. These stations serve over 98% of the country's population.

V.H.F. YIG modulator

A yttrium iron garnet (YIG) modulator depends on the Faraday effect in a magnetic material, in which the plane of polarization of a beam of plane polarized light is rotated as it propagates through a medium magnetized parallel to the direction of the light.

Using this property of YIG, R. W.

Cooper and J. L. Page of Mullard Research Laboratories have modulated a light beam with the signal from a television camera. The beam is focused on to a photodetector, the output signal from which is amplified and fed to a television monitor.

In the device a rod of single crystal material is mounted in a transverse bias magnetic field provided by two small permanent magnets. A small coil wound on the rod and fed with the drive signal induces a component of magnetization parallel to the light direction. This results in a rotation of the plane polarization of light traversing the rod. This polarization modulation is converted to amplitude modulation by passing the beam through a polarizer. Whilst the bandwidth required by the TV signal is only 5MHz, the modulator has been tested at frequencies up to 100MHz, and bandwidths of several hundred MHz are possible. A tungsten lamp is used as a source of radiation. Lasers operating in the near infra-red may also be modulated using this device.

Granada Television Network officially took possession of the first of its fleet of colour television outside broadcast vehicles on 2nd December. This is a 5-camera mobile unit which has been designed and built by EMI to meet the special programme requirements of Granada. The picture shows the view from the sound control position into the production control area.

New year honours

There were but a few men in the electronics and radio world among those receiving honours in the New Year list. They included.

C.B.

H. E. Drew, F.I.E.R.E., director general of quality assurance, Ministry of Technology.

C.B.E.

R. J. Clayton, O.B.E., M.A., F.I.E.E., technical director, the General Electric and English Electric Companies Ltd.

D. Gabor, F.R.S., professor of applied electron physics, Imperial College, University of London.

O.B.E.

L. F. Mathews, F.I.E.R.E., director and general manager (Midlands), Associated Television Network Ltd.

R. J. P. Middleton, engineer, Directorate of Electronics Production (Radar), Ministry of Technology.

M.B.E.

T. E. Allon, M.I.E.R.E., engineer-in-charge, Caversham, B.B.C.

J. D. V. Lavers, head of maintenance section, I.T.A. Engineering Division.

S. Marsden, senior executive engineer, Post Office Telecommunications Headquarters Research Branch.

B.E.M.

D. P. Scott, unit supervisor, Associated Semi-conductor Manufacturers Ltd., Mullard Southampton Works.

Scotland ⟷ I.E.A. air trip

Our associate journal, *Instrument and Control Engineering,* has organized a special air trip to the I.E.A. Exhibition (May 11–16) for engineers living in Scotland. To quote *I.C.E.* "We will get you to Olympia and home again with the minimum fatigue and the greatest expediency". The cost is the same as the normal air fare £19 6s. Interested readers should contact *Instrument and Control Engineering* at Dorset House, Stamford Street, London, S.E.1.

Hearing Aid Council

The Hearing Aid Council, created by the Hearing Aid Council Act 1968, came into being on December 29th. Under the Act "all dispensers of hearing aids provided commercially, and persons employing such dispensers" must register with the Council before June 29th this year. The new Council, of which Harold Campbell is chairman, is required to advise on the training of persons engaged in such business, and to regulate trade practices. All enquiries and requests for application forms for registration should be made to the Hearing Aid Council, 16 Mumford Court, Lawrence Lane, London E.C.2.

Colour tube factory

Thorn Colour Tubes Ltd. have acquired a 25-acre factory site on the Gillibrands Estate at Skelmersdale New Town in Lancashire for the construction of a purpose-built factory at a cost of £10m for the mass production of Mazda colour television picture tubes. It will be one of the largest purpose-built colour tube factories in Europe and production capacity will initially be 300,000 tubes a year, rising as the market increases. Thorn Colour Tubes is jointly owned by the Thorn Group and RCA.

More help for instrument makers and users

Extensions to the Siraid instrument enquiry service are announced. The service is operated by the British Scientific Research Association, from its headquarters at Chislehurst, Kent. For twelve years Siraid has been providing enquirers throughout the world with information on where to obtain the measuring instruments and controllers they need.

Now Siraid will give enquirers information on where to obtain assistance in prototype design and manufacture for one-off or small-batch production. Siraid will also signpost the firms that specialize in four other areas—maintenance and servicing of instruments, environmental testing and calibration, consultancy, and hire of instruments.

A new register of firms which can carry out these types of work has been prepared by Siraid and made readily accessible on punched cards.

Further information on these new extensions, or on other Sira information services, is available from J. W. Ede, Sira, South Hill, Chislehurst, Kent BR7 5EH (Telephone 01-467 5555).

Radio aids for new cargo vessel

The *Amra,* the first of six new cargo vessels on order from Swan Hunter Shipbuilders Ltd, for the British India Steam Navigation Co. Ltd, is fitted with a wide range of Marconi Marine communications equipment and navigational aids, including two transistor radars with full inter-switching facilities. The main communications installation is based on a 'Commander' single-sideband transmitter and its associated receiver, which will provide a medium- and high-frequency radiotelegraph service as well as a single- or double-sideband radiotelephone service in the intermediate- and high-frequency bands. V.H.F. radiotelephone requirements are met by the installation of an Argonaut transmitter/receiver, while aids to navigation include a Lodestar fully automatic direction-finder, a Seagraph III recording echosounder and a Metron III visual depth indicator. The two radars fitted in the new vessel are a 16-inch display Raymarc 16 with true motion facilities, and 12-inch display Raymarc 12HD high-definition radar.

Graphical Symbols

Principles of their formation and use

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

One of the characteristics of technical literature is the extensive use made of diagrammatic, tabular, mathematical and non-textual presentation. It has often been said that a good diagram is worth hundreds of words: this is, in fact, an understatement because a diagram can present technical information which is almost impossible to put into words or which would make tedious reading if so expressed. This is particularly true of the block diagrams and circuit diagrams of electronics and telecommunications. Clarity in such diagrams is therefore as important as in text and the choice of symbols, their arrangement and orientation, and the layout of the inter-connecting lines should be chosen with as much care as the selection of words, syntax and sentence length in text. A clear diagram cannot be made of symbols the meanings of which may not be understood by the reader.

Diagrams are intended to facilitate the understanding of equipment or a piece of circuitry; block diagrams in broad general terms and circuit diagrams in more detail. Both types of diagram represent only electrical or electronic abstractions and use graphical symbols to portray the essential electrical characteristics of the components. Ease of reading is vital to aid understanding of a circuit and the layout of a diagram should be chosen with this as the primary aim. It follows that the arrangement of the symbols on the diagram does not necessarily agree with the physical disposition of the components in the equipment itself. Indeed, for complex equipments, particularly those using detached representation (described later) there is usually little correlation between circuit diagram and equipment layout. Similarly, the symbols, which represent electrical behaviour, need bear no resemblance to the physical form of the components.

Symbols represent electrical behaviour . . .

A good example of a circuit symbol is that of the triode shown in Fig. 1. This shows that the valve has a grid interposed between an anode and a cathode, and it is easy to sketch electron paths passing through the meshes of the grid. The circuit symbol can thus help in explanations of the behaviour of a thermionic valve and is used in this way for teaching purposes. The symbol is (a) simple, (b) easy to draw and (c) illustrates the electrical function of the component needed. These three attributes are essential in a good graphical symbol.

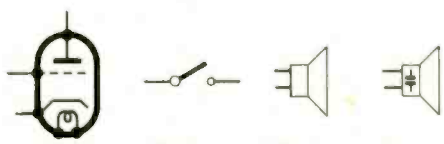


Fig. 1 Fig. 2 Fig. 3 Fig. 4

Fig. 1. Symbol for a triode valve. Fig. 2. A simple switch. Fig. 3. Symbol for a loudspeaker. Fig. 4. An electrostatic loudspeaker.

. . . but not the physical form of components

The symbol of Fig. 1 can be used to represent any kind of triode valve, from a transmitting type four feet high with an air-blast-cooled anode to a miniature acorn type. The symbol thus does not depend on the physical form of the component.

Fig. 2 gives the symbol for a simple make-and-break switch. This can be used to represent a large number of different physical forms. Any urge to invent a symbol for every new physical form of switch should be resisted. It would soon become impossible to devise further simple symbols, and if complex symbols are used, unless they are formed in some obvious systematic manner (such as the modular system described later), it is difficult to remember them, and frequent annoying and time-consuming searches in reference books are necessary. When this point is reached the symbols have ceased to be useful.

It is easy to say that a graphical symbol should represent electrical behaviour or characteristics, but is it always possible to find a simple way of doing this? In particular, can the meaning of the symbols be made obvious? The triode symbol of Fig. 1 is good because its meaning is instantly recognizable. Other characteristics, however, are not so easy to portray, and the symbol then often becomes a simplified and idealized representation of a particular form of component which has the characteristics required. For example, the symbols for a simple make-and-break switch, for a loudspeaker and for relay contacts, all resemble particular forms of component. Similarity to familiar hardware aids recognition, of course, but has the disadvantage of suggesting that symbols represent components rather than their characteristics. For example the loudspeaker symbol (Fig. 3) resembles a sectional view of a moving-coil loudspeaker, and it is an easy step from this to assume that the symbol *represents* a moving-coil loudspeaker; the question that then arises is, what are the symbols for other types of loudspeaker, e.g., an electrostatic type which has an entirely different shape of cross-section? In fact, of course, Fig. 3 represents every possible type of loudspeaker; if it is necessary to indicate that a loudspeaker is electrostatic, we can add the symbol for capacitance to the loudspeaker symbol as in Fig. 4.

It follows from what has been said that a graphical symbol should not resemble the physical appearance of any particular type of component which has the characteristics represented by the symbol. This is a counsel of perfection and few of our graphical symbols satisfy it. Two which do are the valve symbol and the zigzag symbol representing resistance.

Most symbols represent the electrical characteristics of particular classes of component such as keys, transistors or transformers, but there are a few more general symbols which represent a property to be found in a number of different classes of component or even in wiring. Obvious examples are the symbols for resistance, capacitance and inductance. If, for example, the self-capacitance of an inductor is used to tune the inductor, this capacitance should be shown on the circuit diagram by the capacitance symbol. To indicate that the capacitance is not that of a separate capacitor the leads to the symbol can be shown in broken lines or an explanatory note can be added. Such a symbol would not, of course, have an associated component reference because it does not represent a separate component. Similar situations arise when

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the inductance of conductors or the resistance of windings plays a vital part in circuit operation.

Thus the zigzag symbol (or the I.E.C.† rectangular equivalent) does not signify simply a resistor: it should be used to represent any resistance which is made use of in the circuit. For example, it can be used in an equivalent diagram, such as that shown in Fig. 5, to represent the internal resistances of an active element.

A problem arises when a component is used for a purpose quite different from that suggested by its normal graphical symbol, e.g. when a reverse-biased junction diode is used as a voltage-dependent capacitance for tuning purposes. Should the symbol in parallel with the inductor symbol be for a capacitance or a diode? In fact it seems to be generally accepted that the diode symbol should be used, but that a capacitance symbol should be placed nearby, as in Fig. 6, to show that the diode is in practice behaving as a capacitor. It is true that the diode suggests damping or detection rather than tuning but, if the component breaks down, at least the service man looks for the right component—a diode.

Symbols constructed of modules

Fig. 1 is an excellent example of the technique of building up symbols by assembling symbol elements—the modular approach. The triode symbol is made up of the symbols for heater, cathode, grid and anode enclosed by an envelope. These elements can be grouped to form symbols for a wide variety of thermionic valves. From five symbol elements it is possible to produce perhaps as many as a hundred symbols for different types of valve. Here the complexity of a symbol is little hindrance to our understanding of it because it contains only five types of element, all obvious in meaning. Other symbols, similarly built up of elements, are those for switches, keys, relays and semiconductor devices.

A virtue of the modular system is that reference books do not need to list all the possible permutations of a particular group of elements. It is necessary for them to give only the symbols for all the elements and a few typical examples of assemblies of elements.

Block symbols can similarly be made up of standard elements. For example, Fig. 7(a) gives the block symbol for an amplifier. To this we can add a symbol representing a band-pass filter thereby showing, for example, a band-pass, i.f. amplifier (b). By adding the arrow representing variability, we obtain symbol (c), representing an i.f. amplifier with manual gain control. Finally, by adding the filled-in rectangle representing automatic control to the tail of the arrow, we obtain symbol (d) for an i.f. amplifier with automatic gain control. An alternative to Fig. 7(d) which might be more useful in a block diagram of a receiver is that shown in Fig. 7(e): this has the a.g.c. line in place of the arrow and the line can be shown as originating at the detector.

We can distinguish the following three types of module which can be used in making up symbols:

(a) What might be termed *basic or general* symbols—a good example is the capacitance symbol. This can be used in its own right, but also as a component of another symbol as in the case of an electrostatic loudspeaker (Fig. 4).

(b) *Symbol elements.* These are symbols for the essential parts components. They cannot be used on their own and good examples are those for heater, cathode, grid and anode of thermionic valves.

(c) *Qualifying symbols.* These also cannot be used on their own but are added to other symbols to increase the information conveyed. Examples are the arrow representing variability (Fig. 7c), the three sine waves representing radio frequency and the filled-in square representing automatic operation (Fig. 7d).

The technique of producing any required symbols by assembling standard elements and qualifying symbols is most useful, but the temptation to add unnecessary detail should be resisted. There is little point in indicating on a symbol that the device has mechanical linkages, that gain is adjustable in steps, or that control is by a double-acting pneumatic device, if the circuit diagram can be read and understood without these embellishments. One of the best aids to clarity is simplicity, and there is a lot to be said for circuit diagrams composed largely of general symbols.

There is, however, an exception to this general statement. Although the primary purpose of circuit diagrams is to help to give an understanding of the way in which equipment works, they are also extensively used today as an aid to servicing, i.e. to help in the location of faults and the subsequent repairs. To this end, it is common practice to include more information on the diagram than is needed to understand the circuit operation. The range of qualifying symbols now available allows the information given to be increased to almost any degree. Explanatory notes can be added to provide information which cannot conveniently be conveyed by symbols, but the use of wording introduces the language complication discussed later.

Symbols can be split

To improve legibility of circuit diagrams, it is common practice to split the symbols for multi-part devices, such as switches, relays, keys, multiple valves and integrated circuits, and to place the symbols for the separate parts in positions on the diagram which give the simplest and clearest layout. Thus the symbol for a relay with six contact units may be divided into seven parts and the coil symbol and the individual-unit symbols may be located in widely separated positions. This technique is known as detached representation. A familiar example of detached representation is that the symbol for the on/off switch of a receiver or amplifier is not usually shown near that for the volume control even though these are ganged physically. Similarly the symbols for the sections of a ganged tuning capacitor are usually shown near the circuits with which they are associated and not necessarily near each other. Detached representation greatly simplifies diagram layout and legibility but introduces the problem of indicating which symbols are mechanically associated.

There are a number of ways of solving this problem. In telecommunications, the most usual method for a relay is to use a code, such as ABC/6, in which the letters can indicate the circuit function of the relay. The figure in the denominator of the fraction indicates the number of contact units on the relay and the contact symbols are designated ABC-1, ABC-2, etc. Part of a diagram using detached representation is given in Fig. 8.

Distinction between make and break contacts

The contact units of relays are often of the change-over type and if so the contact springs can be selected to give a make or

† International Electrotechnical Commission.

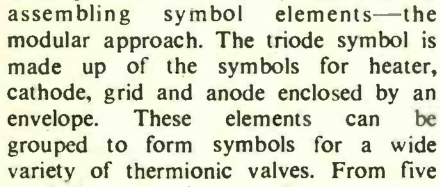

Fig. 5. Equivalent circuit for a transistor in which the symbols do not represent resistors and capacitors but internal resistance and capacitance.

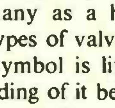

Fig. 6. Symbol for a reverse-biased junction diode used as a capacitance.

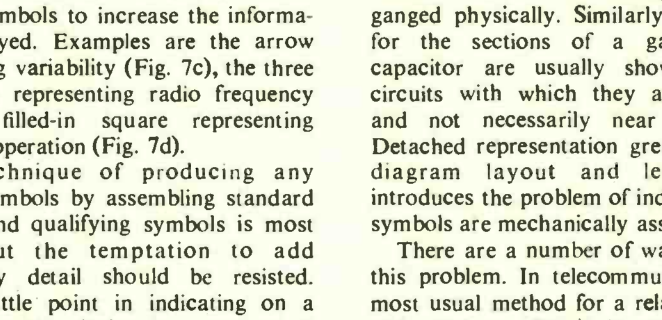

Fig. 7. Stages in the development of a block symbol for an i.f. amplifier with a.g.c.: (e) is an alternative to (d).

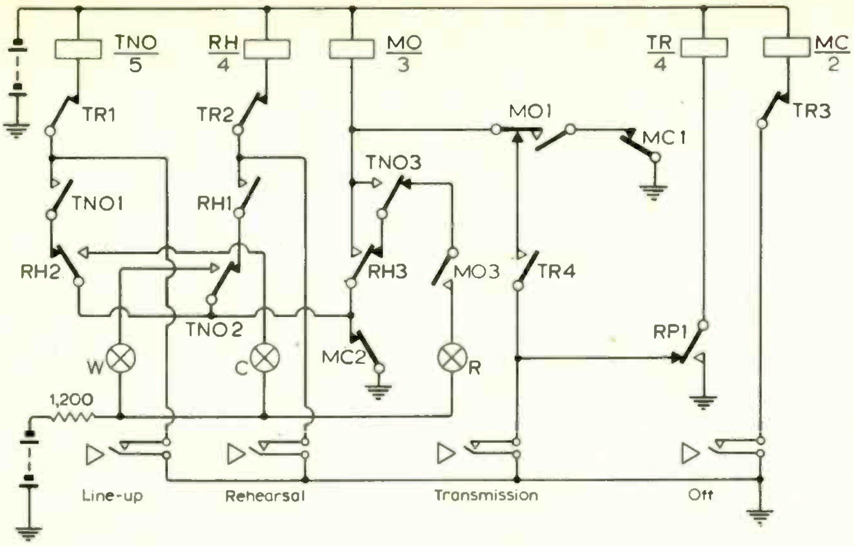

Fig. 8. Detached representation used in the circuit diagram of sound studio equipment. This is only part of the diagram and all the contact units of the five relays are not included. Moreover, the winding for relay RP is not shown.

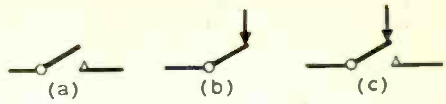

Fig. 9. Conventional symbols for (a) a make contact unit, (b) a break contact unit and (c) a changeover contact unit.

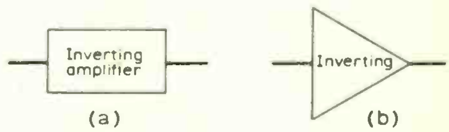

Fig. 10. Two possible block symbols for an inverting amplifier, but the use of wording introduces language difficulties.

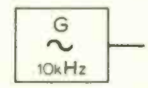

Fig. 11. An example of a block symbol using internationally-understood graphical and letter symbols.

TABLE
Internationally recognized Letter Symbols

Component references		General symbols		Units		Prefixes	
Symbol	Meaning	Symbol	Meaning	Symbol	Meaning	Symbol	Meaning
C	capacitance	f	frequency	A	ampere	T	tera (10^{12})
G	generator	h	hour	dB	decibel	G	giga (10^{9})
L	inductance	s	second	F	farad	M	mega (10^{6})
M	motor	t	time	H	henry	k	kilo (10^{3})
R	resistance	t°	temperature	Hz	hertz (cycles per second)	m	milli (10^{-3})
Z	impedance	λ	wavelength			μ	micro (10^{-6})
		θ	phase angle	V	volt	n	nano (10^{-9})
				W	watt	p	pico (10^{-12})
				Ω	ohm		

break action when the relay coil is energized. It is essential on circuit diagrams to indicate which contacts are made and which broken by energizing the coil. An internationally observed convention for distinguishing between the two types of contact is to draw the symbols for all contact units in the positions they take up when the relay coil is not energized, i.e. as they would be with all sources of power removed from the equipment. Thus make contacts are shown open and break contacts closed.

This means of identification is quite satisfactory on carefully drawn diagrams but in the United Kingdom the distinction between make and break contacts is further emphasized. A *make* contact is shown in line with the lead to the moving spring§ as shown in Fig. 9(a) and a *break* contact displaced from the line of the moving spring as shown at (b). By combining diagrams (a) and (b) the symbol for the changeover contact (c) is obtained.

International standardization

Most block symbols represent either processes or apparatus (or sections or stages of apparatus) and there is a school of thought which maintains that such symbols need consist only of a simple outline containing suitable wording. Thus an inverting amplifier, for example, may be represented as in Fig. 10 (a) or (b). Such symbols have the merit that their meaning is obvious, provided that the reader is familiar with English. The tendency is to avoid wording on graphical symbols, so that they can be understood by any technician no matter what his language. Only in this way is it possible to achieve international standardization of graphical symbols.

Such standardization is desirable not merely to facilitate the exchange of technical information between countries, but also for the utilitarian reason that it saves time and effort in drawing offices of manufacturers who export technical equipment to a number of countries. Substantial progress to this end has been achieved, and the electrical and electronics symbols now recommended by B.S.I.‡ are 99% in agreement with those published by the International Electrotechnical Commission, the body responsible for international standardization of the symbols.

It is preferable, therefore, to use internationally known symbols rather than wording to make the meaning of diagrams clear. The use of letter symbols can also help, and a large number of these are standardized throughout the world; a selection of the commonest is given in the table. In addition all the chemical symbols (Fe, Cu, Hg, etc.) are used internationally.

By using combinations of recognized letter symbols and qualifying symbols, it is possible to embody much useful information in a block circuit symbol and to maintain its international character. An example is given in Fig. 11. The three qualifying symbols within the square show that it represents a generator of 100-kHz sinusoidal signals.

To summarize:

1. A symbol should be simple, easy to draw and should illustrate electrical behaviour or characteristics.
2. A symbol should not resemble the physical appearance of any particular type of component which has the characteristics represented.
3. Complex symbols should be built up from a limited number of basic symbols, symbol elements and qualifying symbols.
4. Detached representation should be used whenever it simplifies a diagram.
5. Basic symbols together with qualifying and letter symbols should be used in preference to wording.

Acknowledgement
This article is based on experience gained by the author as a member of the B.S. committee responsible for B.S. 3939 and thanks are due to a number of members of the committee for helpful suggestions.

§This means the moving spring *in the symbol:* it may or may not be the moving spring *in the contact unit itself.* The mechanical design of some keys is such that changeover action is achieved by moving two springs situated on either side of a stationary centre spring. When the key is operated one or other of the moving springs is brought into contact with the centre spring: electrically therefore the centre spring is the moving contact and is so represented in the symbol.

‡B.S. 3939: Graphical Symbols for Electrical Power, Telecommunications and Electronics Diagrams.

Price increase
Increased production costs have, we regret, necessitated raising the cover price of *Wireless World*. From the March issue it will cost 3s. 6d.

Matching

Some various meanings

*by R. W. Cotterhill,** B.Sc., Ph.D., A.Inst.P.

One often hears the word "matching" used in electronics and it is sometimes the case that, although the user has carried out the process which he means by having matched two pieces of equipment, what he has done may not be recognized as matching by a fellow worker whose experience lies in a different frequency range. It is certainly true that some techniques used outside electrical engineering are adopted, without matching, as understood by electronics workers, being in mind, but which nevertheless are just this. It is the author's experience that some confusion does exist in the subject and that the cause lies partly in loose terminology and partly in the fact that the term has two legitimate but different meanings within our subject which are not sufficiently well delineated at times.

We usually meet it first when considering transfer of maximum power from a source to a load, or when reflections are to be avoided on a transmission line, and it is not always pointed out that these two conditions are not necessarily the same. Again, an output transformer is said to be used to match a loudspeaker to an output transistor or valve, and here we are usually carrying out quite another purpose from either of the two mentioned above.

This article considers these cases in a non-mathematical way and also looks at matching from other points of view which lie outside electronics and illustrate the generality of the concepts.

Getting the most out of it

A source of power with internal resistance R_S is well known to give maximum power to a load equal to R_S but even here confusion has been known to arise. With a choice of load we should make it equal R_S but if the load is fixed there is no advantage at all in adding shunt or series resistance at the source in order to make its resistance equal that of the load. This results only in power being wasted in the added resistance, although sometimes if reflections on a transmission line are the problem we do just this, as we shall see.

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There is a way, however, of giving the source an effective resistance equal to that of the load without wasting power and that is by using a transformer. In what follows we shall assume the properties of an ideal transformer, and by this we shall mean one in which the windings have no resistance, the core no hysteresis, and in which there are no eddy currents. All this implies that no power is lost in windings or core and that all power entering the primary leaves the secondary.

Now if a load R_L is across the secondary terminals then the ratio of voltage to current here must satisfy $V_s/I_s = R_L$. But the primary voltage V_p is N times the secondary voltage, where N is the ratio of primary to secondary turns. Since input and output powers are equal it follows that the primary current is N times less than that in the secondary. Hence the ratio of voltage to current at the primary is N^2 times that at the secondary and we say that "looking into" the primary a resistance N^2R_L is "seen". Thus by making N, equal to the square root of R_S/R_L a load can be presented to the source equal to its own internal resistance and an optimum power match achieved. Notice that if we regard the source-plus-transformer as one unit we have effectively altered the source resistance to equal that of the load but without wastage of power.

The fact that this simple approach is so widely and successfully used indicates the relatively high efficiency of even quite ordinary transformers.

It is not always realised how uncritical is the condition $R_L = R_S$. If R_L differs by even as much as 25% from the optimum, the load power falls by only one or two per cent.

The transformer in our cars

If we make analogies between voltage and force, and between current and velocity, then the products of voltage and the current in phase with it and of force and the velocity of the point of application in the direction of the force each describe a transfer of power. For rotary motion force and velocity are replaced by torque and angular velocity or r.p.m. The engine of a car produces maximum power at a certain value of r.p.m. and it is thus desirable to allow the engine to run at this speed. We are then faced with transferring this power to the road wheels, and for maximum power transfer we should present the engine output shaft with an optimum load, which is an equal and opposite torque produced at the angular velocity at which the engine provides its maximum power. The road wheels have a much lower angular velocity than that which is required, but demand at the axle a correspondingly greater torque. The gearbox, in conjunction with the fixed-ratio gear on the axle has the property of converting a lower torque at a higher angular velocity to a higher torque at a lower angular velocity. If the gearbox were ideal, and did not waste power in itself, the products of input torque and r.p.m. and of output torque and r.p.m. would be equal, and if the ratio of the number of teeth on the output gear to the number on the input gear were N (assuming for simplicity only two meshing gears), then the torque would be increased N times. The r.p.m. would of course be reduced N times, so the ratio of torque to angular velocity at the output shaft would have been increased N^2 times over their ratio at the engine shaft. The gearbox acts like a transformer with selectable turns-ratios, by means of which the engine can be presented with something near to its optimum load resistance of torque/angular velocity although that presented by the road wheels changes.

. . . and in our gardens

When we vary the orifice of our hosepipe outlet, we are varying the ratio of back-pressure to volume flow, presenting a different load to the source of power. This is the water mains plus the hosepipe, which constitutes part of the internal resistance of the source. A hosepipe without nozzle gives maximum water-flow (current) but it almost falls out of the end with a low terminal "voltage". A finger over the end can however provide the means for sending a reduced flow high into the air. We are not often concerned with obtaining most power in our jet, (except perhaps for dislodging dirt quickly when washing the car) but a properly designed nozzle can provide an approach to this match between the source, mains-plus-pipe, and the outside world.

The output transformer— a confusion of aims

It ought to be the case here of all places that we use a transformer to match the output resistance of the transistor or valve to the load of, say, a speaker, and indeed the much-used term "matching" is often employed here. But if the turns-ratio of an output transformer is examined we are disillusioned. A transistor may have an output resistance of 10 kΩ and a speaker may be three ohms demanding a turns-ratio of about 55:1. In fact the ratio may be less than ten.

The transformer *is* presenting an optimum load to the transistor, but what is being optimized is not now the power transfer; it is the functioning of the transistor. The transformer is providing a suitable load-line, and by suitable is meant one that will allow the current and voltage of the transistor to swing as far as possible over the characteristics. A figure is helpful here; Fig. 1 shows, on axes of collector voltage and current, the familiar P_{max} curve, a line joining all points for which the product of I_C and V_C equals the maximum permissible heat dissipation for the transistor.

If we assume for simplicity that the transistor can be "swung" right across the load-line from axis to axis then it is not difficult to show that any load-line drawn tangential to the P_{max} curve gives the same power output at the same efficiency as any other such line. The intersections of the load-line on the axes are at values equal to twice those where it touches the P_{max} curve, and in order to permit the swing to be symmetrical this point is the bias point; it has co-ordinates equal to V_s, the d.c. supply voltage, and I $(= P_{max}/V_s)$, the bias current. These values are also the amplitudes of the maximum a.c. swings, and so the power output is $\frac{1}{2}V_s\ (P_{max}/V_s) = \frac{1}{2}P_{max}$. The d.c. power taken from the supply is P_{max} and thus the efficiency is 50%.

However, the extremes of the voltage and current swings must not exceed the maxima laid down by the manufacturer and it is here that the transformer provides the necessary versatility in the setting of a load line which will, as far as possible, satisfy all the desired criteria. It can be seen that in general a load equal to the output resistance of the transistor would be unlikely to do this. For example, take a transistor for which P_{max} were 100 mW and the output resistance 20 kΩ. The bias point on the P_{max} curve would be at 44.6 volts, and to allow the symmetrical swing necessary to obtain most power from the transistor V_C would have to withstand twice this, which would usually be much beyond the range of most such transistors.

So we see that using an output transformer has as a general rule little to do with the kind of matching for which $R_L = R_S$.

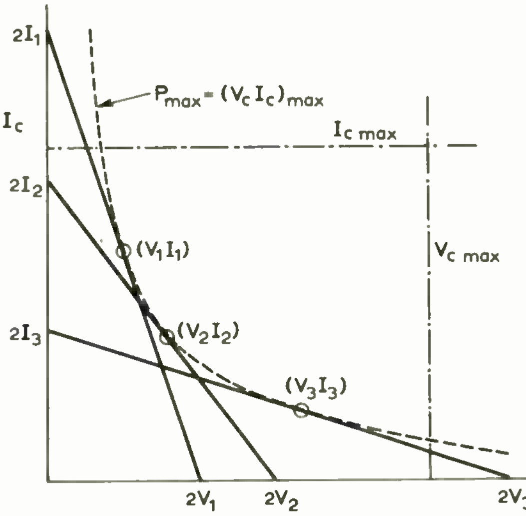


Fig. 1. All load lines tangential to the P_{max} curve have the properties: (i) Their intersections on the axes are at twice the values of the tangent point, and therefore, (ii) A sinusoidal swing over the whole load line delivers a power to the load of $P_{max}/2$. However, a workable line must lie within the limits V_{Cmax}, I_{Cmax}.

Matching a complex load impedance

This can be done on a simple basis for only one frequency at a time. Suppose the load consists of a resistance R_L shunted by a reactance X_L. (Any complex impedance can be represented by such a combination; the actual values of the equivalent parameters depend, however, on frequency.) The procedure is then to tune out the reactance with a component providing an equal and opposite reactance. Having done this it is necessary to match the source and load resistances as before, using a transformer if required. In fact, since a transformer not only transforms resistance but also reactance in the same way, the tuning may be carried out on the source side of the transformer where perhaps for example a smaller component might do.

When the resistive parts of the source and load (transformed if necessary) are equal, and the reactive parts are equal and opposite, so that they tune out, the match is said to be conjugate.

The seeming handicap of being able to tune and match at only one frequency at a time is not so severe as may be imagined, since in practice the reactive parts of a complex load often become significant only at intermediate or high frequencies and then the transfer of information is usually being carried out at or near one frequency only.

Transmission lines

When power, usually in the form of a signal, has to be transmitted at frequencies so high that the resulting wavelength is no longer very much greater than the length of line being used, complications of theory arise, but fortunately these are not accompanied by corresponding practical difficulty; in fact usually the apparatus needed for matching is very simple. However, it may be worth while to go over the essentials before actually considering the question of matching itself.

Although the basic physical phenomena are the same, the theories useful in dealing with the transmission of electromagnetic energy at lower and higher frequencies take two viewpoints, and this is not because of an academic tendency to complicate things but quite the reverse.

At what we might call "normal" frequencies (i.e., those not requiring special transmission lines), we look at things from the viewpoint of voltages and currents, and because the lower frequencies are the ones usually met first and also because the theories enabling us to deal with these frequencies are easier, most electronics workers acquire a natural feel for these quantities. At high frequencies, however, it becomes very complicated to try to work in terms of voltage and current, and much easier to think of electric and magnetic fields. (The units for these quantities are respectively volts/metre and amps/metre and this reveals their close relationship with the more familiar voltage and current.) It would be more complicated in fact to work out what happens when a pocket torch is switched on, in terms of electric and magnetic fields, than to go to the other extreme and work with transmission lines in terms of voltage and current, and the chief reason would be because of the irregular shape of the torch circuit. Transmission lines are very simple in shape (e.g., two parallel wires, or a coaxial cable, or a rectangular tube forming what is called a waveguide) and their uniformity makes one of their properties a constant; this is their characteristic impedance, discussed later. It is not intended in this article to reproduce the mathematics of transmission lines, which may be found in text books, but to try to give sufficient discussion of them to relate the aspects of matching in systems using them to those already considered earlier.

In order to focus our attention on something specific let us think of the parallel-wire system, especially since this comes closest to the kind of circuit met at lower frequencies. If an a.c. voltage is applied to the end of such a system, then it takes time for this to travel along the wires; not much time because the wave travels at or near the speed of light on most lines. (This is not surprising since light is itself an enormously high-frequency version of the electro-magnetic wave we are considering.) However, even with these speeds the distance travelled by our voltage wave in one of its periodic times may not be far. A 500-MHz wave travels only 60cm, the sort of lead-length not uncommon in connection of one piece of apparatus to another, in a time equal to its own period.

Assuming an ideal line, just as previously we have assumed ideal transformers and gearboxes, as one which does not itself dissipate power, then if we could examine the ratio of voltage between the wires to current in them at any point as the wave flowed down them, we would find this ratio to be constant (and that therefore the two would be in phase). The quantities themselves would not, of course, be constant; they would be varying at the frequency being transmitted, but they would be rising and falling in phase. Their ratio is what is called the characteristic impedance of the line; it depends on the geometry of the cross section of the line and on the dielectric between the conductors. Lines are manufactured having certain standardized impedances; e.g., 50-Ω coaxial cable.

In terms of fields, the ratio of electric to magnetic field at any point in the space occupied by the wave is equal to the characteristic impedance. This is also true for light waves (and sound waves if we take pressure and velocity as our analogies). If any wave meets a change in the characteristic impedance of the medium in or on which it is travelling some of the power carried by the wave is reflected. The most familiar example of this is the sound echo from a wall; some of the energy does travel into the wall but a great deal is reflected.

Returning to our parallel wires, if these have open ends, or are short-circuited, or indeed are altered in any way, then some fraction of the voltage-current wave returns down the line. It is superimposed on the outgoing wave with the result that an interference pattern is produced on the line; this is usually called a standing wave. The ratio of voltage to current is now no longer constant but varies from point to point along the line and the two are in phase only at certain points separated by half-wavelengths. In between there are points where the voltages subtract and the currents add, and if we regard this point as the input terminals of the system then here we "see" a low resistance. Similarly there are points where the voltages add and the currents subtract and here we would "see" a high resistance. At points between, the combined voltages are not in phase with the combined currents and here the impedance presented to a source of power would be complex. Thus we see that a transmission line on which there is a standing-wave acts like a transformer. Although the discontinuity existing at the end of the line, and giving rise to the reflections (we may now think of this as the load), has its own particular impedance, the source of power connected to the near end is presented with a different impedance. What this impedance is depends on three factors: the load impedance, the length of line between source and load, and the characteristic impedance of the line.

The actual relationship giving the impedance seen at the source is rather complicated and has led to the use of a special chart—the Smith Chart—for quick calculation. It is not proposed to go into this detail, however, which again may be found in the text-books. Instead let us consider various loads and look back along the line, quoting some easily remembered results as we go.

If the load impedance is Z_L then since Z_L decides the ratio of voltage to current at the far end of the line, and since any standing-wave pattern repeats itself every half-wavelength, it follows that the impedance presented at any number of half-wavelengths from the load is also Z_L.

If the characteristic impedance of the line is Z_O then at the intermediate quarter-wavelength points it can be shown that the impedance presented is given by $Z = Z_O^2/Z_L$ Thus the reactive character of the load is reversed; if the load were partly capacitive then at these points it will have been transformed into a partly inductive nature and vice-versa. Note also that at these points a short-circuit load will transform into an open circuit and vice-versa, a facility finding many uses in transmission line work.

Matching on lines

The simplest conception of matching is the case where the load is resistive and of value equal to the characteristic impedance of the line. Then no standing wave occurs for no discontinuity is present and the outgoing power is all absorbed in the load. But what about the impedance presented to the source in this case? This turns out to be equal to the characteristic impedance of the line, whatever its length, although this is true only for the ideal line we are discussing. Thus, in this case, for optimum power transfer from the source into the line, which transfers it to the load, we require a source of internal impedance equal also to the characteristic line-impedance. This requirement is not easily met in every case, although within their frequency limitations transformers can be used as previously described. Similarly at the load, unless this were by nature of the correct impedance, some difficulty would be met.

At this point let us look again at the confusions arising in the use of the term "matching". At these frequencies it is used in two connotations. One is to describe the condition when a line is terminated in a load equal to its characteristic impedance, a condition in which there are no standing waves and for which, whatever the length of the line, its input impedance is that of the termination. This condition is known as an identical match. The other is concerned with the meaning more widely used—obtaining maximum power transfer. The first case we have considered; it is ideal, and provided some inefficiency can be tolerated and the transfer of maximum power is not the aim, it can be created with, for example, coaxial resistive terminations in parallel with the actual load, where this is a high impedance, so that the total termination equals Z_O. In this way reflections at, say, the terminals of an oscilloscope are avoided, although at the cost of sensitivity, and any line length may then be used. Should there be a reflected wave and it be necessary to avoid re-reflection at the source, the output impedance of this can be made equal to the line impedance by the use of added components, a procedure which, as explained at the beginning of this article, has nothing to do with matching for maximum power transfer, and which in fact wastes power.

Finally we take the second case. What can be done when we have a load and a source the impedances of which are not equal to that of the line? Two methods of dealing with this problem are considered.

The first considers the case where we have an experimental arrangement which is permanent in the sense that the source and load impedances are constant and their positions fixed. Here also we must have access to the production of a length of line of chosen characteristic impedance. If both these circumstances prevail then we can make use of the property, already mentioned, of a quarter-wavelength of line, or its equivalent. Suppose the impedance of the source is Z_S and that of the load Z_L. We obtain a length of line of characteristic impedance Z_O equal to the square root of $Z_S Z_L$ and of length equal to, or equivalent to, a quarter wave (on the line itself). We have noted that, if this is connected to the load then at the other end an impedance equal to Z_O^2/Z_L is presented; this then becomes $Z_S Z_L/Z_L = Z_S$ and so the source is given a transformed load of optimum value. (Note that we could also say that the source impedance has been transformed along the line to $Z_S Z_L/Z_S = Z_L$.)

There is an exact equivalent here to a well-known form of matching in optics—the blooming of a lens. A coating of thickness equal to one quarter wavelength of the predominant colour to be transmitted is applied to the lens, and the refractive index of the coating is chosen so that the impedance of the layer to the light wave is the geometric mean of those of free space and the glass. Total reflection from the system is then much reduced.

What can be done now if we have no access to the manufacture of an intermediate line of suitable property, or if we have a load which is different from time to time? We then resort to the most widely used matching device at these frequencies, the matching or tuning stub, and this is often no more than a simple screw which may be inserted to a depth, and at a position in the line, both of which may be varied by the experimenter. In order to understand the function of the stub let us return to the transformation of impedance which is seen as we move away from a load.

Within a distance of half a wavelength the transformed impedance will have gone through a complete cycle of change, with both resistive and reactive parts altering. Now let us imagine moving along the same stretch of line but this time looking toward the source, regarded as inactive and presenting at the other end a "load" of impedance equal to its own internal impedance. This will, of course, have been transformed by the length of line between the source and the section of line we are considering, and as we move over the half-wavelength range the transformed source impedance will vary. Now at some point the resistive parts of the transformed source and load impedances will be equal. This may be thought to be wishful thinking but a numerical case will give an insight.

Suppose we take a 50-Ω line and suppose the source is resistive and 100Ω. At a quarter wavelength from the source the transformed impedance will have become $50^2/100 = 25\,\Omega$ resistive; this is its minimum transformed value and over the next quarter wavelength it climbs again to $100\,\Omega$ and this process is repeated cyclically. (Over this traverse there will have appeared in addition a reactance, which in the course of the traverse will have gone through both inductive and capacitive natures.)

Now suppose the load were also resistive and $500\,\Omega$. At one quarter wavelength away this will have become $50^2/500 = 5\,\Omega$, climbing back to $500\,\Omega$ at a half wavelength, and as before these changes will have been accompanied by reactive ones. The ranges of variation of the transformed resistances are seen to overlap and it can perhaps be accepted that this will always be true, even when the source and load are complex, and that a point on the line can be found where the transformed impedances of source and load have equal resistive parts. In fact, because of the cyclic nature of the standing wave, there may be many such points, separated by half-wavelengths.

Having found such a point we can imagine the line to be severed and regard the source and its length of line as an effective source of a certain complex impedance. Similarly the load and its line become an effective load with a complex impedance, the resistive part of which is equal to that of the effective source, but the reactive part of which is not that required to tune out the reactive part of the effective source impedance. All that is necessary now, in order to obtain a conjugate match, is to alter the reactance at this point in the line. This is done by screwing in a tuning stub, which acts predominately as a reactance the value and nature of which depends on the depth of insertion. When it reaches the value required to tune out the reactance present at that point on the line the job is done and the source and load are matched.

Note that there are standing waves on the line—we have used their transforming property to achieve a match—but there is in consequence a caution to be given, and this also applies to the previous method described in which standing waves were also present. The points of maximum voltage in the standing-wave pattern exceed the voltage due to the incident wave, and so care is needed in the use of these methods if there is any danger of exceeding the breakdown properties of the line.

Returning to the use of stubs, in practice the power supplied to the load is monitored and the position and depth of the stub are varied by trial and error until maximum power is observed, a process which is usually quick and easy.

Tuning stubs may take different forms from that described. They often consist of two or three stubs, variable in depth but fixed in position; this makes for ease of manufacture, and the lack of the facility of longitudinal movement is overcome by being able to combine the effects of more than one stub. The stubs themselves may be lengths of line set transversely to the main line, and with a short-circuit movable along them. This is transformed down the stub, and presents a variable impedance at the junction with the main line.

Announcements

An **Aerial Contractors Association** is being formed, the main objects of which will be to promote and agree on a standard code of practice within the aerial erection industry, to consider, originate and promote a standard of business ethics and to form a mutual trade protection association for its members. Applications for membership should be sent to the Secretary, Aerial Contractors Association, 9 Fairlawnes, Manor Road, Wallington, Surrey.

A four-week training course for **technical authors** beginning 2nd March, is offered by Technivision Services. Further details may be obtained from The Communication Training Centre, Technivision Services, King's House, 125/127 Promenade, Cheltenham, GL50 1NW.

The Electrical and Electronics Industries Benevolent Association has accepted the offer from GEC-English Electric to take over the **Lady Nelson Home** at Thorpe-le-Soken, Essex. The Home will be used as a permanent residence for needy and infirm people from the industries the E.E.I.B.A. serves.

Politechna (London) Ltd, have announced the formation of **A.K.G. Equipment Ltd**, which has been formed in association with A.K.G., Vienna. The company will take over the marketing of A.K.G. products in this country and also in Eire, Republic of South Africa, Australia and New Zealand. This company will operate from Eardley House, 182/4 Campden Hill Road, London W.8 (Tel: 01-229 3695), the headquarters of Politechna.

Plessey Components Group, of Swindon, have announced that they no longer manufacture **audio amplifier modules.** These modules can now be obtained from Britmac Electronics, Shelley Road Works, Preston, Lancs.

Ferranti Ltd, of Edinburgh, and **Northrop Corporation**, of California, have completed an agreement for Northrop to manufacture under licence the Ferranti inertial navigation and attack system for the Harrier vertical take-off and landing (V/STOL) aircraft, when this is built in the United States.

Microwave International (U.K.) Ltd, 33-37 Cowleaze Road, Kingston-upon-Thames, Surrey, have been appointed exclusive agents for the range of **circuit frames** and microwave integrated circuit microstrips and ancillary components manufactured by Tek-Wave Inc, of Princetown, New Jersey.

The London Electrical Manufacturing Co. have appointed **WEL Components** as sole distributors in England for their range of mica, ceramic, plastic film and electrolytic capacitors.

Plessey Components Group's Wiring and Connectors Division has appointed **Intel Connectors Ltd**, of Vereker House, Gresse Street, London W.1 as distributors for the complete range of Plessey connectors.

Pye of Cambridge Ltd has announced a merger with **BEPI (Electronics) Ltd**, of Galashiels and Kelso, Scotland, manufacturers of a wide range of multilayer printed circuit boards.

Following completion of an original £50,000 contract for 10 **television detector systems**, Vosper Electric, the industrial and marine controls division of the Vosper Thornycroft Group, has started work on a repeat order valued at about £100,000. This latest Government order calls for 18 detector systems plus two sets of spares. The detectors have been developed by Vosper from a prototype operated by the Post Office for the Ministry of Posts and Telecommunications.

The Marconi Company has received an order for major extensions to **sound and television broadcasting** facilities in Greece and the Aegean Islands. Two 100kW h.f. broadcast transmitters are being supplied for use on the International External Broadcasting Service. The order includes sixteen Marconi Mark V and two Mark VI cameras for use at the new television centre planned for Athens.

The Ministry of Technology has placed a further order for Cossor CDU.150 (CT.531) **oscilloscopes**, bringing the total Ministry orders of this instrument to more than 1,200 in the past year.

Redifon Ltd, has supplied **manpack transmitter-receivers** worth £30,000 to the Malaysian Ministry of Defence for the country's security forces.

Marconi Marine has supplied two interswitched radars, a complete single-sideband communications system, v.h.f. radiotelephone, navigation aid equipment and television for the crew, for the latest refrigerated cargo vessel under construction for the Fyffes Group Ltd.

GEC-AEI Telecommunications Ltd, has received an order from the Post Office worth over £375,000 for **data transmission equipment**, bringing the total value of G.P.O. orders received by the company for this equipment to nearly £1.75M.

The new address of **Silvers Lab. U.K. office** is Old Haverhill Road, Little Wratting, Suffolk.

UK Solenoid Ltd, of Hungerford, Berkshire, have opened a **Northern Ireland depot** and office at 163 University Street, Belfast, BT7 1HR. (Tel: Belfast 34582).

Instrumentation Amplifier

A d.c. amplifier of very high performance using integrated circuits

*by A. E. Crump**

This amplifier design is for use in simple instrumentation systems where a quantity to be monitored is represented by a proportional d.c. signal which has to be relayed over a cable to a meter at a remote point. It may also be used as a buffer or pre-amplifier to an analogue-to-digital converter in more sophisticated systems.

The majority of industrial grade transducers have an output circuit that approximates to a current source and that give outputs of around 10 mA and are therefore not significantly affected by the varying resistance of reasonable lengths of cable. Sometimes, however, it is necessary to use a long cable run that may exceed the maximum resistance specified by the transducer manufacturer. It is in these circumstances that one or more amplifiers are needed. It is important that the output circuit of such an amplifier should be a current source so that the output signal shall be insensitive to varying resistance in the driven portion of the cable.

Occasionally transducers with very low output signals have to be used, and in these cases it is prudent to amplify the signal, before transmission, to a level approaching 10 mA (full scale) in order that the effects of noise and other interference within the cable are reduced. Even where such signals are not transmitted over a cable it is usually necessary to provide amplification for driving analogue-to-digital converters, pen recorders etc., and here again a current-source output stage is preferable.

The amplifier described has a symmetrical current source output stage, has excellent stability and can produce a 10 mA output current from input signals as low as 50 mV. The design does not involve heavy cost of components and its accuracy is adequate for most applications. Fig 1 is the block diagram of the amplifier. Each block will be discussed in turn.

Sink/source stage

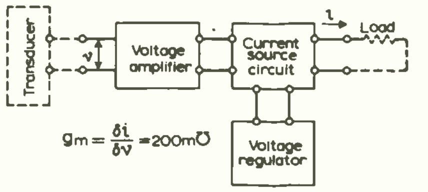
The elements of this stage are shown in Fig. 2(c). At first sight this might seem to be an unnecessarily complicated method of producing an output current (I_{out}) proportional to an input voltage (V_{in}). It is interesting, therefore, to look at the simpler circuit shown in Fig. 2(a) first.

The problem with this simple common emitter stage is that the linearity of the stage deteriorates as V_{in} approaches V_{be}, and when $V_{in} = V_{be}$ the transistor starts to turn off. The other point is, of course, that the output signal current can only flow in one direction, whereas, with the arrangement shown in Fig. 2(c) the output current is able to flow in either direction.

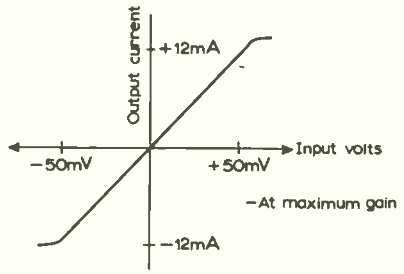
Fig. 2(b) illustrates the basic principle. The current generator I_R produces a fixed reference current whereas the current generated by the source I_S varies proportionately to the signal voltage V_{in}. The difference current flows through the load, the direction of flow depending upon which current is the greater.

Now let us assume that I_S is generated by a circuit similar to that of Fig. 2(a). Provided that the transistor is never allowed to approach either saturation or cut off, then the difference current I_{out} can fall to zero and then increase in the reverse direction while maintaining very good linearity.

The circuit is designed so that when the input to the complete amplifier is zero, then the voltage amplifier generates an offset



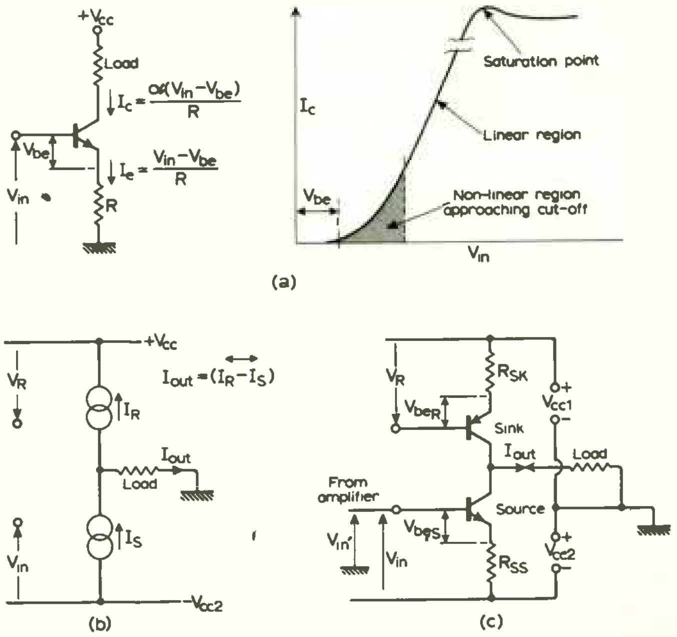
AMPLIFIER SPECIFICATION



Maximum transconductance	= 200mA/V
Maximum recommended output swing	= ±10mA
Output overload point	= ±12·5mA
Input resistance at maximum gain	= 10kΩ
Common-mode rejection	= 60dB
Supply voltages	= ±12V
Temperature range	= 0-60°C
Maximum error over temperature range	= ±1%

Fig. 1. (Left) Block diagram of the amplifier.

Fig. 2. (Below) (a) Single-ended current source and transfer characteristic, (b) Simplified current source stage, (c) Final current source stage.



potential large enough to drive 12·5 mA through the source transistor. The sink transistor is designed to sink exactly this amount of current, hence the output current to the load is zero. A "fine" offset adjustment is provided on the amplifier to compensate for component variations. When a signal is applied to the input terminals then the source transistor conducts either more or less depending upon the signal polarity, and produces a corresponding signal in the load.

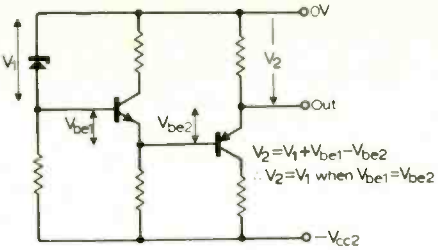


Fig. 3. Self-compensating current source.

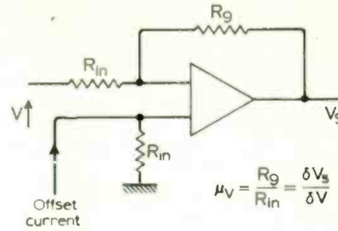


Fig. 4. A voltage amplifier.

Design

The reference, or sink, current is required to be constant and stable and to this end a high-grade reference diode is used to generate V_R. In order that the full stability of the reference diode can be used it is necessary to keep the diode bias current as steady as possible at the recommended current of 5 mA. If a different bias current is used, the very low temperature coefficient of 0·001 %/°C cannot be maintained.

The value of R_5K has been chosen so that the sink transistor base current is considerably less than the diode bias current therefore fluctuations in base current should not significantly affect the bias current.

High-stability reference diodes tend to produce voltages in the range 5·6 to 10 V and the ZS7 used in this design was found to give a nominal 7 V.

As the supply voltages V_{cc1} and V_{cc2} are only 12 V each it is necessary to reduce the reference voltage to prevent premature overload of the output stage under full drive conditions.

The reduction is effected by means of a precision potential divider network formed by R_8 and R_{10} (Fig. 5).

The value of R_7 has been made equal to R_4 to ensure optimum thermal tracking of the source and sink transistor V_{be} characteristics. In order to further assist thermal tracking the sink and source transistors are type BFX81 which is an integrated circuit complementary transistor pair on a single chip.

The effect of V_{be} changes upon the value of the output current can be seen from the following equations.

$$I_R = \frac{V_R\left(\frac{R_8}{R_8+R_{10}}\right) - V_{be}R}{R_7}$$

$$\therefore \delta I_R = \frac{-\delta V_{be}R}{R_7}$$

and

$$I_S = \frac{V_5 - V_{bes}}{R_4}$$

$$\therefore \delta I_S = \frac{-\delta V_{bes}}{R_4}$$

Now the design is such that

$$V_S = VR[(R_8)/(R_8+R_{10})]$$

in the quiescent state (i.e. transducer signal = zero), hence provided that $V_{be}R$ is equal to V_{bes}, both statically and incrementally, then $I_R - I_S$ will also be zero, thus maintaining the output conditions despite thermal fluctuations.

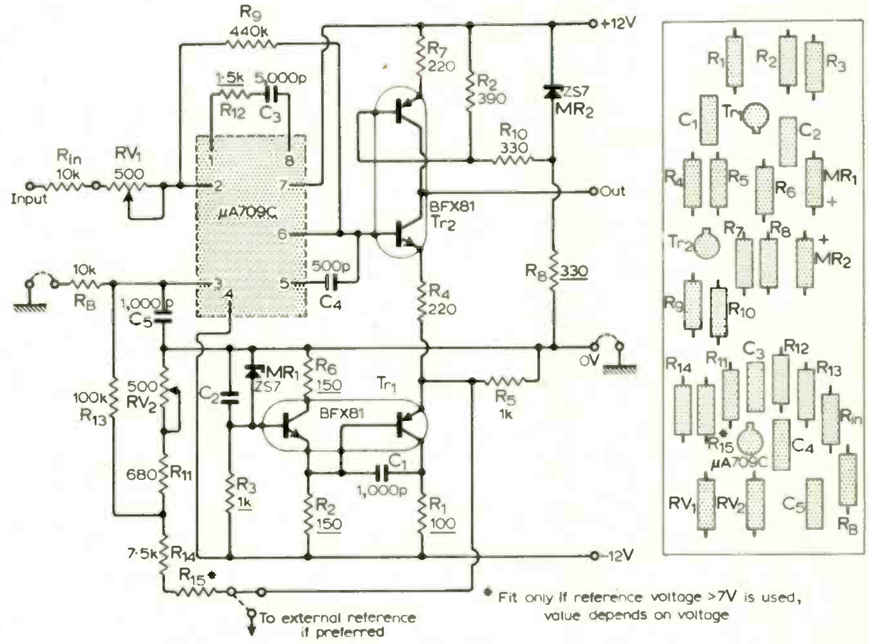


Fig. 5. Overall circuit diagram of the amplifier and suggested layout of components.

R_5 is present to ensure that there is always a bleed current from the voltage regulator, thus ensuring that it never cuts off.

Voltage regulator

Referring to Fig. 5 it is apparent that if V_{cc1} varies, then I_R will not be effected at all as its magnitude depends only on the V_R circuit.

In the case of V_{in} however the situation is not quite so straightforward because the magnitude of V_{in} is normalized to zero volts by the voltage amplifier, whereas the resistor R_4 is returned to V_{cc2}. Should any change occur in V_{cc2} therefore, the difference voltage δV_{cc2} will appear as an error signal in I_S and would degrade the accuracy of the amplifier.

The error signal at the output due to a change in V_{cc2} would be:

$$\delta I_R = \frac{\delta V_{cc2}}{R_4}$$

It is necessary therefore to design a voltage regulator using a reference diode normalized to the 0 V rail.

The arrangement is shown in Fig. 3. The requirements for the reference diode are similar to those used for the sink circuit as any variations in reference voltage appear as an error signal given by $(\delta V_{ref})/R_4$. It is necessary to buffer the reference diode from the source transistor to stabilize the diode bias current against changes in I_S, but in so doing a transistor is introduced whose own V_{be} changes would produce a further error signal. A complementary transistor is therefore used to compensate for this and to ensure good tracking the BFX81 has been used again.

The collector load resistors R_1 and R_6 have been chosen in such a way that the dissipated power in the two transistors is substantially equal—this being a further aid to thermal tracking.

The voltage amplifier

The voltage gain is derived from a conventional operational amplifier configuration, as illustrated in Fig. 4.

The voltage gain is given by

$$\mu_V = \delta V_S/\delta V = R_9/R_{in}.$$

Now in order to obtain an output swing (SI_s) of 10 mA from the sink/source stage, the value of V_s will have to swing by an amount $(SI_s)(R_4) = 10\times0·22$ that is 2·2 volts.

Now in order that this 2·2 V swing is obtainable with transducer signals as low as 50 mV, the gain of the voltage amplifier needs to be:

$$\mu_V = 2{,}200/50 = 44$$

Thus if we select 10 kΩ as being the minimum permissible input resistance, the value of R_9 must be 44(10) = 440 kΩ.

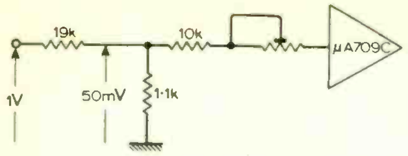


Fig. 6. An example of a modified input network.

It would not be wise to use higher absolute resistance values due to the difficulty of obtaining precision resistors in the megohm range.

The gain can, of course, be varied by suitable choice of R_{in} but because of noise problems it is not recommended that the value of R_{in} should be reduced below 10 kΩ.

A small variable resistance RV_2 is included to provide the means of absorbing component tolerances and by its use the gain can be adjusted to the exact value of 44.

Offset control

As previously mentioned, when the transducer signal is zero, a negative offset voltage must be present on the source transistor to achieve cancellation of the sink current.

The supply from which this voltage is derived must be stable otherwise an error signal will appear at the output. It is convenient to use the voltage regulator output for this purpose and the arrangement is shown in the complete circuit diagram, Fig. 5. A disadvantage of this method is that in certain circumstances it could lead to instability due to positive feedback and it is then preferable to use an external reference source or a further ZS7 diode.

Layout and instability

The semiconductors used have cut off frequencies in the megahertz region, therefore care has to be taken with the physical layout of the printed circuit board to ensure that the interconnecting tracks are as short as possible.

The components R_{11}, C_3 and C_4 ensure a stable gain/phase characteristic for the operational amplifier, and C_4 provides a similar stabilizing effect on the voltage regulator.

Gain setting

In the circuit shown in Fig. 5 R_{in} is 10 kΩ (i.e. 50 mV input swing produces 10 mA output swing). If it is required to use a lower gain setting it is preferable to keep R_{in} within the range 10–50 kΩ in order to maintain the specified accuracy. Where still lower gains are required it is preferable to use a series attenuator designed so that the net value of R_{in} is always within the above range. As an example the network shown in Fig. 6 has an attenuation factor of 20 thus 1 V input would produce 10 mA output from the amplifier.

Transient-catching diodes and suppression capacitors may be connected across the input and output terminals as required.

Advance in i.c. manufacturing technique

A new method for producing integrated circuits has been announced by the SGS International Group of companies.

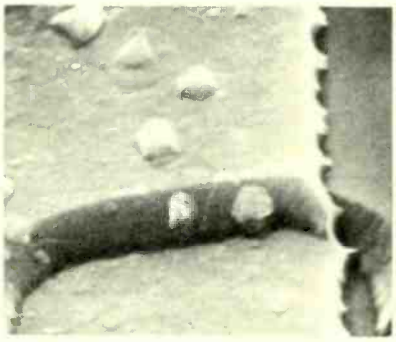
The new process, called Planox, (which has been developed at the SGS laboratories at Agrate, Milan) is applicable to both bipolar and m.o.s. devices, but is of particular importance in the production of m.o.s. integrated circuits.

In an m.o.s. device, the oxide layer grown on the gate regions has to be extremely thin in order to achieve low threshold voltage sensitivity; and the oxide layer in the field region has to be thick to avoid spurious effects. When produced by conventional methods, the thick layer on the field region gives rise to high 'steps' of oxide on the chip surface over which the metal pattern has to be formed. The sharp bends in the metal layer can result in weak spots or 'microcracks'.

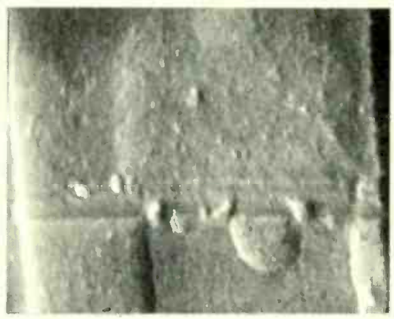
In the Planox process this possibility is eliminated by removing sufficient underlying silicon to accommodate the oxide thickness, so that the resultant surface is almost flat. This is achieved by depositing on the silicon wafer a thin film of silicon nitride, which prevents oxidation, and which can be selectively etched with respect to silicon dioxide. The nitride film is then masked and etched to lay bare the regions where thick oxide is to be grown. The growth of silicon dioxide on the bared regions uses sufficient underlying silicon to provide an oxide layer that has the required thickness and a surface which is co-planar with that of the nitride film.

When used in the production of m.o.s. devices, the silicon nitride is then selectively etched, exposing the regions that are to be diffused to create the source and drain electrodes.

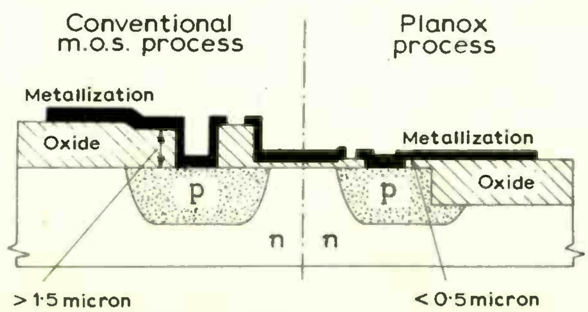
Source and drain are passivated by the thick oxide and the remaining nitride is selectively etched away from the gate. The subsequent steps of gate oxidation, opening of contacts and metallization are carried out using conventional techniques. The Planox process will be used in the production of SGS m.o.s. devices during the second quarter of 1970.



Conventional device



Planox device



Letters to the Editor

The Editor does not necessarily endorse opinions expressed by his correspondents

Digitally-set audio oscillator

An i.c. is used to provide a digitally settable square-wave oscillator, operating over the range 10-4990Hz. The circuit (Fig.1) is one of the saturating multivibrator circuits described by G. B. Clayton in his 'Operational Amplifiers' series. For the astable multivibrator the frequency is given by $f=k/C$ where k is a constant and C the capacitance in circuit. To achieve decade selection of frequency increments of 10Hz, 100Hz, and 1kHz are added by adding in the appropriate increments of $1/C$, corresponding to the frequency desired. If the increments are added in the correct manner, the frequency will be correctly selected. The oscillator provides an output of about 20V pk-pk. Switching time effects cause the frequency law to deviate from the theoretical at high frequencies, the actual frequency being somewhat lower. In consequence the values of the × 1kHz capacitors should successively decrease. The arrangement of capacitors is shown in Fig.2.

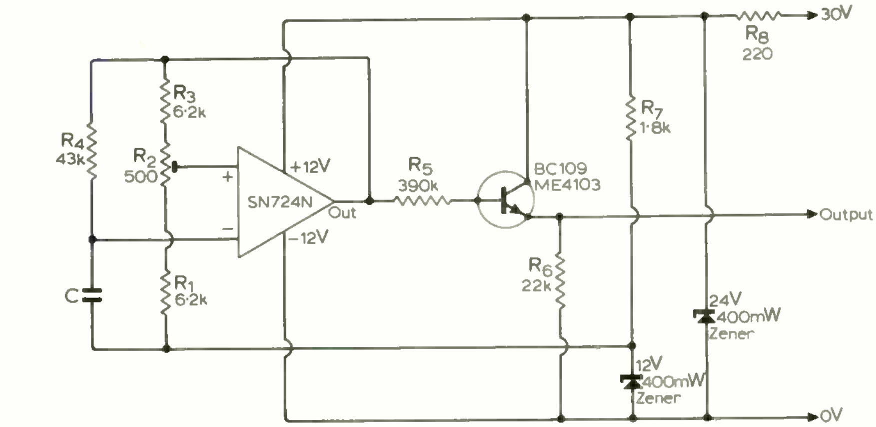
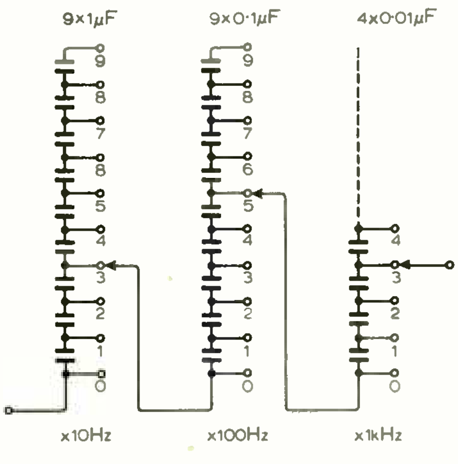


Fig. 1. Square wave oscillator circuit



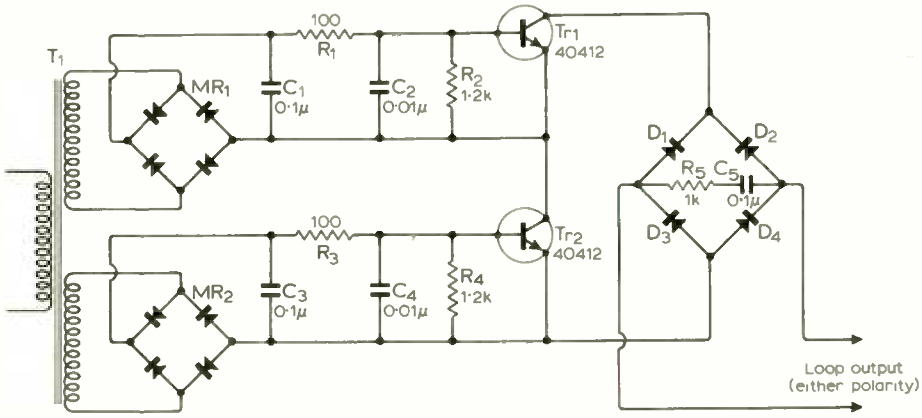
Set to 3·53kHz

Fig. 2. Decade capacitor array—replaces C in Fig.1.

DAVID TAYLOR, G8ARV,
Jesus College,
Cambridge.

Audio switch

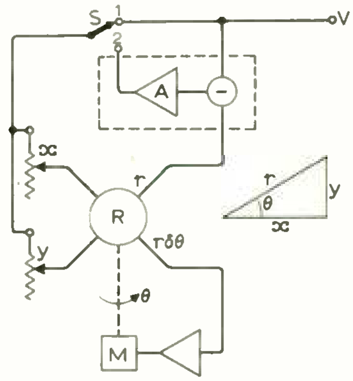
The circuit was developed to close a d.c. circuit when an audio signal was present. A relay proved to be not quite suitable. The circuit responds equally well to sine- or square-wave signals. T_1 in the circuit is a Collins 667-0522-00 15mW audio transformer with primary impedance of 10k and two 600 secondaries providing approximately 1.7V r.m.s. to the bridge rectifiers. No doubt any small transformer could be used provided the secondary is split, and experiments with pot-cores gave the same results. Mr_1 and Mr_2 are bridge rectifiers consisting of OA81 or similar diodes—the base current requirements are quite small on both transistors. The filtering used gave reasonably interference-free switching at approximately 2kHz input. Tr_1 and Tr_2 are R.C.A. type 40412 with small heatsinks, since they switched 250V at 15mA. D_1 to D_4 used were silicon diodes rated p.i.v. 600, at 1A. R_5 and C_5 reduced switching transients further. C_5 must be at least 1.5 times the open circuit voltage of the loop.



J. DU P. DE BEER,
South African Broadcasting Corporation.

Resolver with gain control

Conversion from cartesian (x, y) to polar (r, θ) co-ordinates in an analogue computer can be done with a resolver as shown. The normal method is with switch S in position 1, but the gain of the resolver servo then varies with r. This can be compensated with a multiplier ($\times$ $1/r$) in the loop but a better way is to add the components in box A and change S to position 2; the resolver output is then compared with the fixed voltage V and the potentiometer feed adjusted by the amplifier to keep it constant. The servo loop operates at fixed gain and if the resolver is magnetic its magnetization remains constant, which gives best accuracy.



C. N. GORDON,
Defence Operational Analysis Establishment, Surrey.

Letters to the Editor

The Editor does not necessarily endorse opinions expressed by his correspondents

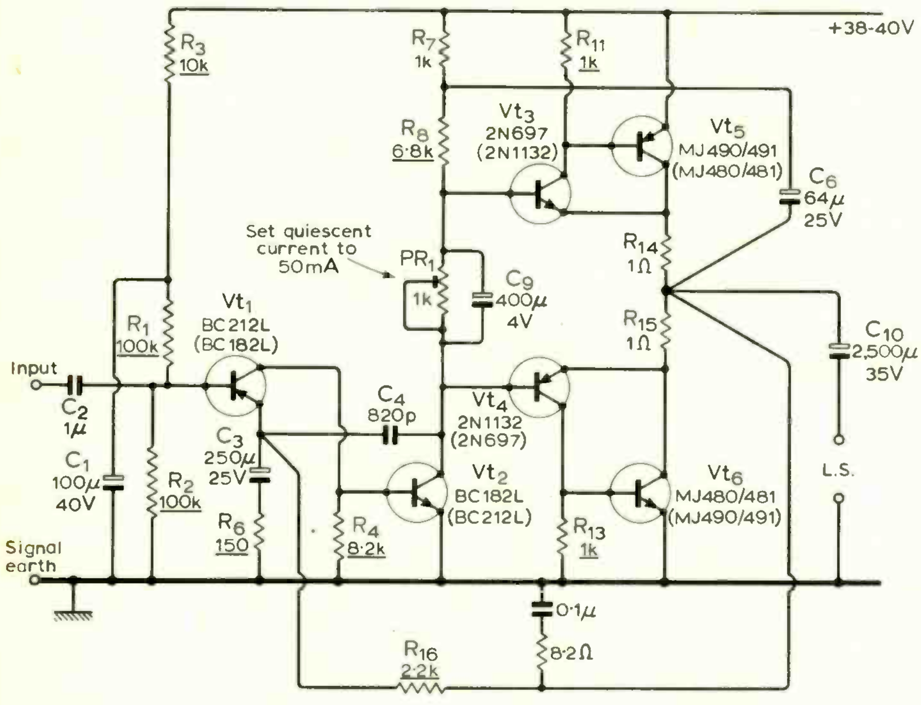
Dinsdale amplifier mods

In his most interesting article "design in retrospect", in the November 1969 issue of *Wireless World*, Mr. Dinsdale refers to the development of the Tobey-Dinsdale 10-watt audio amplifier, first described in the *W.W.* in November 1961, and expresses an interest in hearing of successful modifications which have been made to this design.

Since some of the components for this were a bit inconvenient to obtain, I produced a modified version of this, for a friend, some years ago, and this has recently been further modified very successfully to use a full complement of silicon transistors. In view of the very good performance which can be obtained from this, it is possible that the design may be of interest to others of your readers. The distortion is typically 0.07 % at 1kHz and 10W and the square wave response is free from overshoot or ringing, even with capacitive loads, up to beyond 20kHz. The circuit can be used on negative h.t. rails with the transistor types shown in brackets, provided that the electrolytic capacitors are reversed. The numbering of the components is that used in Mr. Dinsdale's January 1965 article.

The loudspeaker "plop" on switching on is avoided by d.c. coupling the n.f.b. to the first transistor via R_{16}. This causes the potential at the loudspeaker output to rise fairly slowly, as C_1 charges. This arrangement reduces the hum pick-up on badly smoothed h.t. supplies.

J. L. LINSLEY HOOD,
Taunton, Somerset.



Modified "Dinsdale" amplifier, for use with silicon planar transistors. Output 10W, 15Ω or 15W, 8Ω. Suitable for use with either positive or negative h.t. line depending on transistors and polarity of electrolytic capacitors. Amended component values are underlined. Capacitor C_5, diode D_1 and resistors R_5, R_9, R_{10} and R_{12} in the original design were omitted.

In defence of S.I. Units

On page 548 (the right hand column) of Mr. Kelly's interesting and informative article in the December issue he devotes a paragraph to the subject of S.I. Units. I am surprised at some of the remarks he makes which seem to imply that S.I. does not allow of the normal subdivision etc. of its basic units. It is perhaps worth pointing out that it is standard Continental practice to work in mm for dimensions and then on any occasion where calculations are made involving other fundamental units. a factor of 10^{-3} would be introduced to convert to the basic S.I. unit. Does Mr. Kelly think that we can no longer use µF or nF or pF but instead write 10^{-6} F, 10^{-9} F, 10^{-12} F? Of course we can, and of course we can also still talk in grammes, milligrammes, cm, mm, km, or what have you! The only difficult unit is compliance, normally expressed in cm/dyne. This is a nongravitational unit and there is a simple conversion factor to m/newton for calculation purposes which is 1 cm/dyne = 10^3m/newton. Thus introducing the S.I. will see off "thous" ounces etc. but not grammes, milligrammes or mm, µm (microns) . . .

B. J. C. BURROWS,
Abingdon,
Berks.

The author replies:

I seem to have stirred up a hornet's nest in my "obdurate insistence on the familiar"; however, I am unashamedly unrepentant.

In my review of the products of a virile and viable industry I employed terms and dimensions in general use in this industry. The Editor originally suggested that I should use S.I. units, but having discussed the question of dimensions with a number of manufacturers, persuaded him to permit me to use the classic c.g.s. and British dimensions.

Possibly in the next few years the industry during its conversion to metrication will adopt S.I. units as standard; when this occurs I shall be most happy to record events in the vernacular.

STANLEY KELLY

Local radio

Derek Faraday's letter (page 565 December *W.W.*) advocating extensive use of m.w. transmitters in the U.K. can be dismissed in one sentence. These transmitters are and would be incapable of reproducing music—either classical, light or 'pop'.

Sound broadcasting in the U.K. is already about twenty years behind the rest of Europe. There is a vicious circle affecting the public, the B.B.C. and set makers which, after all this time, has prevented v.h.f./f.m. radio from getting off the ground.

In this small country (Belgium), for example, there are six separate national programmes on v.h.f., plus several regional programmes. Two of the best music programmes are on v.h.f. only—the public abandoned listening to music on a.m. years ago.

It is possible to listen to stereo programmes here all day, as it is in most north European countries. Apart from all kinds of music in stereo, there are frequent drama programmes in stereo.

You could not sell a purely a.m. receiver in continental Europe. In fact, more and more people are buying only a v.h.f. tuner as their sense of reproduction quality makes them completely disinterested in a.m. Also, a car radio without f.m. is unmarketable here, especially as a.m. cuts out under bridges and in tunnels.

There is a lot of negative discussion in the U.K. on the difficulties of v.h.f. reception. In Waterloo, Belgium, I can receive the Wrotham transmissions perfectly, in mono, on a medium-price Grundig receiver. In frosty or foggy weather I get Wrotham in stereo without background noise. Without difficulty, I can listen any day to more than fifty v.h.f. transmitters (not fifty different programmes, of course) twelve of them in stereo. There is no difficulty with reception of stereo from France, Holland and Germany at distances of 100 miles. Mono programmes on v.h.f. from places as far away as Hamburg (N.W.D.R.) can be heard clearly any evening. It is true that the v.h.f. broadcast band, here, is uncluttered by any public service transmissions. (When is the Home Office going to get the Police and ambulances off the broadcast bands?)

My Blaupunkt car radio, with one metre of telescopic aerial, picks up the Wrotham v.h.f. programmes in Brussels! Teenagers in Belgium, Holland and Germany listen to Radio Luxembourg on v.h.f., not on long- or medium-waves.

I could go on and on citing examples showing how sound radio in Britain has stayed the poor cousin of Europe. There is deadlock in Britain, and the only way I can think to break this is for the B.B.C. to do as the administrations have in France, Holland, Belgium and Germany; that is, to broadcast the most popular programmes on v.h.f. only, gradually shutting down the m.w. transmitters.

BASIL JACKSON,
Waterloo,
Belgium.

The Engineer in State and Private Enterprise

You question in your leading article in the December issue what there is in common between chartered engineers of various institutions.

The answer is that they are all trained in a target-directed discipline that calls for the highest degree of intelligence and involvement. Engineering contains financial, human and sociological factors which are absent from pure science. There are no natural divisions, and the man-made ones are crossed more frequently as the science of engineering develops.

A new branch of engineering tends to breed specialists, but their specialization becomes absorbed in time into the background training of all engineers. What differentiates the chartered engineer from the technician is the ability to apply his training to the solution of any engineering problem rather than to become expert in one technique.

The chartered engineer is loyal, keen on his job, independent, logical, outspoken and obstinate. He can neither be led nor driven. He has a high standard of ethical conduct and resents being taken for a ride. He is impatient with obstacles and sometimes lacks finesse in dealing with them. Today he is unhappy about the weak direction which has allowed others to threaten his security by strong-arm methods. But he will not give his conscience to the keeping of a union in which his voice as a professional man cannot be heard.

That is why twenty three thousand membership forms have already been issued by the United Kingdom Association of Professional Engineers in response to applications. U.K.A.P.E. is the engineering profession's own union and will be run democratically to serve its interests. It will protect its members against injustice from all quarters, the government, employers, institutions or other unions. It will improve the status and conditions of the chartered engineer by giving him a stronger voice in society and a stable career structure, while at the same time not forgotting the interests of the technician engineer and the engineering technicians.

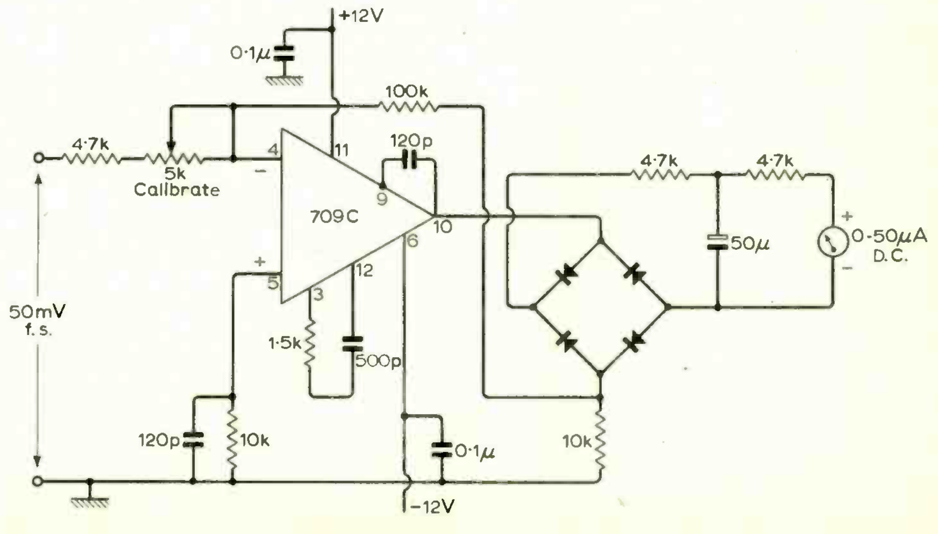
U.K.A.P.E. believes that those engaged in engineering are people of a special quality with a common interest. While insisting on the sanctity of individual freedom, it also believes that disruption could be disastrous both socially and technologically.

R. L. CLARKE,
Vice-president, U.K.A.P.E.,
London, S.W.1.

Op. amp. a.c. millivoltmeter

In your issue of October 1969 the article "Operational Amplifiers—9" by G. B. Clayton gives a circuit for a precise a.c. millivoltmeter. We recently had occasion to construct a similar forced feedback meter circuit to give a full-scale reading with 50mV r.m.s. input down to 3 Hz. The circuit below may be of some interest to readers. A Fairchild op. amp. was used.

M. V. DROMGOOLE,
Dept. of Scientific & Industrial Research,
Christchurch,
New Zealand.



Linear integrated circuits

Mr. Hirst, in his article on linear integrated circuits in your January issue, reveals a need for three specific devices, in addition to the ubiquitous operational amplifier, which should be cheaply and easily available as standard linear 'building blocks'. These are an h.f. amplifier, an l.f. amplifier and a transistor ring modulator for mixer use. He suggests that the first two might be combined in a general purpose a.c. amplifier.

For over 18 months this company has manufactured such devices and they are all available at prices in the £1-£2 range.

The types are:

L.F. amplifiers. Low power; the SL630C has 40dB gain from a few Hz to 100kHz and has an internal gain control giving 60dB control. High power; the SL402A and SL403A will give over 2W and over 3W output respectively over a slightly lower frequency range. They have very high input impedance.

H.F. amplifiers. The SL610C, SL611C and SL612C provide gains of 10, 20 and 50 respectively over the frequency ranges of 80kHz to 100MHz, to 80MHz, and to 12MHz respectively. All can drive 1V r.m.s. output at less than 1% intermodulation and all have over 40dB a.g.c. range.

Mixers. We do not manufacture a ring modulator but the SL640C and the SL641C double balanced modulators will out-perform most ring modulators over the frequency range of 10Hz to over 100MHz without the need for transformers. They have low signal and carrier leakage.

In addition we make the SL610C and the SL621C which are a.g.c. circuits having fast attack, slow decay and the ability to track a signal fading faster than the decay rate. They may be used with the SL610-612 and the SL630.

To satisfy Mr. Hirst's other condition—that continued supply be assured—these devices form an integral part of several professional and military equipments and their availability for the next five or ten years is assured.

J. BRYANT,
Plessey Company,
Components Group,
Swindon, Wilts.

Active Filters

7. The two-integrator loop

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

The two-integrator loop is an active *CR* analogue of a passive *LCR* circuit, in which outputs which may be identified with the voltages severally developed across the inductance (high-pass response), the resistance (tuned-circuit response), and the capacitance (low-pass response), are available simultaneously. These outputs are developed with low source impedance and, together with the input voltage, have one terminal in common. They are therefore easily added in the proportions required to give any desired 2nd-order transfer-function. Thus the analogue can be the basis of a universal building block for higher-order filters of any kind, using the method of synthesis by factors.

The two-integrator loop is particularly useful where higher *Q*-factors are needed than are practicable from a circuit which depends for *Q* factor on a single amplifier; and it is particularly convenient when variable tuning is required.

In Parts 5 and 6 were described a number of circuits based on the lag-and-integrator loop for obtaining second-order response, low-pass, tuned-circuit, high-pass, and notch. In a following article it will be shown how a number of such circuits can be put in tandem (together with, when required, simple lag and simple lead networks) to make higher-order filters. In general terms the sharper the corner at cutoff the higher the Q factor of at least one of the second-order constituents (or factors). The weak relationship between maximum Q factor and amplifier gain ($q \not> \frac{1}{2}\sqrt{A}$) is then often a serious limitation with circuits of the lag-and-integrator type, and a more powerful method is needed. This is provided by the two-integrator loop, which can draw on the product of the gains of two amplifiers.

The two-integrator loop, in one form or another, is probably the most important system to be described in this series of articles. It is an analogue of any basic oscillatory system, e.g. a pendulum, a mass and spring, or a tuned circuit, since in the ideal case of zero damping it is defined by the equation

$$\frac{d^2\theta}{dt^2} = -\frac{1}{T_1T_2}\theta. \qquad (1)$$

θ may represent any variable such as linear position, angular position, voltage, etc., and the equation states that the restoring acceleration is proportional to the displacement. Hence the natural motion is simple harmonic of period $2\pi\sqrt{(T_1T_2)}$, i.e.

$$\omega_c = 2\pi f_c = \frac{1}{\sqrt{T_1T_2}} \qquad (2)$$

Fig. 1 shows the system schematically. By working backwards from the output, it can be seen that the "error" between input and output $(\theta_{in}-\theta)$ equates to $p^2T_1T_2\theta$, and that hence when there is no input stimulus ($\theta_{in} = 0$) equn. (1) is obtained.

The two-integrator loop has been described previously in these general terms[1]. In the present article it is derived as a particular analogue of an *LCR* tuned circuit, so that the corresponding properties of the active and passive systems can be more readily identified.

Because of the multiplicity of amplifiers required, the use of the two-integrator loop as a means of realising active filters, especially ones of higher order, has until recently seemed both cumbersome and costly; but with the arrival of silicon integrated circuits the position began to alter, and now two operational amplifiers are available on a single chip and three have been promised. It is therefore becoming increasingly attractive to take advantage of the versatility, improved performance, and greater designability, offered by the system.

Analogue of an LCR network

A functional diagram of an active system which copies the working of a series *LCR* passive network can be derived by the steps shown in Fig. 2.

Since, in Fig. 2(a), the same current flows through all three components, the ratio of the voltages across any two components will equal the ratio of their operational impedences. Therefore the ratio of V_R (the voltage across the resistance) to V_L (the voltage across the inductance) is given by

$$V_R/V_L = Z_R/Z_L, \qquad (3)$$

and hence

$$V_R = \frac{1}{pL/R}V_L, \qquad (4)$$

which shows that V_R may be developed from V_L by integration carried out to the scale defined by the time constant L/R.

Similarly V_C (the voltage across the capacitor) may be developed from V_R by integration to scale defined by the time constant CR, i.e. since

$$V_C/V_R = Z_C/Z_R, \qquad (5)$$

$$V_C = \frac{1}{pCR}V_R. \qquad (6)$$

Thus, given the voltage V_L, the voltages V_R and V_C may be developed, as in Fig. 2(b).

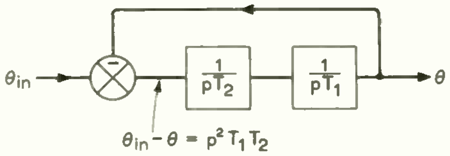


Fig. 1. Ideal two-integrator loop.

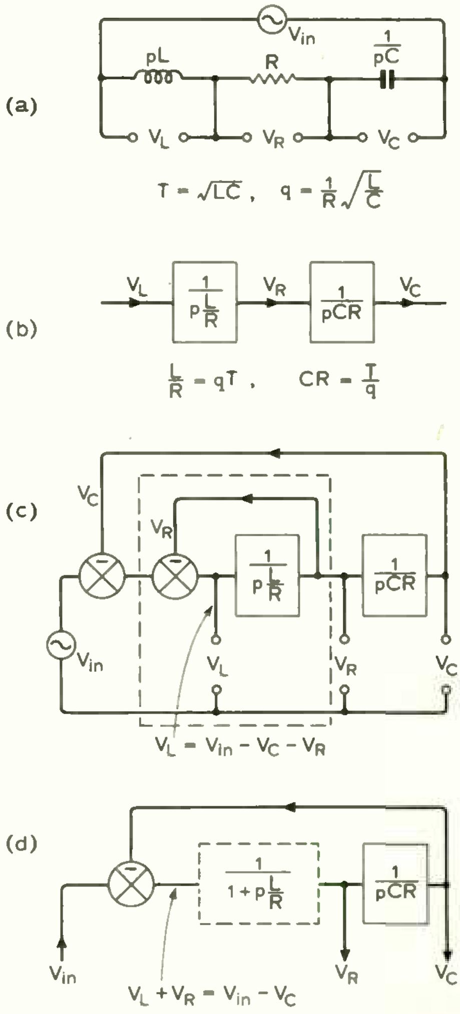


Fig. 2. Two-integrator loop modelled on passive LCR circuit.

*Royal Radar Establishment.

by the use of two integrators connected in series. In terms of the parameters T and q, the Ts of the two integrators are $L/R = qT$ and $CR = T/q$. To complete the analogue it only remains to establish the input V_L. This may be done by making the further connections, as shown in Fig. 2(c), in accordance with the self-evident relation

$$V_L = V_{in} - V_C - V_R \quad (7)$$

Properties of the analogue

The schematic of Fig. 2(c) shows only the essence of the mathematical processes that have to be instrumented, and incidental sign changes that may attend the use of electronic integrators and summing amplifiers have been ignored. Each integrator will use an amplifier; and, since in a practical circuit account must be taken of sign changes in order that the loops may be closed in their correct sense, it is clear that a total of three or four amplifiers may be needed. This will hardly be justified unless this apparently extravagant use of gain can be shown to confer important advantages, and in particular a higher Q factor will be looked for than can be obtained from the single-amplifier lag-and-integrator loop.

One advantage is immediately apparent. It has already been shown that many active-filter networks can yield two or more different responses by introducing the input voltage into different branches and/or by taking the output from different pairs of terminals. The system shown in Fig. 2(c) gives three responses simultaneously:

V_C, low-pass

V_R, tuned circuit

V_L, high-pass.

Remembering the results given in Part 2, it should be noted that at the resonant frequency, $\omega_C = 1/\sqrt{LC}$, the responses at V_C and V_L both have magnitude q while that at V_R is depressed to unity for all values of q.

It is easy to show, however, that the particular arrangement of the analogue which is shown in Fig. 2(c) does not make effective use of the available gain from two integrators. The contents of the broken-line enclosure reduce to the simple lag $1/(1+pL/R)$ shown in Fig. 2(d); that is to say, apart from the loss of the separate terminal for V_L, this part of the analogue could be replaced by a passive network. This reduction can be made by substituting $\mu = R/pL$ and $\beta = -1$ in Black's formula $G = \mu/(1-\mu\beta)$ or, alternatively, by copying the working of the LCR network according to the relation

$$\frac{V_R}{V_R+V_L} = \frac{Z_R}{Z_R+Z_L} = \frac{1}{1+pL/R} \quad (8)$$

and by closing the loop to implement equn (7) as

$$V_R + V_L = V_{in} - V_C. \quad (9)$$

Thus, although it has two integrating amplifiers, the analogue has been constrained to behave as a loop with a lag and a single integrating amplifier, and it can have only a comparable performance. That this constraint can easily be removed will be shown. It is useful, however, to continue the argument to emphasize the importance of taking account of the effect of finite gain upon the relative merits of different circuits.

Equivalent circuit for loop with finite-gain integrators

As shown in Part 5, when allowance is made for finite amplifier gain, an integrator degenerates to a simple lag, of time constant $(A+1)$ times the 'T' of the integrator, multiplied by the gain factor A. Thus

$$G(p) = \frac{A}{1+(A+1)pT} \quad (10)$$

which, when $A \gg 1$,

$$= \frac{A}{1+pAT}\,\text{(approx)} = \frac{1}{\frac{1}{A}+pT}. \quad (11)$$

When this substitution is made in Fig. 2(c) for the ideal form $1/pT$, Fig. 3(a) is obtained.

For sine-wave excitation $j\omega$ is written for p, and it follows that terms of the type $1/A$ in the denominators represent components of input voltage in phase with output voltages. This corresponds in the passive prototype, Fig. 2(a), to a current in shunt with the capacitor which is in phase with the voltage across it, and to a voltage in series with the coil in phase with the current through it, and so leads to the equivalent circuit shown in Fig. 3(b). The Q factors of the lossy reactors (and those of the corresponding imperfect integrators) are

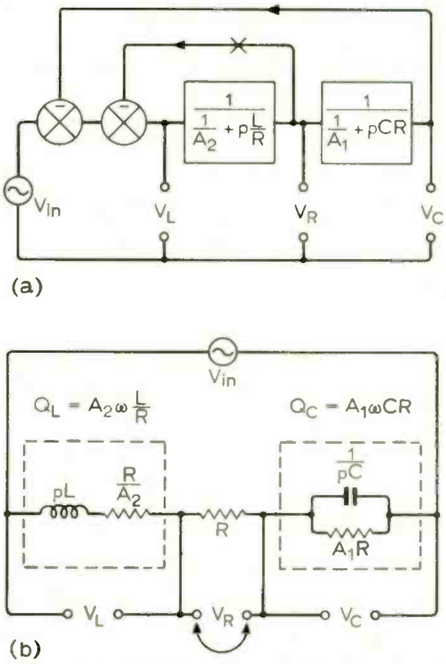


Fig. 3. Modifications to LCR circuit to correspond to finite gain in integrators.

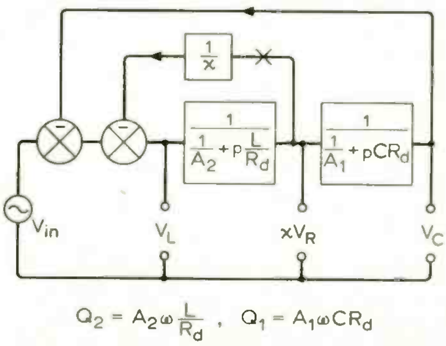


Fig. 4. Modification of Fig. 3(a) to allow arbitrary scaling of voltage representing V_R.

$$Q_C = A_1\omega CR, \quad Q_L = A_2\omega L/R. \quad (12), (13)$$

When $A \to \infty$, the desired value of q is set in by making $CR = T/q$ and $L/R = qT$, where $T = 1/\omega_C = \sqrt{LC}$ and $q = \frac{1}{R}\sqrt{\frac{L}{C}}$.

With A finite, the achieved value of q will be lower, but it is convenient to retain the notion of the ideal value of q and denote it by q_i, thus

$$q_i = \frac{1}{R}\sqrt{\frac{L}{C}} \quad (14)$$

Any shift in resonant frequency can usually be neglected so it can be taken that $\omega_C = 1/\sqrt{LC}$, as before, and at ω_C the Q factors are

$$Q_C = A_1/q_i, \quad Q_L = q_iA \quad (15), (16)$$

The shorting out of R (with the arrowed link) in the equivalent circuit, Fig. 3(b), corresponds to opening the inner loop (at X) of the analogue, Fig. 3(a). The residual circuit quality is then determined solely by the losses due to finite Q_C and Q_L; and, as explained in Part 5, these losses add as the reciprocals of the Qs. Denoting the residual circuit quality by q_r, it follows, from equns (15) and (16), that

$$\frac{1}{q_r} = \frac{q_i}{A_1} + \frac{1}{q_iA_2}, \quad (17)$$

and that the net circuit quality with R re-introduced (and the inner loop closed again) will be given by

$$\frac{1}{q} = \frac{1}{q_i} + \frac{1}{q_r}. \quad (18)$$

Using similar amplifiers, so that it is sensible to put $A_1 = A_2 = A$, the residual loss is $(q_i + 1/q_i)/A$, which is a minimum, $2/A$, when $q_i = 1$; i.e., when $R = \sqrt{L/C}$. But with q_i either > or < 1 the added loss increases, tending to q_i/A.

At $q_i = 1$, the Ts of the two integrators are equal, and at resonance both integrators are working at a frequency equal to their unity-gain frequency. For $q_i > 1$, the CR integrator is working at a frequency below its unity-gain frequency and its phase defect (or loss factor), as explained in Part 5, is increased, and this is compensated to only a very small extent by the fact that the L/R integrator is working at a frequency above its unity-gain frequency with a reduced phase defect. For $q_i < 1$, the same steps are followed in reverse order, but as the q decreases the extra loss is of little consequence.

Corresponding explanations in terms of the parameters of the equivalent current expose the quite unnatural situations which the analogue is constrained to reproduce. For example, it is as if, in attempting to raise the q by reducing R, one were obliged at the same time to change the capacitor for another of equal value but of poorer Q factor, and so on.

The preferred analogue

The root cause of the trouble with the analogue of Fig. 2(c) is that the three variables L, C and R in the passive network have been reduced to two, L/R and CR. This has come about because the voltage between the integrators, whose basic purpose is really only to provide a quantity proportional to the current I flowing through the network, has been arbitrarily, developed to a scale which makes $V_R \equiv IR$, whereas it may clearly be to any scale, provided only that the same loop gains are maintained.

Thus, as in Fig. 4, the two Ts can be made L/xR and xCR, or L/R_d and CR_d by putting $x = R_d/R$ and $T^2 = LC$, as before. It follows then that the voltage between the integrators will be modified by the factor $x = R_d/R$, and the overall balance must be restored by scaling the inner loop by the inverse factor $1/x$.

With finite gain the Q factors of the corresponding imperfect integrators and lossy reactors are

$$Q_C = A_1\omega CR_d, \quad Q_L = A_2\omega L/R_d \quad (20)\,(21)$$

and the equivalent circuit is as Fig. 3(b) with R_d replacing R within the broken-line enclosures only. The residual loss due to Q_C and Q_L (at ω_C) is now given by

$$\frac{1}{q_r} = \frac{1}{A_1}\left(\frac{q_i}{x}\right) + \frac{1}{A_2}\left(\frac{x}{q_i}\right) \quad (22)$$

(q_r corresponding to the circuit quality obtained if the inner loop is broken at X). The net circuit quality, with the inner loop closed is given by equn (18) with the value

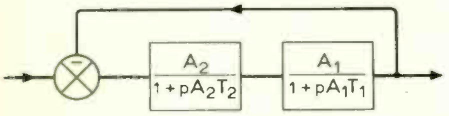


Fig. 5. Loop with two finite-gain integrators and no other damping.

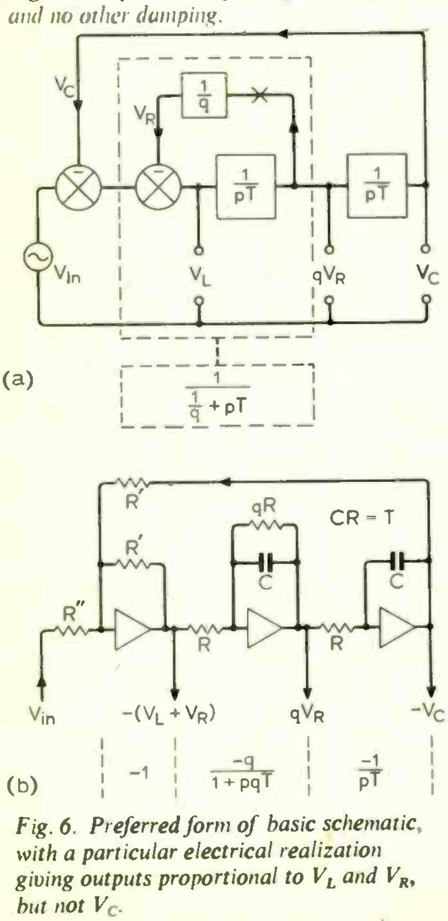


Fig. 6. Preferred form of basic schematic, with a particular electrical realization giving outputs proportional to V_L and V_R, but not V_C.

for q_r determined by equn (22). The residual loss can now be minimized for any given situation by choice of x.

Integrators with equal As

In the normal way it can be expected that similar amplifiers will be used in each position, so that $A_1 = A_2 = A$. Then the residual loss, equn (22) is a minimum when

$$\frac{q_i}{x} = \frac{x}{q_i} = 1 \quad (23)$$

and hence

$$\frac{1}{q_r} = \frac{2}{A}; \quad (24)$$

$$R_d = \sqrt{\frac{L}{C}}, \quad (25)$$

i.e., $R_d = \omega_C L = 1/\omega_C C$, the reactance of L and C at ω_C. This condition also makes the two Ts equal,

$$q_i CR = L/q_i R = \sqrt{LC} = T. \quad (26)$$

The analogue arranged in this way is shown in Fig. 6(a), in which for simplicity the scaling factors are given for $A = \omega_\infty$. The voltage between the integrators, the tuned circuit response, is now

$$qV_R = IR_d = I\sqrt{\frac{L}{C}}. \quad (27)$$

With finite gain the net circuit quality is given by

$$\frac{1}{q} = \frac{1}{q_i} + \frac{1}{q_r} = \frac{1}{q_i} + \frac{2}{A}, \quad (28)$$

from equns (18) and (24); and it is easily shown that with equal Ts and equal As this value of q_r is the maximum q obtainable from a two-integrator loop with a given overall gain (i.e., with $A_1A_2 = A^2$). Thus, with the inner loop broken at X

$$q_r = q_{max} = A/2. \quad (29)$$

Integrators with unequal As

If the Ts are equal but $A_1 \neq A_2$,

$$\frac{1}{q_r} = \frac{1}{A_1} + \frac{1}{A_2} \quad (30)$$

and q_i is less than q_{max}. To obtain the maximum value of q_r the two Ts, say T_1 and T_2, must be chosen so that $A_1T_1 = A_2T_2$.

Discussion of best practical proportioning of loop

In the practical circuits shown in Figs. 6(b) 7(b) the loop is closed with the help of a third amplifier. Normally this will be given a gain -1. It could, however, by increasing the value of the feedback resistor be given a gain >1, so increasing the zero-frequency gain and q_{max}. But since at ω_C the magnitude of the loop gain is 1 approx., the "T" of one or both integrators would have to be increased to give a balancing loss of loop gain at ω_C. For frequencies near ω_C the inverting amplifier would be liable to overload before maximum output was reached at the other two terminals and, also, with the local feedback fraction reduced, the net effect of internal phase shifts is increased. In general both these features are undesirable. For a similar reason to the former it would not usually be a good idea to use integrating amplifiers of different gains and assign to them unequal Ts.

There is however a special case where equal Ts might be used with amplifiers of different As; this is when the emphasis on the requirement is to achieve adjacent outputs, say at V_C and qV_R, which are as accurately in quadrature as possible. If only a low Q factor is needed it might be thought sensible to make only A_f very high.

The general conclusion, then, is that for most practical purposes the arrangement of the analogue as shown in Fig. 6(a) is the most useful and may be regarded as the master schematic.

Comparison with two lags and gain

Fig. 5 is a reminder that a loop containing two finite-gain integrators with no additional damping is equivalent to a loop containing two (buffered) lags, of time constants A_1T_1 and A_2T_2, and with zero-frequency loop gain A_1A_2. Accordingly (see Part 4) maximum q is obtained when $q_0 = \frac{1}{2}$; i.e., when the two lags have equal time constants, $A_1T_1 = A_2T_2$, and so $q_{max} = \frac{1}{2}(A_1A_2)^{\frac{1}{2}}$. This confirms the results already obtained; for example when $A_1 = A_2 = A$ and $T_1 = T_2$, $q_{max} = A/2$.

This is the same as the result $q_{max} = \frac{1}{2}A^{\frac{1}{2}}$ for a single-amplifier system in which the zero-frequency loop gain is A, since in the two integrator loop above the zero-frequency loop gain is A^2.

From the point of view of designing the feedback amplifiers themselves (satisfying the local Nyquist criteria) it is very much easier to handle two fed-back amplifiers, each of gain A, than a single amplifier of gain A^2; wider bandwidth can be provided and the useful range of operating frequencies extended. There is also the advantage that the two Ts (CR products) do not have to be spread out in the ratio q^2. For these reasons, and others, the two integrator loop is the more powerful method for obtaining high Q factors.

Circuits using ideal operational amplifiers

There are many ways in which the basic functional schematic of Fig. 6(a) can be turned into a practical circuit, and techniques based on the operational amplifier concept seem a natural choice, though other techniques, e.g. the use of constant-current earthed-capacitor integrators, are possible. Often the complete generality offered by Fig. 6(a) is not required, and then some of the separate parts of the analogue can be amalgamated.

The contents of the broken-line enclosure, i.e. the integrator together with the inner loop which gives the damping for the system, are described by the transfer function

$$G(p) = \frac{1}{\frac{1}{q} + pT} \quad (31)$$

$$= \frac{q}{1 + pqT} \quad (32)$$

i.e., a lag of time constant qT, multiplied by the gain factor q. This leads to Fig. 6(b), in which the damping is given by the resistance qR connected across the C of the first integrator. This circuit will be most useful when low-pass response, V_C, and/or tuned-circuit response, qV_R, are required, as there is no output proportional to V_L, high-pass response.

It will be obvious that the Cs and Rs in the active circuits need not have absolute values equal to those in any passive prototype. Groups of components with the same marking should ideally be of equal value; but as the circuit does not magnify any errors, the allowable tolerance is no tighter than the accuracy to which the filter parameters are required to be known. Thus if one of the two resistors R' is in error by a small percentage, the loop gain is changed by the same percentage, which is equivalent to a change of that percentage in the 'T' of one of the integrators. Consequently there is a change in ω_C of half the percentage (equn. (2)), and the same in q (because the system may be analysed as a lag-and-integrator loop, and equn. (15) of Part 5 applies). The value of R'' does not affect the parameters of the resonant loop, provided there is enough loop gain round the first amplifier for the virtual-earth principle to apply; it only causes the amplitudes at all outputs to be multiplied by the factor R'/R''.

The only difference between the schematics of Fig. 7(a) and Fig. 6(a) is that the equating of voltages, equn. (7), is carried out as

$$V_L = V_{in} - (V_C + V_R) \qquad (33)$$

The contents of the enclosure are now described by the transfer function

$$G(p) = \frac{1}{q} + \frac{1}{pT} \qquad (34)$$

This leads to Fig. 7(b), in which the damping is introduced by connecting a resistance R/q in series with the capacitor of the second integrator. In this circuit V_C is lost as a separate output voltage, but qV_R (tuned-circuit response) and V_L (high-pass response) remain.

Fig. 8(a) is a realization of the two-integrator circuit in its most general form. Damping is introduced without disturbing the input/output relationships of the integrators, and so all three responses are available as for Fig. 6(a). As drawn, Q factor is determined by the setting of the potential divider, which produces at its slider the voltage $qV_R/q = V_R$. Alternatively the two resistors marked R'' connected to the extra inverting amplifier may be given unequal values, the feedback one of the pair being made q times less than the other.

Thus adjustment of Q factor is independent of tuning, and the converse is also true: tuning can be varied independently of Q factor if the 'T's of both integrators are varied in unison, which in practice means variation of both Rs or both Cs. In Figs. 6(b) and 7(b), because of the presence of a third resistance which must in a constant ratio with the two resistances R, variable tuning is not quite as easy. Tuning independent of Q factor is possible by ganged variation of the two Cs, but tuning by variable resistance would need an awkward three-gang arrangement.

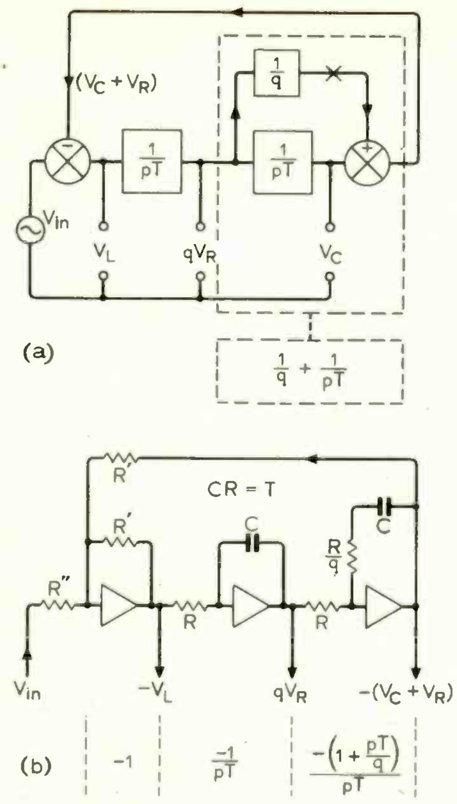


Fig. 7. Alternative form of preferred schematic, with an electrical realization giving outputs proportional to V_C and V_R, but not V_L.

Compound responses

For Fig. 8(a) the transfer functions to the three output terminals (when $R''' = R'$, and $CR = T$) are, assuming ideal amplifiers ($A \to \infty$), given by

$$-V_C = -\frac{1}{1+\frac{1}{q}pT+p^2T^2} . V_{in} \qquad (35)$$

$$qV_R = pTV_C, \qquad (36)$$

$$-V_L = -p^2T^2V_C, \qquad (37)$$

and the corresponding frequency responses (amplitude) are related in the manner sketched in Fig. 9.

Each output voltage, and also $-V_R$ in the inner loop, and V_{in}, appears with one side grounded. It is, therefore, easy by adding, or subtracting, in the required proportions to obtain any second-order transfer function, viz

$$\frac{V_{out}}{V_{in}} = \frac{a_1 + a_2pT + a_3p^2T^2}{1+\frac{1}{q}pT+p^2T^2}; \qquad (38)$$

and the coefficients a_1, a_2, a_3, as well as q and T, may be adjusted independently. The system can therefore be used as a universal building brick for higher-order filters of any kind, using the method of synthesis by factors, which was referred to in Part 1.

Notch response, as shown in Part 2, is obtained when $a_2 = 0$ and a_1 and a_3 have the same sign, Fig. 8(b). And if $a_1 = a_3$, the notch is symmetrical,

$$V_N = V_C + V_L = (1+p^2T^2)\,V_C,$$

corresponding to the network of Fig. 8(c).

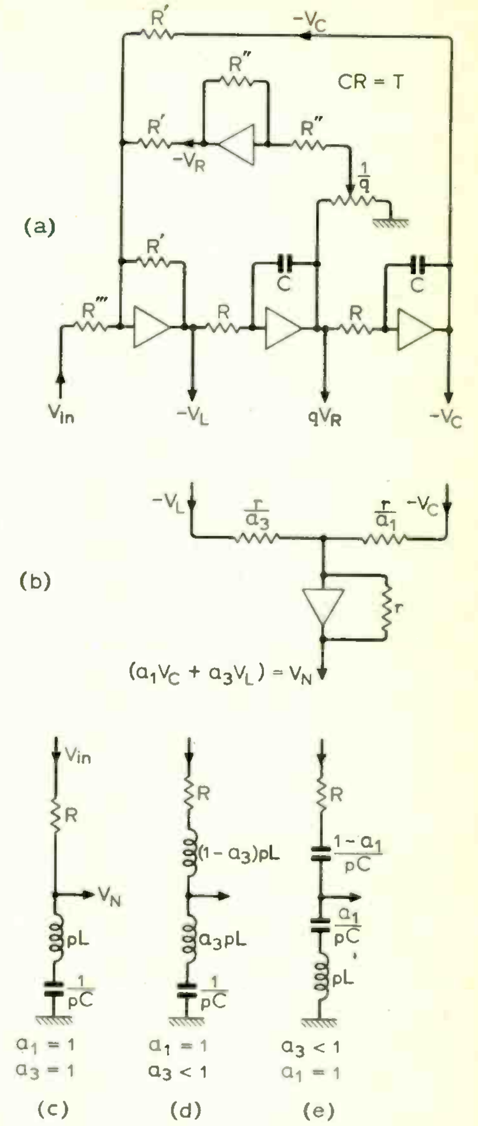


Fig. 8. A general electrical equivalent of the basic preferred schematic.

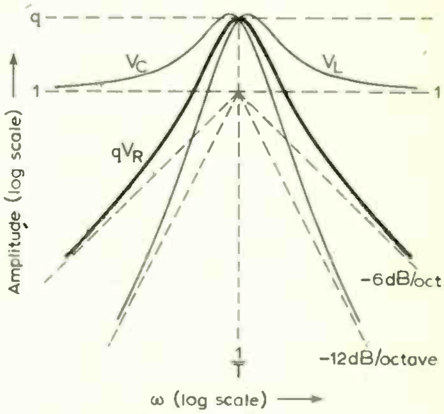


Fig. 9. Showing the relationship between the three outputs V_L, qV_R, and V_C; i.e., low-pass, tuned-circuit, and high-pass.

It is important to remember that at the frequency of zero transmission at the terminal V_N, which is also ω_C, there are large, and perhaps unseen, voltages of magnitude qV_{in} at terminals V_C and V_L. Care must be taken, therefore, to avoid overloading. This is a potential difficulty not present in the circuits described in Part 6, where subtraction occurs on the input side.

If $a_1 = 1$ and $a_3 < 1$, an unsymmetrical notch of low-pass type is obtained, Fig. 8(d),

$$V_N = V_C + a_3 V_L = (1 + a_3 p^2 T^2)\, V_C. \quad (39)$$

Similarity if $a_3 = 1$ and $a_1 < 1$, an unsymmetrical notch of high-pass type is obtained, Fig. 8(e). The notch summing amplifier is not always required in a filter having several factors, because the summation for one stage can be made at the input of the following stage.

All-pass response, second-order,

$$\frac{1 - \frac{1}{q} pT + p^2 T^2}{1 + \frac{1}{q} pT + p^2 T^2} V_{in}$$

$$= V_L - V_R + V_C, \quad (40)$$

is easily obtained by adding all three primary outputs, as the output proportional to V_R already has the necessary relative sign reversal. Note: the relative magnitude of the contribution from the tuned-circuit output is V_R; i.e., qV_R/q.

The effect of parasite phase lags

The effect of parasitic phase lags, provided they are small, can be estimated as shown in Part 5. In the absence of such lags $1/q = \tan \theta$, where θ is the phase margin at ω_C, and therefore for $q \gg 1$, $1/q$ is approximately equal to the phase margin (measured in radians). Parasitic phase lags, by reducing the margin, increase the effective q, and are in effect negative loss factors. When the time constant of such a lag, t, is small compared with T ($T = 1/\omega_C$), its phase lag in radians at ω_C is t/T, and equn. (18) may be further modified to

$$\frac{1}{q} = \frac{1}{q_i} + \frac{1}{q_r} - \sum \frac{t}{T} \quad (41)$$

Lags inside the amplifiers may to a first approximation be taken as divided by the loop gain, which for the integrators is the amplifier gain.

Because the product of the gains of two amplifiers can be drawn on, the two-integrator loop is particularly suitable for realising high Q factors (tens rather than units). This means that $1/q$ may well be small, and then for accurate design unwanted phase lag must be very small compared with the design value of T. In consequence very high values of Q factor are more practicable at low frequency.

When q is low, quite simple amplifiers with perhaps only one stage of gain may be used. This could be the case in, for example, a variably tuned audio-frequency filter. And because the bandwidth of such an amplifier could easily be large compared with the corner frequency of the filter, parasitic lags should be negligible. It will be useful, therefore, to consider in more detail the situation where finite (and rather low) zero-frequency gain is the major imperfection. This will be taken up again in the next article.

REFERENCE

[1] E. F. Good: "A two-phase low-frequency oscillator", *Electronic Engineering*, April and May 1957 (Vol. 29, pp. 164–169, and 210–213).

Continued from p. 60

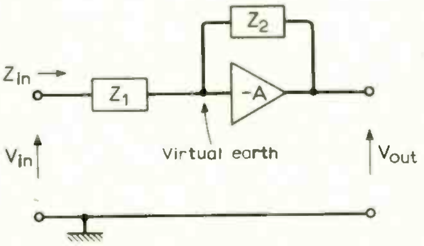
Appendix to Ceramic Pickups & Transistor Pre-amps

(*1*) *Gain and input impedance of virtual earth amplifiers*

For high gain amplifier

$$\frac{V_{out}}{V_{in}} = \frac{Z_2}{Z_1} \quad \text{Junction of } Z_1 \text{ and } Z_2 \text{ is a virtual earth}$$

$$Z_{in} \approx Z_1$$
$$Z_{out} \to 0$$



Amplifier is phase inverting, e.g. one high gain transistor in common emitter mode.

A clear understanding of the operation of the equalization circuit put forward in this article is gained by thinking of the ceramic pickup capacitance as being a part of Z_1:

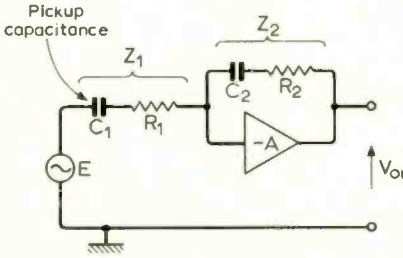
if $R_1 \times C_1 = R_2 \times C_2$
then Z_2/Z_1 = constant, *independent* of f.

Therefore V_{out}/E = constant over whole frequency range, which is the requirement for a mechanically compensated pickup. The virtual earth amplifier was used in the Dinsdale Mk. I pre-amplifier and more recently in the Linsley Hood pre-amplifier.

(*2*) *High input impedance feedback amplifier*

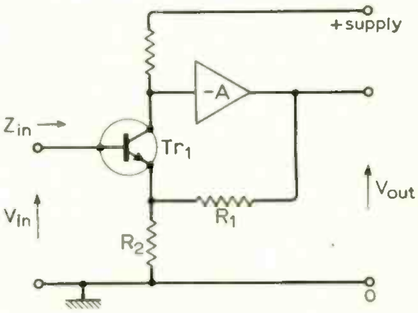
For large value of total gain

$$\frac{V_{out}}{V_{in}} = \frac{R_1 + R_2}{R_2}$$



In general, $\frac{V_{out}}{E} = \frac{C_1}{C_2}$ *at l.f. and* $\frac{V_{out}}{E} = \frac{R_2}{R_1}$ *at h.f.*

If the amplifier $-A$ consists of a transistor (Tr_2) in common emitter configuration and the current gain of Tr_1 and $Tr_2 = \beta$, Z_{in} tends to $\beta^2 \times R_2$ shunted by $R_{b'c}$ and the Miller capacitance of Tr_1.



Total gain = gain of $Tr_1 \times |A|$.

This system is used in the Dinsdale Mk. II pre-amplifier where $Z_{in} \approx 500\,k\Omega$ but it is of course frequency dependent; so normally Z_{in} is shunted by a resistor to stabilize the input resistance to $100\,k\Omega$.

The Bailey pre-amplifier is a development of the Dinsdale Mk. II and an improvement has been made by adding an emitter follower after the second common emitter amplifier transistor to reduce the shunting effect of the feedback network (a frequency sensitive circuit in place of R_1) at high frequencies.

Corrections & Amendments

Pickup Characteristics (December): Garrard point out that the output voltage of their cartridges should have been quoted in volts (not mV) and at 1kHz at 3.54 cm/sec.

Thermistor Hygrometer (December): The U.K. distributors of the Philco Ford op. amp. PA 7709-39 are Electronic Component Services (Worcester) Ltd, 63/6 Foregate Street, Worcester, and not as stated on p. 558.

Electronic Metronome (January): Resistor R_6 should be connected directly to the collector of Tr_2. The junction of VR_1 and R_5 should not be connected to the transistor.

Low-distortion Bias and Erase Oscillator (January): In Fig. 4 the 470 Ω resistor in series with S_3. should be connected to the collector of 2N3704 and not the emitter as shown.

Amplitude Modulation using an F.E.T.

Linear control over a wide range of carrier and modulation frequencies obtained using a junction field-effect transistor as a variable resistance

*by M. E. Cook**

If a field-effect transistor is operated with $V_{DS} = 0$ and v_{ds} is restricted to a few hundred millivolts (peak-to-peak), the device exhibits a resistance r_{ds}, the value of which is dependent upon the gate-source bias voltage $-V_{GS}$. The relationship between r_{ds} and V_{GS} is roughly parabolic.

If the gate-source bias voltage V_{GS} is to be used for modulation, a method has to be found for linearizing this parabolic curve which although ideal for automatic gain control application, is unsuitable for amplitude modulation. By shunting the f.e.t. with a suitable fixed resistor R, the combined resistance will tend to r_{dso} at $V_{GS} = 0$, and to R when $-V_{GS}$ is large.

Amplitude modulation

This combined parallel resistance of R and r_{ds} was used as the un-decoupled emitter resistance of a common emitter amplifier (Fig. 1). A blocking capacitor C_1 was required to prevent the quiescent emitter voltage from appearing across the f.e.t.

Now, if driven from a low impedance source, the voltage gain of the complete amplifier is given by

$$A = \frac{A}{1+\beta A},$$

where A is the gain of the amplifier with the emitter decoupled, and β is the feedback factor.

$$\beta = \frac{R_E}{R_L} \text{ and } R_E = \frac{Rr_{ds}}{R+r_{ds}}$$

Thus the voltage gain of the amplifier can be varied from a maximum value when $R_E \approx r_{dso}$, to a minimum value at large values of $-V_{GS}$, when $R_E \approx R$. In fact, the bias can be taken a few hundred millivolts positive before the gate-source junction becomes forward-biased as is shown by Fig. 2(A). Hence by choice of suitable values for R and R_L, the gain of the bipolar transistor can be made proportional to the f.e.t. bias over a considerable range. As for any large signal amplifier, care has to be taken in selecting the operating quiescent point to give optimum linearity.

An amplitude modulator is thus achieved which will give a 1·5 V peak-to-peak output with a modulation depth of at least 33%, whilst restricting the signal voltage across the field-effect transistor to less than 50 mV (peak-to-peak). The circuit will operate with carrier frequencies up to at least 10 MHz, whilst it can be modulated from d.c. to 25 kHz. The upper limit of modulation frequency is set by the parasitic capacitance between drain and gate of the f.e.t. A typical value of this capacitance is 3 pF. Capacitor C_1, from emitter to drain, should have a low reactance at the carrier frequency compared to r_{dso}. However if C_1 is too large it will allow coupling of the modulation signal, via C_{DG} to the emitter of the bipolar transistor, which acts as a common base amplifier to the modulation signal and will cause phase distortion at the output. This modulation coupling restricts f_c/f_m to greater than 10. Oscillographs of typical outputs are shown in Figs. 2(B) and (C).

Balanced modulation

This was achieved by analogue summation of the unmodulated carrier and the phase-inverted, amplitude-modulated output from the circuit already described. (A linear microcircuit amplifier would obviously perform suitably, but the author was restricted to the use of one supply rail.) The circuit in Fig. 3 was designed to operate over carrier frequencies from 100 to 150 kHz with modulating frequencies from d.c. to 10 kHz.

It was found necessary to equalize the response of the emitter-follower input stage with that of the modulator. This was achieved by the 3·3 kΩ series resistor and the

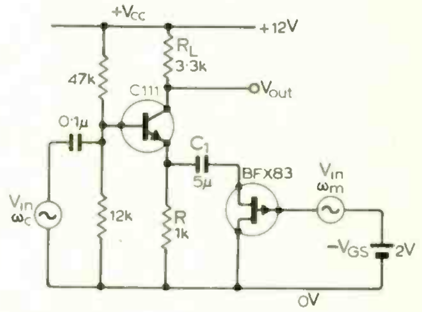


Fig. 1. Basic amplitude modulator.

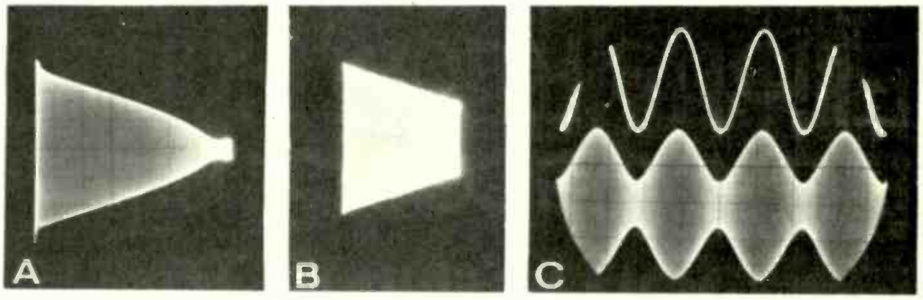


Fig. 2. Oscillographs of waveforms obtained from circuit of Fig. 1. (A) X-Y plot of A' against V_{GS}. (B) X-Y plot of modulated output (f_c = 100 kHz, f_m = 1 kHz). (C) Modulated output on time scale.

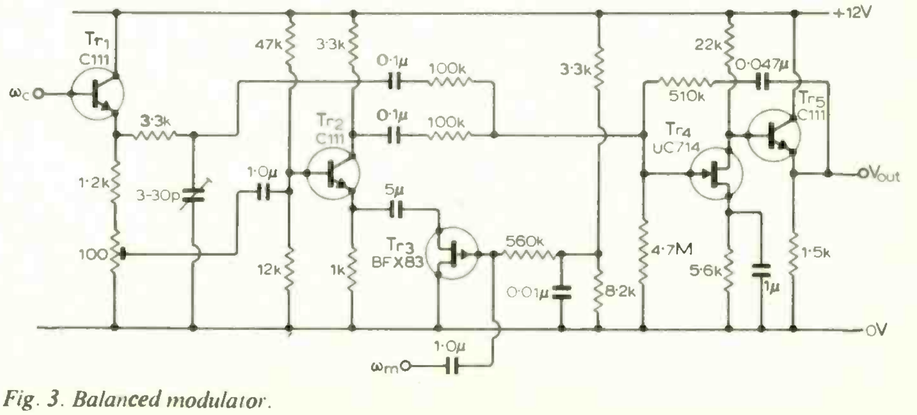


Fig. 3. Balanced modulator.

*Royal Naval College, Greenwich.

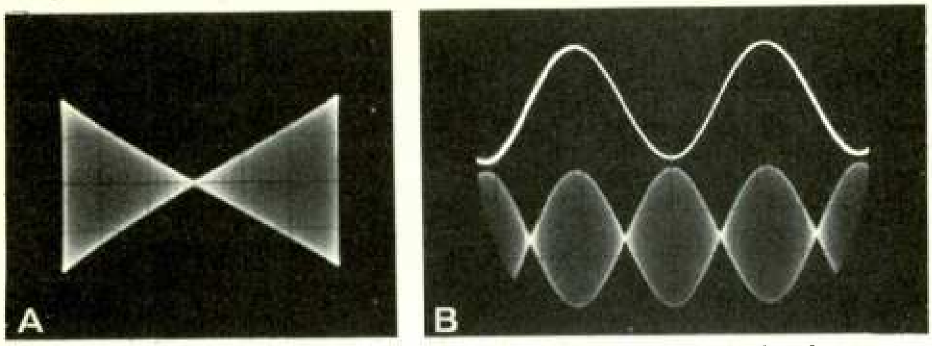


Fig. 4. Oscillographs of waveforms obtained from circuit of Fig. 3. (A) X-Y plot of output against modulation. (B) Modulated output on time axis.

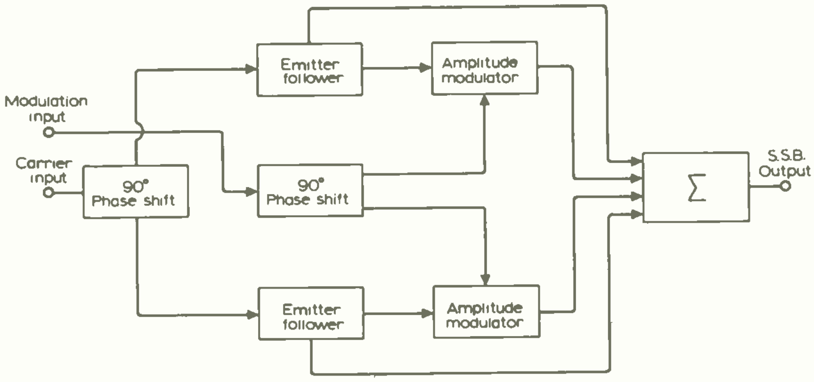


Fig. 5. Block schematic of a single-sideband generator.

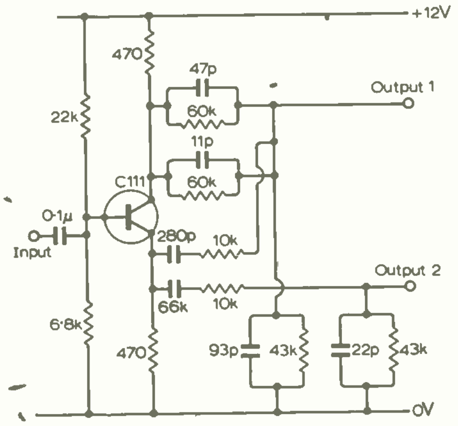


Fig. 6. Dome 90° phase shift circuit for f_c 100–150 kHz. Filter components should be ±1% tolerance.

trimmer capacitor. If higher carrier frequencies are required, a common base or long tailed pair amplifier might be considered in order to give equal phase responses.

Transistors Tr_4 and Tr_5 form a simple summing amplifier, Tr_4 being an inexpensive n-channel field-effect transistor which gives a high input impedance. Tr_5 provides a low output impedance.

Oscillographs of typical outputs are shown in Figs. 4(A) and (B).

Single-sideband generator

A single-sideband generator was constructed using two balanced modulator circuits already described, feeding into a common summing amplifier (Fig. 5). Dome phase shift networks were used to provide the necessary quadrature signals (Fig. 6). These phase shift networks provide two outputs whose phase varies logarithmically with respect to the input, but the phase difference between the two outputs remains at 90°, the amplitude of the outputs also remaining constant.

In the particular application for which the s.s.b. generator was designed, the modulation inputs are in the form of d.c. levels from phase comparators. However, on test, the circuit performed satisfactorily using modulation frequencies down to 0·1 Hz, and also covering the audio range (130 Hz to 3·6 kHz).

Acknowledgement

I am indebted to Professor J. Bell, of the Physics and Electrical Engineering Department at the Royal Naval College, Greenwich, for the support and encouragement that he has given.

A New Book

Colour Television, Vol. 2 by P. S. Carnt, B.Sc. (Eng.) and G. B. Townsend, Ph.D., B.Sc. Pp.276. Published by Butterworth & Co., (Publishers) Ltd., 88 Kingsway, London, W.C.2. Price 75s.

This is the companion to Vol. 1, which was first published in 1961 and dealt exclusively with the N.T.S.C. system of colour television, although a good deal of space was devoted to a 405-line version of it. The present volume deals mainly with the PAL and SECAM systems, but there is a chapter covering ART, NIR and other systems.

On p.3 the authors state that "A thorough understanding of N.T.S.C. is essential for a study of PAL and is very helpful for understanding SECAM." Chapter 1 thus deals with N.T.S.C., but is revisionary, for the authors assume that the reader already has a detailed understanding of the system.

Potential readers who do not already possess this background knowledge may well be disinclined to approach PAL by way of N.T.S.C. preferring a book which dealt only with PAL and left out all reference to N.T.S.C. From the authors' point of view, however, the natural thing was to do what they have done and there is, indeed, much to be said for the historical approach. Certainly, a much more balanced understanding of colour television is obtained.

The treatment is generally good but there is one trap for the unwary which may lead them into confusion. This lies in the use of the terms "chroma" and "chrominance". Chroma is not an abbreviation of chrominance as anyone might be excused for thinking. The careful reader will find (p.31) that "chrominance" means the video colour-difference signals, whereas "chroma" means the modulated sub-carrier and its sidebands. In Vol. 1, the word "chroma" does not appear in the index (we have not checked that, in fact, it is nowhere used!). However, on P.103 of that volume chrominance means in effect the colour-difference signals but is also used elsewhere (e.g., p.211) for the modulated sub-carrier and its sidebands.

If one refers to Supplement No. 3 (1966) to B.S. 204 (1960), chrominance is defined as "A signal which is added to the luminous signal to convey colour information". Unfortunately, this is ambiguous by itself, but the definition of a chrominance sub-carrier is "The carrier which is modulated to form the chrominance signal". This makes it clear that by chrominance B.S. mean the modulated sub-carrier and its sidebands. The term "chroma" does not appear in the standard at all.

In view of the different usage between Vols. 1 and 2 and of the difference from the British Standard, the authors would have been wiser if they had emphasized their own meanings for the terms, instead of merely indicating them in passing. W.T.C.

Conferences and Exhibitions

MANCHESTER
Feb. 23-27 — Belle Vue
Labex Northern
(U.T.P. Exhibitions, 36-37 Furnival St., London E.C.4)

TEDDINGTON
Feb. 25-26 — N.P.L.
Trends in Diffusion Conference
(I.P.P.S., 47 Belgrave Sq., London S.W.1)

OVERSEAS
Feb. 6-11 — Paris
Audiovisual Techniques, Electroacoustics & Electronics Show
(Fed. Nat. Des Ind. Electroniques, 16 rue de Presles, Paris 15)

Feb. 16-19 — Tampa Fla.
Computer-Aided Circuit Optimization
(Dr. G. W. Zobrist, Dept. of Elect. Eng., University of South Florida, Tampa, Florida 33620)

Feb. 18-20 — Philadelphia
Solid-State Circuits Conference
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)

Variable Voltage Reference Source for D.C. Regulators

A design capable of operating from a supply four volts above the regulated output

*by Peter Williams**

A d.c. reference voltage may be obtained by passing a constant current through a known stable resistance. Dividing this resistance into steps of known value provides a range of voltages simply calculated from Ohm's law. Making one of the resistors continuously variable will give intermediate values of voltage. The accuracy of setting may be as high as 1% depending on the resistors used.

Although this approach has been used successfully in designs for high-performance regulators, the provision of the constant current presents some problems. Fig. 1 shows two methods whereby a constant current produces an output voltage proportional to a variable resistance, both using a high-gain amplifier with differential inputs. For use as a voltage regulator the amplifier would need a high current capacity and low output resistance in one direction only, but applying the design techniques of low-drift d.c. amplifiers is often beneficial. Thus Fig. 1 (a) is seen as series voltage negative feedback and Fig. 1 (b) as shunt voltage negative feedback.

The second form is often preferred because the virtual earth at the inverting input ensures that variations in output voltage due to a change in the reference resistance do not affect the circuit defining the reference current. Similarly the constant potential at the inputs removes the need for giving the input stage a high common-mode rejection ratio. Against this it can be seen that the main supply which the circuit is to regulate, and that supplying the reference current, must be of opposite polarity.

In contrast, the method indicated in Fig. 1 (a) would place higher demands on the reference current supply, and on the common-mode rejection capability of the amplifier, because the change in voltage at the non-inverting input is large (being equal to the change in output voltage). The former effect can be eliminated by replacing the variable resistance by a potential divider such that a constant total resistance appears in series with the current generator.

To take the maximum advantage of having current reference supply of the same polarity as the output, it is worth trying to derive the reference current from the main supply. The circuit described here attempts to provide this with maximum efficiency, i.e. the minimum required supply voltage shall be as close as possible to the maximum regulated output voltage. This condition ensures the smallest possible dissipation in the output transistors, and minimizes the specifications required of the transformer and other components in the power supply.

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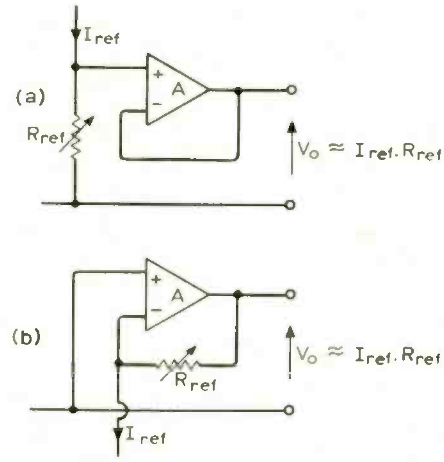

Fig. 1. (a) Arrangement where supply for reference current is of same polarity as that required for the regulator. (b) Using shunt voltage negative feedback reduces common-mode problems and makes design easier, but a separate supply is needed for the reference current.

Practical design

The suggested circuit is shown in Fig. 2. It is derived from a circuit that is equivalent to a constant-current diode, the dual of a zener diode[1]. A bipolar transistor for Tr_2 is not well-suited to this particular form of the ring-of-two reference since the base current would constitute a small but significant load on the potential divider. Here the uni-polar f.e.t. in which the gate current is limited to the very low leakage achievable with silicon devices is much to be preferred.

The choice of zener diode is determined by a conflict of several desirable characteristics. (1) The voltage across the device should be as large as possible to maximize the value of R_1 and hence the stability of current against supply changes. (2) The device should ideally be chosen to have a temperature drift of voltage that cancels that on the base-emitter of Tr_1. (3) The voltage drop across R_1 should be as small as possible to allow the circuit to operate from supply voltages as close as may be to the required output reference voltage. (4) The slope resistance of the diode should be low to reduce its contribution to the supply-induced charges in output. These conditions cannot be met simultaneously with existing diodes and it was considered most important to ensure best temperature stability with maximum efficiency.

The performance in respect of supply changes is still adequate and can be made excellent by known methods of compen-

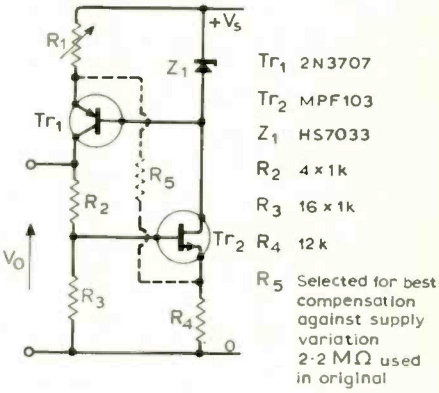

Fig. 2. Full circuit for voltage reference source. R_1 is chosen to provide a current of 1mA in the chain of resistors represented by R_2, R_3. A variable resistor may be used to set the current precisely — $R_1 \approx 2.5k\Omega$.

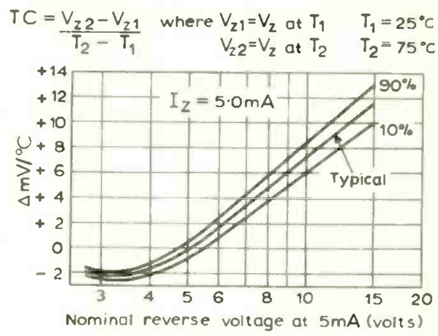

Fig. 3. Graph of drift with temperature change against operating current for zener diodes.

sation[2] or the conversion of either or both transistors into cascode pairs.[3] The writer is much indebted to Emihus Ltd for permission to publish Fig. 3. It can there be seen that at an operating current of 5mA the temperature drift is typically −2mV/°C ±10% for diodes between 2.7V and 4V breakdown. This figure is within the range observed for the drift in base-emitter voltage of silicon transistors.

To allow sufficient gate-drain voltage for Tr_2 (that it shall operate above its knee with consequent high dynamic output resistance), the gate is tapped some way down the chain of resistors simulated by R_2 and R_3. The former may be four resistors each of 1kΩ in series when the latter would be sixteen such resistors. With a current of 1mA to provide a maximum reference voltage of 20V, the value of R_1 requires to be somewhat in excess of 2kΩ.

The semiconductor devices alone were subjected to a range of temperatures from 20°C to 80°C for supply voltages between 24V and 34V. Maximum stability against supply voltage change was obtained by adding the compensating resistor R_5 between the emitter of Tr_1 and the source of Tr_2. For optimum stability against long term changes the value of resistance R_5 must be slightly lower than that needed to compensate for the direct voltage-induced changes. This leads to an initial over-compensation, if the voltage changes instantaneously, with a return to a more exact compensation after a delay dependent on the thermal time-constant of the transistor used. With care the output may be adjusted to be well within ±0.1% for supply voltages between 24V and 34V. This performance is particularly good in view of the closeness with which the supply voltage is allowed to reach that across the reference chain. The relevant details are given in Figs. 4(a) and 4(b). It appears that care in the choice and operating current of the zener diode would be worth while since, on the assumptions made above, drifts of as little as 0.1% for temperature changes of 10° might be attainable.

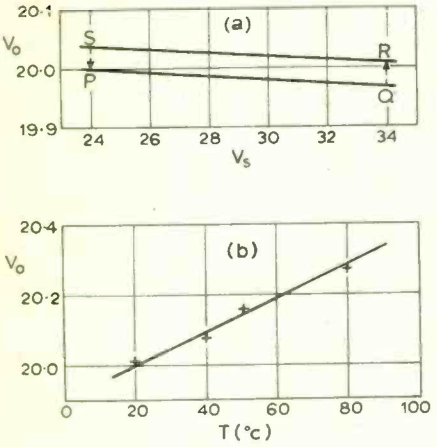

Fig. 4. (a) With $R_5 = 2.2M\Omega$ the circuit is over compensated for rapid increase in supply voltage (P to Q). Self-heating of transistors at higher voltage gives small rise in output (Q to R). With supply rapidly reduced to original value (R to S) the output rises further. On cooling, the output voltage returns to its original value. (b) Positive coefficient of voltage change with respect to temperature ($\approx +0.025\%/^\circ C$). The zener bias current was not optimized.

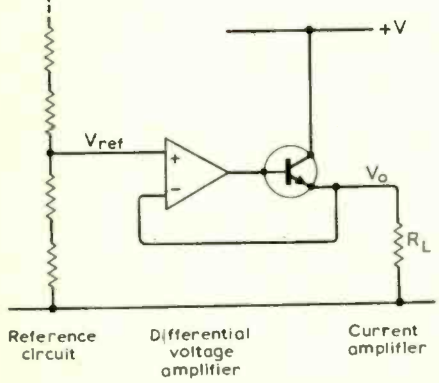

Fig. 5. Simple way of employing the voltage reference in a regulator.

Application

Fig. 5 shows the way in which the reference voltage circuit may be used in the design of voltage regulators. For an ideal amplifier the reference voltage is unloaded by its presence, and the output voltage is forced via the feedback loop to equal the reference voltage i.e. $V_o = V_{ref}$. With a practical amplifier (such as the readily available integrated-circuit operational amplifiers) there are thus two distinct sources of error: (1) the input current lowers the reference voltage; (2) the offset voltage at the input leads to a differential between this modified reference voltage and the actual output.

An output stage consisting of one or more emitter followers allows the output voltage to be fed into as low a load resistance as required. This leaves the properties needed of the amplifier as: (a) very low input current, at least one hundred times less than the reference current of 1mA; (b) the voltage gain should be high enough and the offset voltage low enough that the input differential is less than one hundredth of the reference voltage.

The final requirement of the amplifying stages is that they shall operate from as low a supply voltage as does the reference circuit. It is this that places restrictions on the choice of amplifying circuits and for which special designs may be needed.

REFERENCES

1. P. Williams "Letters to the Editor" *Wireless World*, September 1966, p.456.

2. J. C. Rudge, "Letters to the Editor", *Wireless World*, November 1966, p.610.

3. "A d.c. Reference Voltage with Very High Rejection of Supply Variation" by P. Williams, *Proc. I.E.E.E.*, January 1968, pp.118-119.

Telecine Film Corrector

The problem of varying density in films and slides—particularly news films—televised by broadcasting organizations has been tackled in an automatic compensating device for telecine cameras just introduced by Marconi. The main idea is to free the camera operator from continual manual correction of picture blacks and whites, but in addition the compensator is claimed to have a faster response than a human operator and to result in a more consistent picture quality.

Called the Auto-Light, the equipment is designed to assess the picture content and to make appropriate adjustments to black and white levels. It acts on the central 64 per cent of the picture area to avoid errors resulting from edge information.

The device controls the white picture level as follows. It detects the peak level of the signal from the telecine camera, and then operates a servomotor-controlled light filter in the film or slide projector lamphouse to bring this level to the normal white picture level. The range of control is limited so that the unit will not counteract an intentional "fade to black". Correct black level is maintained by electronically clamping the peak black level of the camera signal to a standard black level. Here again, the range of control is limited so that scenes without any peak black content can be transmitted.

An exceptional scene may demand manual adjustment of black and white. In this case, the camera operator can override the automatic corrector by pressing a button. The equipment is suitable for all line standards.

The equipment fits in a standard 19-inch rack and consists of six solid-state modules, five inches high, to be added to the control unit of Marconi black-and-white or colour telecine cameras. It has its own power supply. If this should fail the corrector is automatically by-passed with no interruption of transmission.

Magnetic Recording Techniques for Colour Television

Educational broadcasting convention report

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

The National Association of Educational Broadcasters (N.A.E.B.) is an organization serving the needs of the non-commercial educational radio and television broadcasting stations, production centres and closed-circuit educational television installations in the U.S.A. Every year a convention is held which includes meetings on production, engineering and legal aspects of educational television as well as an extensive equipment exhibition.

The whole convention is patterned somewhat after the N.A.E.B. conventions, held every spring, the latter of course serving the interests of the commercial broadcasting stations. The recent N.A.E.B. convention, the 45th, was held in Washington D.C., from 9th to 12th November.

Some of the most significant introductions to the show were by Panasonic (Matsushita of Japan) of their new video tape equipment. Two new colour v.t.rs were demonstrated, both of which used the new Japanese "Type I Standard" specifications for ½-inch machines. The tape speed is 7½ inches per second, the two-head helical scanning angle is 3° 11′, audio track width 1 mm and control track width 0.8 mm; resolution is at least 240 lines. Most of the major electronics manufacturers in Japan have apparently developed prototypes to these standards and marketing of production versions is due at the beginning of 1970.

The pictures shown from the Panasonic recorders were to full N.T.S.C., 525-line, colour standards, without external adaptors and were of excellent quality. We saw the same quality colour pictures from a ½-inch recorder as could only be obtained from a 2-inch recorder less than two years ago.

Of the two machines, one was a reel-to-reel recorder with a one-hour recording time and the other was a magazine loading machine with a capacity of 30 minutes per magazine. Both the machines use identical formats, and tapes are therefore interchangeable and have virtually the same specifications: black and white, resolution 270 lines, signal-to-noise ratio, 40 dB; colour, resolution 240 lines, signal-to-noise ratio 30 dB, chrominance bandwidth 450 kHz.

Operation is simple: the magazine is pushed into a slot in a hinged cover, the cover is lowered and the "play" button pressed. Automatically, the tape is threaded around the head drum and in a few seconds the picture appears. The magazine is about 1-inch (24 mm) high, 10¾ inches (269 mm) long and 6½ inches (162 mm) deep, its weight is 1 lb 5 oz (600 grammes). The recorder itself is 15 inches (380 mm) wide, 14 inches (355 mm) deep, 5.2 inches (132 mm) high and weighs only 33 lb (15 kg).

This type of magazine loading v.t.r. seems bound to have a very great impact in the educational, industrial and domestic markets, most likely at the expense of the EVR system of CBS and Motorola and of the more recently announced RCA SelectaVision. Certainly, the ½-inch v.t.r. showed far higher quality colour pictures than have yet been demonstrated on the EVR. Further, the facility exists with the v.t.r. of making one's own recordings on the same machine as is used for playback. Whereas, with the SelectaVision or EVR system, the playback tape or film has to be produced by an agent of the manufacturer. This, of course, does not permit immediate playback of original material produced by the end-user due to the processing time. Also the cost of making a copy of an original for the EVR is said to be economical only in quantities of 50-100 or more and with the SelectaVision in numbers over 2,000.

The Panasonic (Matsushita) magazine loading v.t.r. The unit is built to the specifications laid down in the Japanese Type I Standard for ½-inch video tape recorders. The magazine illustrated contains enough tape for recording and reproducing a 30-minute programme.

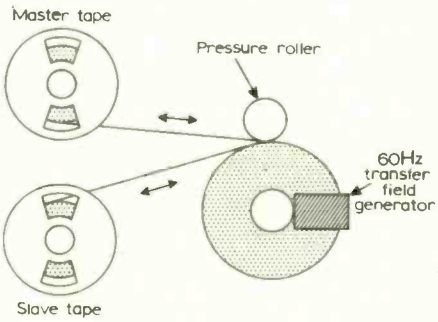

Fig. 1 Bifilar tape winding system of contact printing.

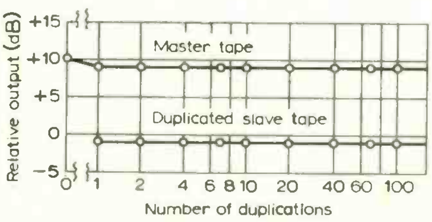

Fig. 2 Master and duplicated slave tape outputs after duplications at a short wavelength (1.9µm). The same results are obtained at longer wavelengths.

Duplication

Another development by Panasonic is related directly to this question of making v.t.r. duplicates inexpensively. The Video Tape Printer copies black and white or colour video tapes, audio tapes or computer data tapes by contact within a 60-Hz transfer field.

In operation the master tape is wound at high speed, in a bifilar fashion, on to a copying reel, in contact with an erased slave tape with the oxide coated sides of both touching (Fig. 1). As the two tapes are fed to the copying reel a pressure roller ensures that no air is trapped between the master and slave and that the two are in close contact. When the two tapes are completely wound together on the copying reel a low-frequency (60 Hz) transfer-field coil is energized while the copying reel turns slowly. When the transfer is complete the reels are reversed and the master and slave rewound on to their original reels. The complete winding, copying and rewinding process takes about two minutes for a one-hour video tape, a 30-to-1 time reduction compared to conventional dubbing.

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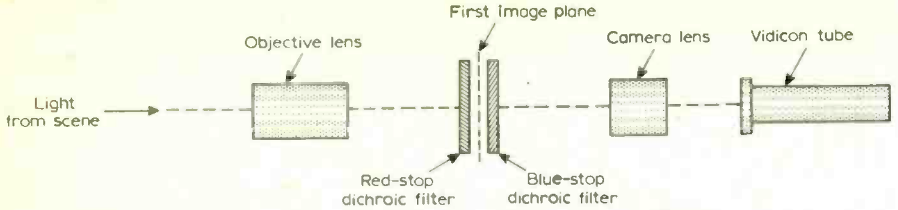


Fig. 3 Optical arrangement of RCA single-vidicon tube colour television camera.

The master tape must have high coercivity so as not to be erased by the transfer-field during the copying process; the slave tape can be any conventional type normally used. The number of copies obtainable from one master is said to be several hundred. Fig. 2 shows the relative output of the master and slave tapes with an initial drop in level of the master of about 1.5 dB or so during the first copy and virtually no further loss during further duplications.

As the copying operation is a contact process the copied tape is a "mirror-image" of the master; it is therefore necessary for the master to be made as a mirror-image of the tape finally required. A special v.t.r. is required for this in which the tape is run in the opposite direction from normal. Another solution might be (depending on whether tapes with the correct characteristics can be developed) to make the master on a normal v.t.r., use this to make a "reversed-master" on the video contact printer and then use the reversed-master to produce the slave tapes.

While in the general subject area of video tape recording, it is worth noting a very useful feature incorporated by International Video Corporation in three of their recorders, the IVC-800, IVC-825 and IVC-900. By placing a special reproduce head as well as the normal combined record/reproduce head on the rotating video head drum, it is possible to monitor the tape while it is actually being recorded (a similar feature to that provided on many audio tape recorders). On the v.t.r. this gives a continuous check of video quality and provides an immediate indication should the recording head become blocked.

Magnetic-disc recorder

Another device which seems likely to have wide acceptance in the educational and maybe the broadcasting fields is the magnetic-disc recorder. Ampex showed their DR-10 which has the capability of recording on one single disc up to 2,400 individual pictures (frames) on concentric, contiguous tracks or 80 seconds of continuous video information. The recordings may be reproduced in still frame, in either forward or reverse at normal speed, in slow-motion by playing each track more than once, or at high speed by skipping alternate frames on playback. The same latter effect can be obtained, with economy of recording material, by recording every second (or every third, fourth or fifth) frame from a camera on adjacent tracks and playing these back in sequence at the regular frame rate. An interesting demonstration showed an ice cube melting at an accelerated rate and then subsequently changing back from water to ice!

Apart from fast and slow-motion effects the disc recorder is useful as a magnetic disc version of an "instant-recall slide-projector". For this application, each track on the machine can be recorded with a still frame caption, station identification card, test pattern, photograph, etc. Any frame may be recalled after any other within one second maximum, and in considerably less time for more-nearly adjacent tracks. Considerable time and effort can be saved by recording on to the disc with a camera directly from art-work compared to the normal system at present used where this art-work is first photographed by a 35-mm camera, the film is developed then printed, the positive is mounted in a frame and the mounted slide is inserted into a slide projector (often inverted or reversed!)

The discs used are highly polished, magnetically coated, metal discs permitting disc and head life in excess of 1,000 hours each. Both sides of the discs may be recorded upon without mutual interaction. Disc speeds may be either one revolution per field or one revolution per frame. The time-base stability is ± 50 nanoseconds, bandwidth 4.2 MHz, and signal-to-noise ratio 40 dB.

Colour cameras

The two main factors which have prevented the use on a larger scale of colour television cameras in education and industry are probably cost and operational complexity. It is interesting to note that a single remedy could be the cure for both: simplicity. At the 1968 N.A.E.B. convention RCA introduced their single-vidicon colour television camera, this year an improved version was shown and many more details were given.

The great advantage operationally of a single-tube camera is that the nightmare of registration of two, three or four scanned rasters becomes non-existent. Instead of having to adjust heights, widths, linearities and positions of four rasters (32 controls) every time the camera is used, with a single-tube only six controls need be provided and they can be preset, needing adjustment on only very few occasions.

At the heart of the optical system is a pair of striped dichroic filters (Fig.3). The filters have alternate, narrow stripes of dichroic material and clear material. Each of the two filters has a different type of dichroic material; one is blue reflecting (passing red and green light), the other type is red reflecting (passing blue and green light). Thus each filter will pass green light over its entire area. The two filters, which have their stripes at the same spacing as each other, are placed in contact in such a position in the optical path that the direction of line scan is perpendicular to the blue-reflecting stripes. The red-reflecting stripes are placed at 45° to the line scan direction. Consider for a moment that the camera is trained on a totally blue-coloured object. The light passing through the blue-stop dichroic will be alternately transmitted to, or reflected away from, the pick-up tube. Thus blue light entering the tube is amplitude modulated at a carrier frequency related to the number of stripes on the filter, the angle the stripes make with the line scan and the rate of travel of the scanning beam in the scan direction. The choice of parameters in this case provides a blue carrier frequency of 5 MHz. The red carrier frequency is generated in a similar manner by the red striped filter; however, as this filter is placed at 45° to the scan direction instead of perpendicular to it, the red carrier is $\cos 45 \times 5\text{ MHz} = 3.5\text{ MHz}$ (approximately).

The output waveform from the camera tube is processed and signal information at 5 MHz is treated as blue signal, that at 3.5 MHz as red signal and that below 3.2 MHz as green signal. The green signal takes two paths. One through a 500-kHz low pass filter is used as the green matrixing input ($-E_m$). The filter is needed to match the bandwidths with the red and blue signal channels. The second path for the green signal is not further reduced in bandwidth but is used as the luminance signal ($-E_y$). A one-microsecond delay line is needed to match the timing of the luminance signal with the narrow bandwidth chrominance signals.

The basic camera encoder makes use of many simplifications. *R-Y* and *B-Y* chroma modulation is used to allow the elimination of the colour-burst modulator and accompanying phasing circuits with a consequent reduction in cost. The burst flag signal is modulated directly in the *B-Y* balanced modulator together with the *B-Y* matrixed video signal.

Another simplification is the utilization of a sub-carrier oscillator which is not locked to the sync generator. However, a switch is provided to allow the connection of an external source of sub-carrier signal phase-locked to external sync for instances where the random colour interlace of the non-locked sub-carrier would prove objectional.

Index to Vol. 75

The index to Vol. 75, January-December 1969, will be available when the March issue is published on February 16th.

Personalities

Several appointments were recently announced by CETA Electronics Ltd, of Poole, Dorset. **David Dillistone** has become chairman. Educated in America and at Oxford University he began his career in electronics with E.M.I. where he worked on missile systems. He then became a senior research engineer with Plessey before moving into management consultancy with SIGMA (Science in General Management Ltd) where in 1965 he became projects manager. Since 1967 he has been with Hoskyns & Co., management consultants, latterly as a director. **Peter Horne** has joined CETA as chief development engineer. He was at one time with Newmarket Transistors but immediately prior to joining CETA was with Plessey as a group leader. **Arthur E. Crump,** who has contributed several articles to *Wireless World* (one is in this issue), is appointed instrumentation manager with CETA. He has worked with G.E.C. and Redifon and was latterly a principal engineer with Plessey where he was responsible for the project management of remote control systems.

George Foot, M.I.R.E., last year rejoined Cosmocord after an absence of five years and has now been appointed chief engineer of the Electrical Division. Mr. Foot, who is 46, originally joined Cosmocord in 1953. After eleven years he left and went to Amplivox where he stayed for one year before going to S.T.C. at New Southgate where he worked in the telephone switching division from 1965 to 1969.

Peter C. McNeill, B.Sc., Ph.D., M.I.E.E., appointed chief engineer designate of British Insulated Callender's Cables Ltd, has, since 1965, been with the National Research Development Corporation, where he was manager of the electrical engineering and electronics group. He was particularly concerned with the provision of financial support for development work on microelectronics and superconducting electrical machines. Dr. McNeill, who is 44, graduated in electrical and mechanical engineering at Queen's University, Belfast, and joined the British Thomson Houston Company, Rugby, as a graduate apprentice in 1950. He subsequently joined the staff of BTH Research Laboratory, where initially he worked on microwave valves and later on electrical discharge devices. Queen's University awarded him a doctorate for his work in this period. In 1960 he joined Elliott Brothers (London) Ltd, as head of the valve research group. Later he became technical manager, radiation sources and detectors department.

Brian Steel, who joined S.E. Laboratories (Engineering) Ltd, of Feltham, Middx, five years ago, has now been appointed sales director covering home and export sales in the industrial, medical and laboratory instrument fields. He started his career with B.A.C. at Weybridge as an apprentice and during his fourteen years with the company was engaged on environmental testing on guided weapons and the design and development of flight test instrumentation, notably on the BAC 111 and VC 10 aircraft.

Robin Smith-Saville, B.Sc., Ph.D., M.I.E.E., has joined AIM Electronics Ltd as technical director. He was a lecturer at Manchester

Dr. Robin Smith-Saville

University and has for some time been assisting the company as an electronics design consultant. He developed the circuitry of the oscilloscope sampling adaptor manufactured by AIM. Dr. Smith-Saville gained industrial experience with Texas Instruments Ltd in Bedford, where he started as a technical assistant in circuit design straight from school, and subsequently with Ferranti Ltd. in Manchester. He studied for his degree in Physics at Manchester University which he obtained in 1962 and was awarded a doctorate for work on techniques for the measurement of fluorescence lifetime of the order of a nanosecond.

Harold Stanesby, F.I.E.E., Hon.C. G.I.A., deputy director of engineering in the Post Office since 1960, has been transferred to the newly formed Ministry of Posts and Telecommunications as director of radio technology. The Directorate of Radio Technology is responsible for dealing with all technical matters relating to the orderly use of the radio-frequency spectrum. It also has overall responsibility for the technical direction of the interference investigation service and the tracing of illicit transmissions; although most of the field work on these problems will continue to be undertaken by the Post Office under contract to the Ministry. Mr. Stanesby joined the Post Office Radio Laboratories at Dollis Hill as a youth-in-training in 1924. Prior to his appointment as deputy director of engineering he had been staff engineer in the radio planning and provision branch of the Engineering Department for eight years. Two deputy directors of radio technology in the new Ministry have been appointed. They are: **C. W. Sowton,** O.B.E., B.Sc.(Eng.), F.I.E.E., A.C.G.I. and **T. Kilvington,** B.Sc.(Eng.), F.I.E.E., both formerly of the Post Office. Mr. Sowton had been staff engineer in the Overseas Radio Planning & Provision Branch for the past eight years and Mr. Kilvington staff engineer in charge of the Inland Radio Planning & Provision Branch since 1963.

A. A. Diggens, who has been with Electronic Instruments Ltd, of Richmond, Surrey, since 1960, has been appointed chief engineer. He was mainly concerned with the company's development of water treatment analysers and since 1967 has been chief engineer of the Twickenham factory where the instruments are manufactured.

Robert C. G. Williams, O.B.E., Ph.D., F.I.E.E., chief engineer of Philips Electronic & Associated Industries Ltd, has been appointed visiting professor of electronics in the Department of Electrical & Control Engineering in the University of Surrey. Dr. Williams joined the Philips organization in 1946 having previously spent 15 years with Murphy Radio, latterly as chief engineer. Prior to entering the industry in 1931 he had spent a year on the staff of Imperial College of Science & Technology.

S. R. Wilkins, F.I.E.R.E., A.M.I.E.E., who recently resigned as deputy chairman and technical director of Avo Ltd, has joined Fleming Instruments Ltd, of Stevenage, as joint managing director. **A. W. Jones,** the founder of the company, remains as chairman and joint managing director. Mr Wilkins, who is 58, joined Avo as a development engineer in 1934.

J. R. Nowicki, F.I.E.R.E., has joined Gresham Lion Electronics Ltd as senior engineer in the Power Systems Division. Mr. Nowicki was previously a senior applications engineer with Mullard which he joined in 1956. Since 1964 he has been in Mullard's Central Laboratory where he was concerned with the application of semiconductor devices.

E. Swinney, F.I.E.E., has been appointed by Marconi-Elliott Avionic Systems Ltd to the newly created post of general manager, Basildon, with responsibility for all of the company activities at a number of sites in the Basildon area. Mr. Swinney, who joined the Royal Air Force as an apprentice at Halton in 1924, was closely associated with the early developments of radar equipment in the R.A.F. at the Air Ministry Research Station, Bawdsey, and was appointed Chief Radar Officer of the N.W. African Air Force in 1942. Two years later he became Chief Signals Officer at the Central Fighter Establishment, moving to the Air Ministry in 1949, as head of the Air Defence Radar Branch. He resigned from the R.A.F. in 1955 with the rank of Wing Commander, and joined the Aeronautical Division of the Marconi Company as a senior project engineer. He was appointed systems manager, and later deputy manager of the Aeronautical Division.

Welwyn Electric have announced three senior appointments to their recently formed Printed Circuit and Interconnections Division. **D. M. Cadenhead** becomes production manager. He was latterly with the Radar Division of the Plessey Co. Ltd based at Addlestone, Surrey, and prior to that held positions with Solartron and Hughes International. **P. Hebden,** who joined Welwyn in 1967, is appointed sales manager. **H. Banner,** appointed technical manager, joins Welwyn from Mills & Rockley (Electronics) Ltd of Skelmersdale, Lancs, where he was technical manager—printed circuits.

New Products

F.E.T. Operational Amplifier

Computing Techniques Ltd have introduced a new operational amplifier with chopper drift correction and a f.e.t. transistor at the input stage, type A8-2. It has an open loop gain of 10^8 and a typical voltage offset, adjustable to zero externally, of 10μV with a temperature drift of 0.2 μV per °C. Input bias current is 50pA with a temperature drift of 0.5pA per °C. Maximum output voltage and current with 2.5kΩ load are ±11V and ±5mA with chopper ripple of 20μV peak-to-peak from an output impedance of 500Ω. The amplifier (plan area is 1.5 × 2.4in., depth is 0.85in.) is fully protected against short circuits or supply reversal, is inverting only and is fully stable under normal conditions of feedback and load with a built-in gain roll off of 20dB per decade. Suitable as a long term precision integrator or low-level signal amplifier, the A8-2 is all silicon solid state and is fully encapsulated in epoxy resin. Computing Techniques Ltd, Westminster Bank Chambers, Bridge Street, Leatherhead, Surrey.
WW306 for further details

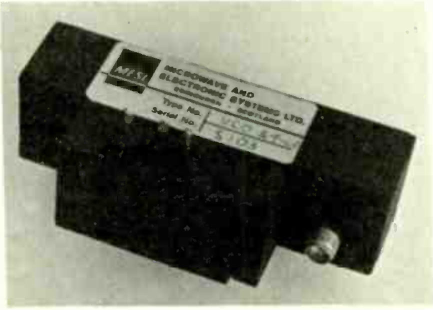
F.E.T. Stereo Tuner

Tripletone Manufacturing Co. Ltd are marketing their first solid-state f.m. stereo tuner. It comprises f.e.t. tuner, i.f. strip, decoder, emitter followers and power unit all in one chassis. The use of dual gate f.e.t. reduces drift and improves signal-to-noise ratio. Mono-to-stereo switching is automatic, and if a mono version is purchased, a decoder unit is available separately. Frequency coverage is 88-108Hz, sensitivity is 2.3μV for 20dB quieting, bandwidth is 210kHz, aerial input is 70-80 Ω coaxial, a.f.c. hold is 400kHz, output is 0-1V via emitter follower and cross talk is better than 30dB at 1kHz. Chassis model measures 11×7½×3¾ in. high, cabinet model

measures 13×9×5¼ in. high. Chassis model weighs 6lb, cabinet model 9lb. The Tripletone Manufacturing Co. Ltd, 241a The Broadway, Wimbledon, London S.W.19.
WW321 for further details

Solid-state Multiplier Sources

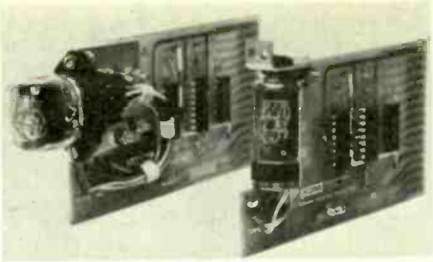
Microwave and Electronic Systems Ltd have announced a new range of multiplier sources covering the frequency range 2.5 to 8.5GHz, using step diodes with electronic tuning to 600MHz. They measure 1 × 1½ × 3¼in. and weight 6oz. Typical performance includes a frequency of 3.5 to



4.25GHz, tuning voltage of ± 15V or 0 to ± 30V, power output of 40mW minimum, input of 2W and operating temperature of −40 to +80°C. Phase-lock and crystal-controlled variants are also available. MESL, Lochend Industrial Estate, Newbridge, Midlothian, Scotland.
WW324 for further details

Indicator Tube Driver

K.G.M. Electronics Ltd have introduced their Series 600 Driver Package, a complete drive system for most end- and side-viewing cold-cathode indicator tubes. Tubes with decimal point characters and tubes with separate anodes are alike catered for. The package uses dual in-line t.t.l.i.cs and has a decade counter, register and decoder/driver, complete with indicator tube. Supplied with just decoder/driver and tube, it will provide a decimal display from a parallel binary input. The register stores and updates the displayed value. Used with the counter, counting occurs during a constant display which is updated when the counting is complete. Maximum counting



rate is 18MHz. If used with a binary input, the register stores the displayed value and allows the input signal to be changed or removed. A binary data highway allows the counter (or register) to produce an ancillary binary output, and the same highway will take input signals direct to the decoder (or register) when the counter is not fitted. By using various types of connectors—spills, edge-connector and socket etc—the package can be made compatible with the main equipment receiving it. K.G.M. Electronics Ltd, Clock Tower Road, Isleworth, Middx.
WW319 for further details

Transistors for V.H.F. Transmitters

Two new medium-power transistors for use in class 'B' amplifiers of v.h.f. transmitters and in frequency- or amplitude-modulated systems, have been introduced by Mullard. The BLY85 operates with a supply voltage of 13.8V, and so is suitable for use in mobile equipment powered by car batteries. With an input of 0.4W, the BLY85 will give an output of 4W in a typical f.m. system at 175MHz, while the BLY97, 24-V version of the BLY85, requires an input of 0.2W to give the same output in the same system. In an a.m. system and with a supply voltage of 13.8V, the BLY97 will provide an output of 2.5W. Mullard Ltd, Mullard House, Torrington Place, London W.C.1.
WW322 for further details

10 Hz to 10MHz Sinewave Source

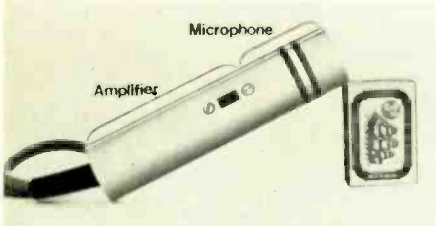
Britec Ltd have introduced the Preston X-Mod 134 sinewave signal source. Output range is variable from 10Hz to 10MHz in six decades and output impedance is 50Ω. The unit provides twelve switch-

selected calibrated output voltages ranging from 2mV to 10V peak, with a twenty-to-one vernier control, and a sync output voltage of 5V ± 0.25V peak-to-peak from 10Hz to 10MHz, with an output impedance of 5000Ω. Unit has a sync input which allows an auxiliary input to synchronize the waveform output with an external signal so that a second oscillator may be used to modulate the unit or phase-lock with it and control a precision phase shift of up to 180°. This unit can be incorporated along with others in the X-Mod range, into an instrumentation system via optional racks; all units in the range have both front panel and rear patchboard connections and feature all-silicon components and plug-in printed circuit boards. Britec Ltd, 17 Charing Cross Road, London W.C.2.

WW311 for further details

Integrated Microphone-amplifier

Brim-Exports Ltd are marketing a new integrated microphone-amplifier manufactured in Norway by Polar. The Unikum amplifier requires a power supply of 12-24V d.c., and has a maximum output at 24V of 10W into 6 ohms, and at 12V of 4W into 4 ohms. The only connections are



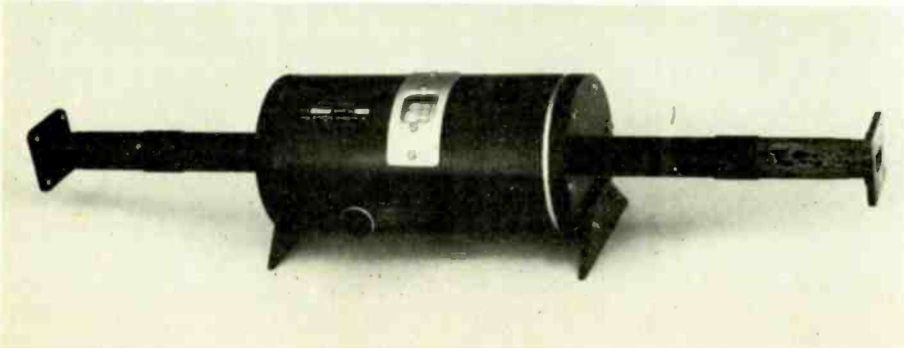
two leads to the battery and two to the loudspeaker. The unit can be delivered with talk-back facilities for use as an intercom system, and as a hand microphone or with goose neck for permanent mounting. It measures 35mm × 130mm. Brim-Exports Ltd, 42 Portobello Rd, Kensington. London W11.

WW302 for further details.

Rotary Waveguide Phase Changers

New from Flann Microwave Instruments, a 10-model range of direct-reading rotary waveguide phase changers. The 6-2 series controls phase change from −360° to +360°. The differential phase change is monitored on a drum scale linearly calibrated in degrees. The dielectric phase change element is a low-loss material suitable for medium-power systems. Transitions from rectangular to circular section are multi-stepped to give the shortest length and lowest s.w.r. Frequency coverage of the various models ranges from 2.6-3.95GHz to 26.5-40GHz, maximum insertion loss over this range varies from 2 to 4dB, s.w.r. from less than 1.25 to 1.3, and power rating from 2W to 15W, depending on model. Flann Microwave Instruments Ltd, 9 Old Bridge Street. Kingston-upon-Thames, Surrey.

WW326 for further details



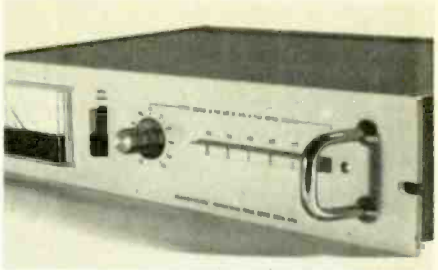
Polystyrene Foil Capacitors

Polystyrene foil capacitors type KS17, which are especially suitable for use in frequency-determining and filter networks, have been developed by ITT. The connecting leads are welded to the layers over the whole front which gives the capacitors low attenuation, highly reliable connections even at low voltage, and makes possible low inductance wound construction. They are also claimed to have a uniform temperature coefficient over the whole range and a low dissipation factor at high frequencies. The capacitors have a uniform overall length of 12.5mm and are available in a range of 350 to 24000 pF with nominal d.c. voltage ratings of 63V and 160V. Capacitance values are graded on the E 192 series; they can be supplied in tolerances of ± 1%, ± 2.5% or ± 5%. ITT Components Group Europe, Standard Telephones and Cables Ltd, Edinburgh Way, Harlow, Essex.

WW303 for further details.

Solid-state, Photomultiplier Power Supply

Designed with the latest photomultiplier tubes in mind, the Brandenburg power unit, model 472R, is suitable for both bench use and rack mounting. It is completely solid state and is designed for operation from 200/250 volt 50Hz power supplies. The output can be varied over the range 100 to 2100 volts, maximum current 5mA with an effective resistance of less than 20Ω. Ripple is quoted as 1 volt p-p and stability over a 24-hour period is 1 part in 10^4 against $\pm 7\frac{1}{2}$% mains change. Drift: 5 parts in 10^5 per hour, 1 part in 10^4 per day. Dimensions:

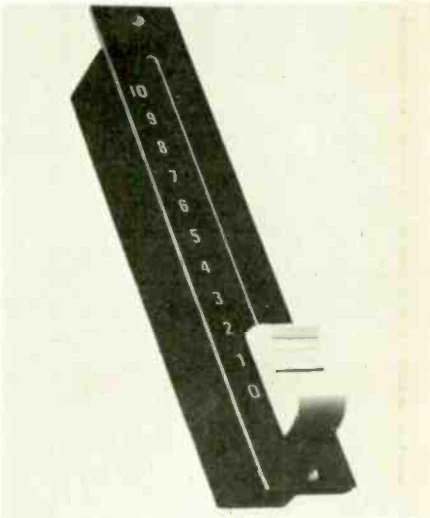


483 × 89 × 248mm (19 × $3\frac{1}{2}$ × $9\frac{3}{4}$ in.). Weight: 6.35kg (14lb). Price, delivered in U.K. or Europe: £125. Brandenburg Ltd, 139 Sanderstead Road, South Croydon, Surrey.

WW328 for further details

Audio Faders and Potentiometric Controls

Complementing their range of professional studio faders, Penny and Giles are introducing a new range of low cost audio faders and potentiometric controls for use with semi-professional sound mixers, thyristor-



controlled studio lighting, and mobile or temporary installations. Operational Control is over 3in.. resistance values are from 500Ω to 40kΩ, power rating is 2W and movement resolution is better than 0.06%. Penny & Giles Ltd, Mudeford, Christchurch, Hants.

WW307 for further details

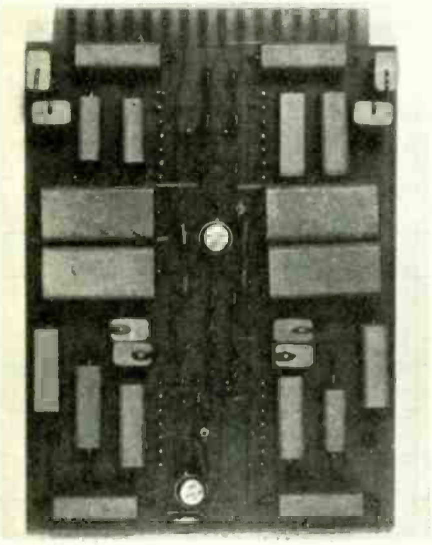
Precision Trimmer Capacitors

Voltronics Corporation of U.S.A. are marketing their range of trimmer capacitors through Salford Electrical Instruments, a member company of GEC Electrical Components Ltd. Capacitors are non-rotating and linearity is better than 1%. The screw stays positioned for simple blind-hole turning and does not move axially: the design is claimed to allow a shorter r.f. current ground path directly to the base which prolongs life to 10,000 cycles minimum, enlarges current capacity up to 2A, gives high resolution and resetability, wide capacitance range with units ranging from 0.1 to 180 pF and higher Q's

with no self-resonance below 1200MHz. These components can be supplied with standard glass, quartz and embedded glass dielectrics suitable for printed-circuit or panel mounting. Split stator, differential and extended shaft constructions are among the many available. Salford Electrical Instruments Ltd, Peel Works, Barton Lane, Eccles, Manchester.
WW314 for further details

RC Active Filters

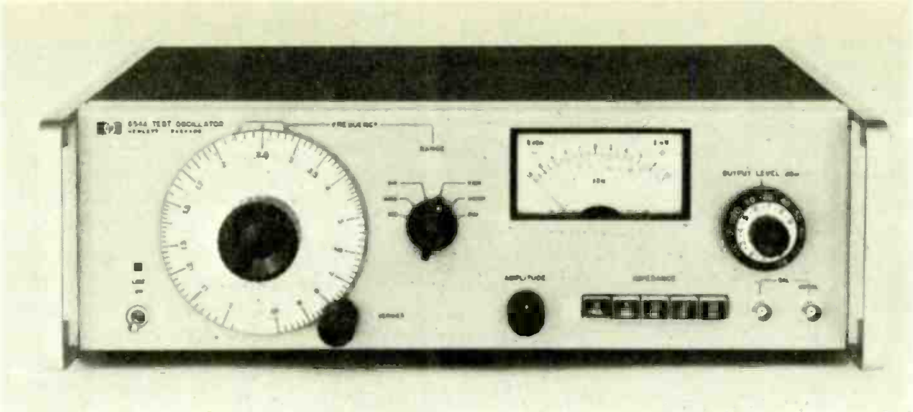
Kemo Ltd are offering a wide range of active RC filters. Frequencies range from 0.01Hz, and in general, filters have a voltage gain of unity, high (100kΩ) input resistance, low (50Ω) output resistance, operate from + and −15V, and where l.p. units are concerned, good d.c. drift character-



istics. Standard synthetic derivations available include Tchebycheff, Butterworth, linear phase and elliptic. The range of 1/6, 1/3, 1/2 and whole octave filters, supplied as units or as complete analysis or equalizer systems, is suitable for environmental engineering. Kemo Ltd, 42 Chancery Lane, Beckenham, Kent.
WW323 for further details

Constant Amplitude Wideband Oscillator

A new wideband test oscillator from Hewlett-Packard, model 654A, covering the range 10Hz to 10MHz in six decades has an amplitude stability of ± 0.05dB (0.5%) over the full range. This kind of flat response should considerably reduce the time consumed when making multipoint frequency response tests by eliminating the need for frequent readjustment of the oscillator amplitude. The exceptionally flat frequency response of this oscillator is obtained by use of a level controlled buffer amplifier between the oscillator circuits and the output amplifier. Output level sensing is by a detector which controls an attenuator (a photo-controlled resistor pad) in the buffer amplifier. A balanced output amplifier is incorporated which enables balanced outputs for 600, 150, 135Ω impedances to be push-button switch selected plus two



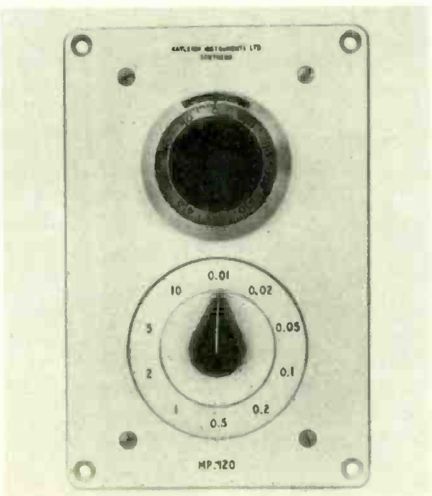
single-ended outputs of 50 and 75Ω impedance respectively. Maximum output is +11dB (2.5V into 600Ω), the precision attenuator has an 89-dB range in 1-dB steps, with an accuracy of 0.15dB on the higher ranges. The centre-zero output meter has an expanded scale with a range of −1 to +1dB, giving a 0.02-dB resolution for precise incremental adjustment of the output level. Price: £403. Hewlett-Packard Ltd, 224 Bath Road, Slough, Bucks.
WW325 for further details

Miniature Dual Power Supply

New from Ancom Ltd, a miniature power supply measuring 2 × 2½ × 1 in. The Ancom DPS-25 is an encapsulated power supply designed to feed small operational amplifier systems where supply voltages are not used as reference potentials. Input is 210V to 250V a.c., 50-60Hz, and outputs are +15V at 25mA maximum, and −15V, not adjustable, at 25mA maximum, short-circuit current is ±25mA, regulation is 0.2 to 0.3V no load to full load and ripple and noise is 1-2mV p-p typical. Unit is housed in a shielded metal case with blue finish. Ancom Ltd, Devonshire Street, Cheltenham.
WW318 for further details

Motorized Potentiometer

Rayleigh Instruments Ltd are marketing a new panel-mounted motorized potentiometer, MP120P. The unit is fitted with a 10-speed gearbox having either of two progressions: 10,5,2,1,0.5,-0.01 r.p.m., or 10,3,1, 0.3-0.0003 r.p.m. Speed setting



is via a 20 click-stop rotating knob, 10 stops for the respective r.p.m. drive speeds and ten intermediate neutral positions to aid manual potentiometer setting via the turns counter. Resistance values range from 10Ω to 100kΩ and the potentiometer is of the 10-turn helical type. The unit employs a slipping clutch, and limit switches function at either end of the track. Each unit has a reversible synchronous motor which, in standard models, is 24V, 50Hz. The motor may be connected to higher voltages by adding a ballast resistor. Rayleigh Instruments Ltd, 271 Kiln Rd, Thundersley, Benfleet, Essex.
WW313 for further details

Solder Creams

Alpha Metals Inc have expanded their line of solder creams, which are now available as standard and special alloy compositions, curable or non-curable, in a variety of viscosities and powder mesh sizes, with resin and acid flux bases in all degrees of flux activation. The creams are claimed to permit close control of deposit size, and to eliminate a separate fluxing process. All solder powders are pre-alloyed for lowest wetting temperatures and highest joint uniformity. Creams are designed for use on continuous or indexed mass production lines. Alpha Metals Inc, 56 Water Street, Jersey City, New Jersey 07304, U.S.A.
WW317 for further details

X-Band Gunn-Diode Oscillator

Silvers Lab have introduced a new X-band Gunn-diode oscillator. Model PM7015X is tunable over the range 8.3-10.5GHz with output power over 15mW at midband. The tuning mechanism is GHz-calibrated, and a protection circuit guards against over-voltage or wrong polarity. Silvers Lab, Box 42018, Elektravägen 53, Stockholm 42, Sweden.
WW327 for further details

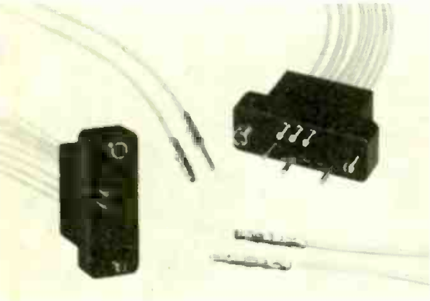
Miniature Carbon Resistors

ITT have introduced a new range of carbon composition resistors. The resistors, type numbers RC025 and RC050, are now available in ¼W and ½W

sizes. These ratings apply to up to 70°C ambient temperature operation. Resistance values are from 2.2Ω to 1.0MΩ for the $\frac{1}{4}$W series and 2.2Ω to 4.7MΩ for the $\frac{1}{2}$W series. Resistors are available with ±5%, ±10% and ±20% tolerances. Features claimed for the resistors include high overload capacity, good h.f. characteristics, low temperature coefficient and full insulation. Further data including performance curves are set out in a trilingual booklet. ITT Components Group Europe, Standard Telephones and Cables Ltd, Edinburgh Way, Harlow, Essex.
WW305 for further details

Multi-Micro Coaxial Connector

New from Radiall Microwave Components Ltd, a multi-micro coaxial connector, series MMC. The glass loaded phenolic connector shell, which measures 41.4 × 14.2 × 22.70mm accepts 26 simple pin and socket contacts or coaxial inserts in any combination. The contacts are first crimped to the cables using standard M.S. tools and then inserted or extracted from the back of the shell which has an insert



retention of better than 5kg. Both the inner conductor and the screen are individually crimped to the coaxial inserts for high reliability, and the pin and socket contacts are rated at 13A with a contact resistance of 15mΩ. Connector will operate between 125 °C and −55 °C, and conforms to the environmental specifications of MIL-C-39012 and CCTU 10-04. Radiall Microwave Components Ltd, Station Approach, Grove Park Road, Chiswick, London W.4.
WW309 for further details

Variable Directivity Microphone

Jagor Interelectric Ltd has introduced a new variable directivity microphone to the UK market. The Pearl DC 63 capacitor microphone has casing mounted continuously variable controls producing 44 directivity patterns. A microphone head amplifier using a f.e.t. and twin-sided insulated microphone capsule, produces frequency response from 25 to 20,000Hz, a sensitivity at 1 dyne per sq cm of −56 to −60dB depending on selected directivity pattern, and a dynamic range of 130dB. The power source may be a $6\frac{1}{2}$V dry battery fed to the microphone capsule through a balanced circuit using the symmetrical

signal cable powering system, which permits the use of a screened twin cable to carry the microphone current (0.5 to 0.7mA) and the output signal current. Suitable for all broadcasting and recording use, the unit measures 150 × 31mm, has stand adaption or can be hand-held. Jagor Interelectric Ltd, Mercury House, Hanger Green, Ealing, London W.5.
WW316 for further details

Silicon Photodiode

A new silicon photodiode has been introduced by EMI's Electron Tube Division. Type SPD1 is all solid state and claims a fast rise time and wide spectral range, with low noise levels ensured by the use of an effective guard ring structure. The active area is one cm², making it a general-purpose detector with broad applications to sites where space and power are at a premium. EMI Electronics Ltd, Hayes, Middx.
WW308 for further details

Zero Temperature Factor Toroids

Salford Electrical Instruments have added Feralex ferrite ring cores to their range of toroids. The new R grade has a permeability of +0.5 to −0.5 p.p.m./°C over the range of +20 to +70°C. Nominal permeability is 2000 and the cores can be supplied graded. The material retains its fundamental properties up to 300kHz and thereafter may be used for pulse transformer applications up to several MHz. Salford Electrical Instruments Ltd, Times Mill, Heywood, Lancs.
WW304 for further details

Solid Tantalum Capacitors

A cylindrical capacitor with an unusually low dissipation factor has been developed by Emihus. It is stated to be well within the limits of MIL-C-390038 and has what is claimed to be "the lowest ever leakage current." Emihus also have a rectangular plastic-housed unit of precise shape and size with the same levels of current leakage and dissipation factor. The devices range from 3V to 35V and 330μF to 0.1μF. Typical leakage currents are of the order of 1mA per μFV. A 3.9-μF 10-V capacitor has a leakage current of 39 nA at 25°C. Emihus Microcomponents Ltd, Glenrothes, Fife.
WW301 for further details

Integral-cycle Zero Voltage Switch

Electronic Component Supplies Ltd have introduced an integral-cycle zero-voltage switch, model CA3059. A 14-lead dual in-line plastic package, it may be operated from an a.c. line direct, provides triac gating signal at zero-voltage crossings, drives a triac gate directly, has fail safe circuit for accidentally opened or shorted sensor, optional output control, and temperature range is from −25 to +75 °C. Radio interference caused by the unit, which may be used as a differential comparator, is minimal. Electronic Component Supplies (Windsor) Ltd, Thames Avenue, Windsor, Berkshire.
WW310 for further details

Digital Panel Meter

Bach-Simpson have introduced a new digital panel meter, Model 2800, suitable for equipment panel mounting. Non-blinking read outs and storage circuitry for securing the number, ensure rapid and clear readings. Five d.c. voltage or current ranges are available at a standard accuracy of

±0.1% (f.s.d.). Unit is available with b.c.d. output, relay set points to give high and/or low alarm signals or without its built-in power supply for O.E.M. applications. Apart from the read out tubes, circuitry is all solid state. Bach-Simpson Ltd, 331 Uxbridge Road, Rickmansworth, Herts.
WW315 for further details

Desoldering Wick

"Solder Wick" for desoldering joints, is available from Southern Watch and Clock Supplies. It is supplied in reel form and used in direct contact with the joint, heat being applied with a standard soldering iron. No flux is required. The wick draws the solder into itself quickly and without the need for much heat. There are approximately 60in. of dry wick in each dispenser, and prices range from 18s to 20s per reel, according to pad size and width. Southern Watch and Clock Supplies Ltd, Industrial Tools Division, 48-56 High Street, Orpington, Kent, BR6 OJH.
WW312 for further details

World of Amateur Radio

Security restrictions on Service licences?

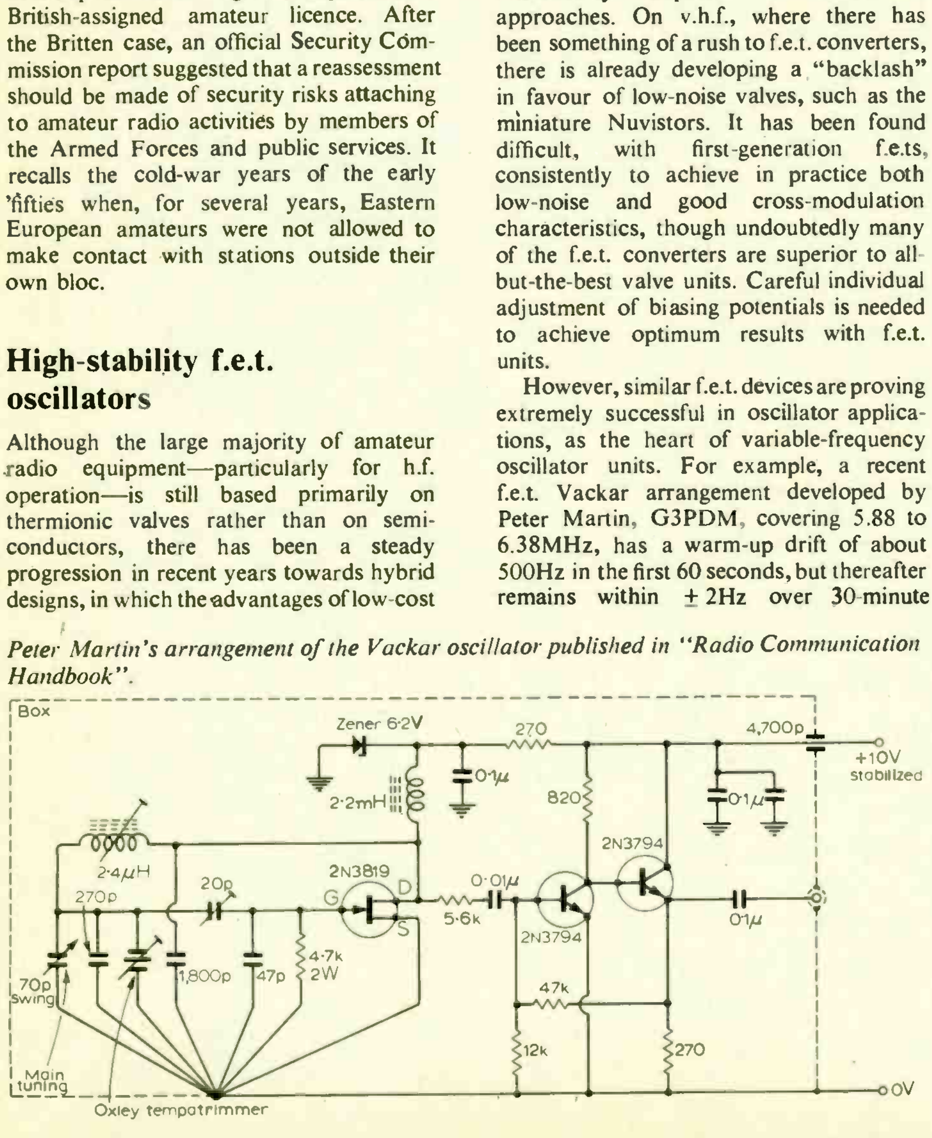
A curious, and potentially far-reaching "political" restriction—possibly the outcome of the 1967 Britten spy case—is reported to have been imposed on an amateur licence issued to a meteorological officer on Gan, the R.A.F. base in the Maldive Islands in the Indian Ocean. This I understand forbids the station operator from making contacts with stations in the Eastern European bloc, and is believed to be the first time that such a condition has been reported as having been imposed on a British-assigned amateur licence. After the Britten case, an official Security Commission report suggested that a reassessment should be made of security risks attaching to amateur radio activities by members of the Armed Forces and public services. It recalls the cold-war years of the early 'fifties when, for several years, Eastern European amateurs were not allowed to make contact with stations outside their own bloc.

High-stability f.e.t. oscillators

Although the large majority of amateur radio equipment—particularly for h.f. operation—is still based primarily on thermionic valves rather than on semiconductors, there has been a steady progression in recent years towards hybrid designs, in which the advantages of low-cost small-signal transistors are resulting in their selective adoption. There still exist appreciable problems in all-transistor equipments: the relatively high cost of r.f. transistors of appreciable power rating for the main power amplifier stages of transmitters, and the difficulty of achieving really good dynamic range in the front-ends of receivers. The latter problem appeared to be disappearing with the arrival on the scene of low-cost junction f.e.ts, and single- and dual-gate i.g.f.e.ts but there are increasing doubts as to whether the results achieved in practice with these devices are consistently superior to alternative approaches. On v.h.f., where there has been something of a rush to f.e.t. converters, there is already developing a "backlash" in favour of low-noise valves, such as the miniature Nuvistors. It has been found difficult, with first-generation f.e.ts, consistently to achieve in practice both low-noise and good cross-modulation characteristics, though undoubtedly many of the f.e.t. converters are superior to all-but-the-best valve units. Careful individual adjustment of biasing potentials is needed to achieve optimum results with f.e.t. units.

However, similar f.e.t. devices are proving extremely successful in oscillator applications, as the heart of variable-frequency oscillator units. For example, a recent f.e.t. Vackar arrangement developed by Peter Martin, G3PDM, covering 5.88 to 6.38MHz, has a warm-up drift of about 500Hz in the first 60 seconds, but thereafter remains within ±2Hz over 30-minute periods; after switching off for 12 hours it returns to within 10Hz of its previous frequency. To achieve such performance requires considerable care in both electrical and mechanical aspects of the unit, but it is clearly easier to achieve such a standard of performance with an f.e.t. than it would be with the greater heat-change of a thermionic device. This unit is a further example of the popularity of the Czech Vackar oscillator circuit for both bipolar and f.e.t. semiconductors. The two closely related Vackar and Seiler oscillators, both derived from the basic Colpitts oscillator, have proved reliable and straightforward circuits for simple semiconductor oscillators.

Peter Martin's arrangement of the Vackar oscillator published in "Radio Communication Handbook".



V.H.F. meteor scatter

Meteor scatter communications during the November Leonids shower included the first 144 MHz telegraphy contacts between the British Isles and the Faeroes. John Stace, G3CCH, of Scunthorpe, and Peter Blair, G3LTF, of Chelmsford, made brief contacts with the Faeroes station OY2BS. The next major meteor shower is the Lyrids, due April 19th-23rd, but amateur meteor-scatter communications are possible at many other times, between stations working on precisely known frequencies: the frequency band used for this type of operation is 144.09 to 144.10 MHz. John Stace, G3CCH, 38 Skippingdale Road, Scunthorpe, Lincolnshire, has compiled a list of amateurs interested in meteor-scatter operation, and is also anxious to hear from amateurs outside the U.K. wishing to set up schedules with British amateurs.

In Brief: First sections of the A.R.R.L. annual DX contest will be held on February 7th-8th (phone) and February 21st-22nd (c.w.). . . . At the recent A.G.M. of the Radio Society of Great Britain, the Society's "Calcutta Key"—an award made for outstanding service to the cause of international friendship through the medium of amateur radio—was presented to René Vanmuysen, ON4VY, the Belgian amateur responsible for the organization of the 1969 I.A.R.U. Brussels Conference and for the start of reciprocal licensing in Europe which today allows amateurs freely to obtain temporary licences in many countries. . . . Marie de Forest, widow of the inventor Lee de Forest, now operates as WB6ZJR. . . . Yugoslav amateurs established emergency communication links following the earthquake in the Banja Luka area of Bosnia. . . . Because of a new channel requirement for television, 50 MHz facilities for Rhodesian amateurs were withdrawn at the end of 1969. . . . An informal international amateur meeting is being planned by E.D.R., the Danish amateur radio society, during Whitsun (May 16th-18th) near Nyborg on the island of Funen. Projects include "fox hunting" (d.f. tests) and a v.h.f. balloon translator. Details from Joergen Dam-Johansen, OZ9DA, Hammershusvej 43, DK-8210 Aarhus V, Denmark.

PAT HAWKER, G3VA

Test Your Knowledge

*Series devised by L. Ibbotson**, B.Sc., A.Inst.P., M.I.E.E., M.I.E.R.E.

21. Amplitude Modulation

Questions 1 to 9 all refer to a 1-MHz sinusoidal carrier voltage of peak value 2V which is amplitude modulated in turn by three signals, each of frequency 1kHz, and each of mean value zero (no d.c. component) and peak value 1V. The three signals have sinusoidal, square and sawtooth waveforms respectively.

1. The depth of modulation is:
(a) the same for all three modulating signals
(b) greatest for the sinusoidal modulating signal
(c) greatest for the square-wave modulating signal
(d) greatest for the sawtooth modulating signal.

2. For the case of the sinusoidal modulating signal the depth of modulation is:
(a) 0.2
(b) 2
(c) 0.5
(d) 5.

3. Assuming that all side frequencies are included, the power in the sidebands (when the modulated carrier is applied to a load) is:
(a) the same for all three modulating signals
(b) greatest for the sinusoidal modulating signal
(c) greatest for the square-wave modulating signal
(d) greatest for the sawtooth modulating signal.

4. The ratio of the total power in the sidebands of the square-wave modulated carrier to the power of the unmodulated carrier (feeding the same load) is:
(a) unity
(b) 1/2
(c) 1/4
(d) 1/8.

5. The spectrum of the modulated carrier contains only a single pair of side frequencies:
(a) for all three of the modulating signals
(b) for none of the modulating signals
(c) for two of the three modulating signals
(d) for one of the three modulating signals.

*West Ham College of Technology, London E.15.

6. The amplitude of the carrier-frequency component of the spectrum of the modulated carrier is the same as the amplitude of the unmodulated carrier:
(a) for all three of the modulating signals
(b) for none of the modulating signals
(c) for two of the three modulating signals
(d) for one of the three modulating signals.

7. The frequencies of the three modulating signals are each doubled. This results in each case in a doubling of:
(a) the depth of modulation
(b) the amplitudes of the side frequencies
(c) the amplitude of the carrier-frequency component of the spectrum
(d) the frequency separation of the components of the spectrum.

8. The amplitude of each modulating signal is increased until "over modulation" occurs. Assuming perfect modulating equipment:
(a) the amplitudes of all three signals will be the same
(b) the sinusoid signal will have the lowest amplitude
(c) the square-wave signal will have the lowest amplitude
(d) the sawtooth signal will have the lowest amplitude.

9. In the spectrum of the sinusoidally modulated carrier the component of frequency 1.001 MHz has amplitude:
(a) 2 volts
(b) 1 volt
(c) 0.5 volt
(d) 0.25 volt.

10. A sinusoidal carrier voltage is amplitude modulated by a complex audio signal, which, over a short period of time, has a constant amplitude. If the depth of modulation measured during this time is *m*, the ratio of total sideband power/carrier power supplied to a load during this time will be approximately:
(a) m; (b) $m/2$; (c) m^2; (d) $m^2/2$.

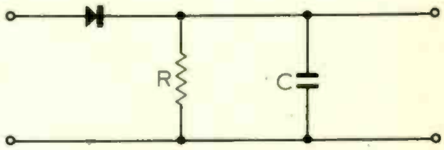
11. A monochrome television video-modulated carrier differs from a sound-radio audio-(amplitude) modulated carrier in that:
(a) the depth of modulation is always 100%
(b) the mean carrier amplitude is not constant
(c) frequency modulation is present as well as amplitude modulation
(d) the spectrum only has one sideband.

12. The power required to be transmitted in a communication system using amplitude modulation can be greatly reduced, without reducing the information transmitted, by suppressing the carrier-frequency component at the transmitter and reinserting it at the receiver. If both sidebands are transmitted *gross* distortion will occur in the output unless the carrier is replaced with *exactly* the correct:
(a) amplitude
(b) phase
(c) frequency
(d) waveform.

13. A carrier is amplitude modulated by an audio signal. If one sideband only is transmitted the original modulating signal can be recovered by detection after adding to the sideband, at the receiver, a carrier-frequency signal. If the detected output is to have an acceptably low amount of distortion, the carrier-frequency signal added must:
(a) have exactly the same frequency as the carrier at the transmitter
(b) have exactly the same phase as the carrier at the transmitter
(c) have exactly twice the amplitude of the sideband
(d) have an amplitude at least 10 dB above the amplitude of the sideband.

14. A signal voltage and a carrier voltage, of appropriate frequencies and amplitudes, are added in series and applied to a circuit in order to produce amplitude modulation of the carrier by the signal. To produce the required effect the circuit *must* include:
(a) a source of e.m.f (other than the two signals)
(b) a non-linear amplifying device
(c) a passive non-linear component
(d) any non-linear component.

15.



The diagram shows an envelope detector for amplitude-modulated signals. For correct and efficient operation the values of *C* and *R* must be selected with care. One requirement is that the output must follow the modulation at all times; to meet this requirement the product of *C* and *R* must:
(a) be very much greater than the period of the highest modulating-frequency component
(b) be very much less than the period of the highest modulating-frequency component
(c) be very much greater than the carrier period
(d) be very much less than the carrier period.

Answers and comments, page 95

February Meetings

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

LONDON

2nd. I.E.E.—Discussion on "Electronic measurement related to fundamental standards" at 17.30 at Savoy Pl., W.C.2.

3rd. I.E.E.—"Dispersive acoustic devices" by Dr. D. P. Morgan and W. S. Mortley at 17.30 at Savoy Pl., W.C.2.

4th. I.E.R.E.—"Passive satellite communications" by R. L. Harris at 18.00 at 9 Bedford Sq., W.C.1.

6th. I.E.E.—"Some aspects of direct television reception from satellites" at 17.30 at Savoy Pl., W.C.2.

10th. Radar & Electronics Assoc.—"Microwave semi-conductors" by M. B. Fletcher at 19.00 at B.I.C.C. Ltd., 21 Bloomsbury St., W.C.1.

12th. R.T.S.—"Dial a programme—communication television" by E. J. Gargini at 19.00 at the I.T.A. 70 Brompton Rd., S.W.3.

18th. I.E.E.—"Recent advances in radar anti-clutter techniques" by Dr. W. S. Whitlock at 17.30 at Savoy Pl., W.C.2.

19th. I.E.E.—Faraday lecture "People, communications and engineering" by J. H. H. Merriman at 18.00 (public) at the Central Hall, Westminster.

20th. I.E.E.—"Field store television standards conversion" by S. M. Edwardson, R. E. Davies and R. V. Harvey at 17.30 at Savoy Pl., W.C.2.

20th. I.E.E.—Faraday lecture "People, communications and engineering" by J. H. H. Merriman at 18.00 (students) at the Central Hall, Westminster.

23rd. I.E.E.—"Terminal units and transmission in electronic telephone exchanges" by T. H. Flowers at 17.30 at Savoy Pl., W.C.2.

25th. I.E.R.E.—"Low light television tubes" by Dr. P. H. Batey at 18.00 at 9 Bedford Sq., W.C.1.

26th. R.T.S.—"A colour camera and one-inch VTR for C.C.T.V." by Dr. G. L. Sanchez at 19.00 at the I.T.A. 70 Brompton Rd, S.W.3.

BIRMINGHAM

2nd I.E.E.—Sir Oliver Lodge lecture on "Man, electronics and aerospace" by R. F. Young at 19.00 at the Town Hall.

25th. Brit. Acoust. Soc.—"Micro-electronics and its influence on underwater acoustic systems" at 10.00 at the Dept. of Electronic Engineering, the University.

BRIGHTON

17th. I.E.R.E.—"Discriminators for broadcast f.m. transmission" by Hugh Mayo at 18.30 at the College of Technology.

BRISTOL

18th. I.E.R.E./I.E.E.—"Use of computers in designing automatic process controllers" by D. J. Norton at 18.00 at the University.

CARDIFF

11th. I.E.R.E.—"Navigational aids" by C. Powell at 18.30 at the University of Wales Inst. of Science & Technology.

17th. I.E.E.—Faraday lecture "People, communications and engineering" by J. H. H. Merriman at 14.30 (students) and 18.30 (public) at Sophia Gardens.

CHATHAM

19th. I.E.R.E.—"Display tubes for colour television" by B. Eastwood at 19.30 at the Medway College of Technology.

CHELMSFORD

25th. I.E.E.—"Hi-fi" by J. Moir at 18.30 at the King Edward VI Grammar School.

COLCHESTER

10th. I.E.R.E.—"Dynamic information displays" by D. W. G. Byatt at 18.30 at the University of Essex.

DORKING

25th. I.E.E.—"Stereophonic transmission" by Dr. G. J. Phillips at 19.30 at the Star and Garter Hotel.

EDINBURGH

10th. I.E.E./I.E.R.E.—"Colour television receiver design and maintenance" by G. D. Barnes at 18.00 at the Carlton Hotel, Northbridge.

GLASGOW

9th. I.E.E./I.E.R.E.—"Colour television receiver design and maintenance" by G. D. Barnes at 18.00 at the University of Strathclyde.

GUILDFORD

4th. I.E.R.E.—"Optical communications through glass fibres" by Prof. W. A. Gambling at 19.00 at the Technical College.

LOUGHBOROUGH

10th. I.E.R.E./I.E.E.—"Generation, propagation and application of microwave acoustics" by Prof. K. W. R. Stevens at 18.30 at the University of Technology, Edward Herbert Building.

NEWCASTLE-UPON-TYNE

11th. I.E.R.E.—"Aerials" by Dr. A. R. Ritson at 18.00 at the Dept. of Physics and Physical Electronics, the Polytechnic, Ellison Place.

NEWPORT, I.o.W.

13th I.E.R.E.—"Integrated circuits into second decade" by A. Barnes at 19.00 at the Technical College.

PORTSMOUTH

18th. S.E.R.T.—"Use of transistors in colour TV receivers" by A. E. Baker at 19.00 at Highbury Technical College, Dovercourt Rd, Cosham.

RUGELEY

5th. I.E.R.E./I.E.E./I.P.O.E.E.—"Pick-up design" by S. Kelly at 19.00 at the Shrewsbury Arms Hotel, Market St.

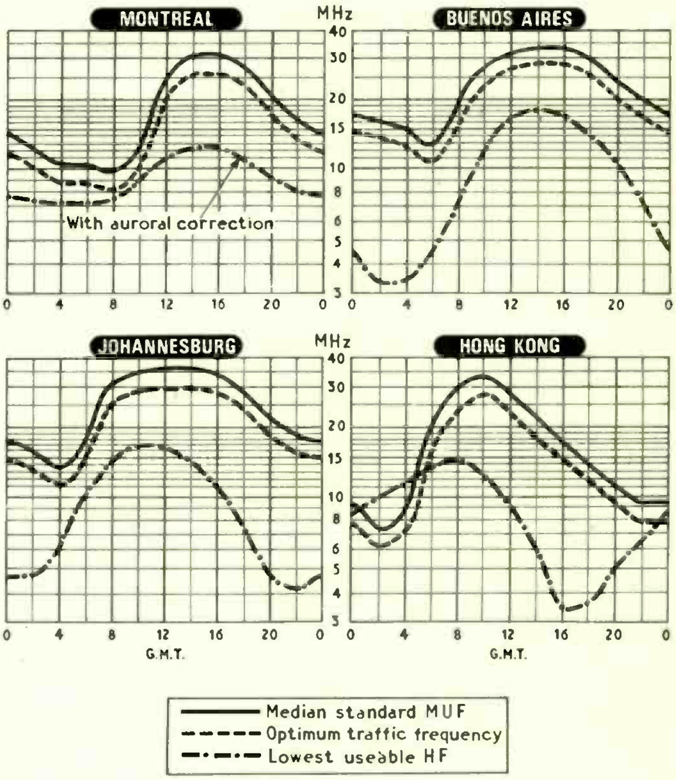
SHEFFIELD

10th. I.E.E.—Faraday lecture "People, communications and engineering" by J. H. H. Merriman at 10.30 and 14.30 (students) and 19.00 (public) at the City Hall.

STEVENAGE

11th. S.E.R.T.—"Basic design and construction techniques in guided weapon electronics" by C. H. Smith at 19.30 at the College of Further Education, Monkswood Way.

H.F. Predictions—February



Daytime MUFs continue to peak around 30 MHz. Duration and position in time of these peaks depends on longitudes of terminals relative to G.M.T., highest MUFs occurring when ionospheric reflection points are above the sun's horizon. On the South African route conditions between 20 and 30 MHz should be excellent and the fading which begins about two hours after sunset should be slight. Conditions for South America will be similar.

Far East routes will probably be unworkable from midnight till 06.00 G.M.T. due to the almost continuous change of MUF.

When auroral zone absorption is not evident North American LUFs will be about 3 MHz at 05.00 and 8 MHz at 15.00 G.M.T. All LUFs are calculated for reception in the U.K. of automatic telegraphy. Broadcast LUFs will be similar but several MHz higher for amateur transmissions.

Answers to "Test Your Knowledge"

Questions on page 93

1. *(a)* The depth of modulation is, by definition, the ratio of the peak value of the modulating signal to the peak value of the carrier.

2. *(c)* It is, of course, also this for the others.

3. *(c)* For any modulating signal which has a mean value of zero the ratio (sideband power/carrier power) is half the ratio (mean-square modulation voltage/mean-square carrier voltage). The square wave has the largest mean-square voltage.

4. *(c)* This follows from the formula given in ans. 3.

5. *(d)* For each sinusoidal component of the modulating signal the modulated-carrier spectrum contains a pair of side frequencies.

6. *(a)* This is true for any modulating signal which has zero mean value.

7. *(d)* Doubling the frequency of a square or saw-tooth wave doubles the frequency separation of its sinusoidal components.

8. *(a)* Over modulation occurs in all cases when the depth of modulation exceeds 100%.

9. *(c)* This is the upper side-frequency. The modulated carrier may be represented as $(V_c + V_m \sin \omega_m t) \sin \omega_c t$ and expansion of this expression shows that the upper side frequency has amplitude $V_m/2$.

10. *(d)* In effect we are assuming here that the ratio mean-square modulating voltage/mean-square carrier voltage is equal to the ratio peak modulating voltage/peak carrier voltage which is only true if the modulation is sinusoidal. However, with a sound signal the error is not generally very great.

11. *(b)* One carrier level represents peak white in the video signal, another represents the black level; all shades of grey in the picture give carrier levels between these two extremes. Hence the mean carrier level depends on the mean brightness.

12. *(c)* A change in the amplitude of the carrier will alter the depth of modulation, but this will not cause distortion so long as the carrier is not too small. A change in the carrier phase causes the depth of modulation to be reduced—a $\pi/2$ shift reduces it to zero—and introduces angle modulation (it also causes some second-harmonic distortion). This is not serious for a few degrees of phase shift, but if the carrier frequency is not exactly right the carrier phase relative to the sidebands will drift continuously causing large cyclic variations of modulation depth.

13. *(d)* The disadvantage discussed in ans. 12 does not apply if only one sideband is present, but the reintroduced carrier must be large, otherwise significant harmonic distortion occurs.

14. *(d)* Any non-linear component will cause "mixing" resulting in frequency components which can be filtered out to form an amplitude-modulated wave.

15. *(b)* Analysis shows that if the output is to follow the modulation while it is falling the product of C and R must be less than $\frac{T_m\sqrt{1-m^2}}{2\pi m}$ where Tm is the period of the highest modulating frequency component. It is apparent from this that if envelope detection is to be used the depth of modulation cannot be allowed to reach 100%.

Literature Received

ACTIVE DEVICES

A design for a practical ×8 single-stage step recovery diode frequency multiplier with a typical maximum output power of 75mW at 16GHz is given in a new 16-page application note (No. 928) from Hewlett-Packard Ltd, 224 Bath Road, Slough, Bucks. WW401

Small selenium rectifiers is the subject of a leaflet available from Cole Electronics Ltd, 7-15 Lansdowne Road, Croydon CR9 2HB WW402

A new series of thyristors (type CR31) is described in a leaflet from A.E.I. Semiconductors Ltd, Carholme Road, Lincoln, which also includes information on fuse selection and circuit design WW403

A new price list for 74N t.t.l. is available from Athena Semiconductor Marketing Co. Ltd, 140 High Street, Egham, Surrey WW404

The M-O Valve Company Ltd, Brook Green Works, Hammersmith, London W.6, have available four valve data sheets intended for inclusion in their loose leaf binder. The components described are types ACT00 CAT200 and RL16 and the RL2 series WW405

PASSIVE COMPONENTS

A leaflet we have received from Jack Davis (Relays) Ltd, 9-10 Mallow Street, London E.C.1, gives details of the range of Post Office 3000 and 600 relays available from them WW406

F. C. Lane Electronics Ltd, Albion Road, Horsham, Sussex, recently established as suppliers of connectors, have sent leaflets and price lists of the various makes handled (Smart & Brown, Ether, Transradio, Rendar and Plessey) WW407

A set of amended price lists is available for the Erie catalogue. They may be obtained from Erie Electronics Ltd, South Denes, Great Yarmouth, Norfolk WW408

The Electronic Components Bulletin from Siemens of Berlin numbered 5-69 is available from Cole Electronics Ltd, 7-15 Lansdowne Road, Croydon CR9 2HB WW409

We have received the following short-form catalogues from Standard Telephones and Cables Ltd, Edinburgh Way, Harlow, Essex:

Three-phase Miniature Precision Motors WW410
Miniature Precision d.c. Motors WW411

A wide range of electrical components is listed in the new catalogue called "Swift Service" from the D.T.V. Group Ltd, 126 Hamilton Road, West Norwood, London S.E.27 ....WW412

Catalogue No. P869E from Superior Electric Nederland N.V., of The Hague, Netherlands, describing a range of variable transformers, is available in the U.K. from Superior Electric, Aylmer House, Linkway, The High, Harlow, Essex WW413

A range of moulded trigger transformers intended for use in s.c.r. triggering applications is described in a leaflet from Sprague Electric (U.K.) Ltd. Sprague House, 159 High Street, Yiewsley, West Drayton, Middlesex WW414

Fans, relays, stepping motors, coaxial connectors, meters, resistors, potentiometers, switches, rectifiers and capacitors are some of the components covered in the stock catalogue Summer 1969 of Distronic Ltd, 23-31 King Street, Acton, London W.3 ....WW415

HARDWARE

A new series of eight data sheets is now available from A. & M. Fell (Manufacturing) Ltd, Denton Road, Newhaven, Sussex, outlining the characteristics of their latest range of tungsten carbide precision tools, including wire bonding capillaries, ultrasonic bonding wedges, unplugging punches and contact probe needles WW416

Instrument cases, card-frames and racks and cabinets in the Elmaset system are described in a catalogue from Radiatron Ltd, 76 Crown Road, Twickenham, Middlesex WW417

The range of i.c. accessories, including d.i.l. sockets, flat-pack holders, card connectors and i.c. patch cords is described in a short-form catalogue (91A) from Cambion Electronic Products Ltd, Cambion Works, Castleton, Nr. Sheffield WW418

Imhofs CDX and JX systems of equipment packaging are described in a 22-page catalogue available from Alfred Imhof Ltd, Ashley Works, Cowley Mill Road, Uxbridge, Middlesex WW419

The techniques of assembling plastic or plastic and metal parts using ultrasonic equipment are described in a brochure from Dawe Instruments Ltd. Concord Road, Western Avenue, London W.3 WW420

Properties and suggested applications for more than seventy grades of Testolite (industrial laminates) are described in a revised 20 page booklet available from the International General Electric Company of New York Ltd, Lincoln House, 296-302 High Holborn, London W.C.1 WW421

EQUIPMENT

Aim Electronics Ltd, The River Mill, St. Ives, Huntingdon, have sent us the following literature.

Catalogue of Test Equipment WW422
Guide to Modules and Systems WW423
"Programming Modules" WW424

An automatic l.f. spectrum analyser is described in a leaflet from Fenlow Electronics Ltd, Jessamy Road, Weybridge, Surrey WW425

Two airborne h.f./s.s.b. transceivers are discussed in literature received from Avco Electronics Division, 2630 Glendale-Milford Road, Cincinnati, Ohio 45241, U.S.A. WW426

Literature labelled Dynaform 7000 describes electronic tachometers and is available from the Dynalco Corporation, 4107 N.E. 6th Avenue, Fort Lauderdale, Florida 33308, U.S.A. WW427

A high-stability (2 μV/°C maximum drift) battery-powered operational amplifier that draws only (1 μW of quiescent power is described in a leaflet available from Analog Devices, Inc. 221 Fifth Street, Cambridge, Mass. 02142, U.S.A. WW428

GENERAL INFORMATION

We hear from Mullard that stocks of their 1969 Pocket Data Book are now exhausted and that they regret no further orders can be accepted.

Metron, the Pergamon reviews and abstracts journal, has produced a supplement on photon detectors which surveys literature on detectors for the ultra-violet visible and infra-red wavelengths (0.01 to 1000 μm). The price of the supplement is £4 from the Pergamon Press Ltd, Headington Hill Hall, Oxford.

Papers read at the Electronics Symposium, which was held by Ferranti at the Royal Garden Hotel, London, in November, are now available from Ferranti Ltd, Gem Mill, Chadderton, Oldham, Lancs WW429

Those who require an introduction to logic circuits cannot go far wrong with the book that has just been published by Marconi Instruments Ltd, St. Albans, Herts. The book follows the programmed method of instruction and costs £2.

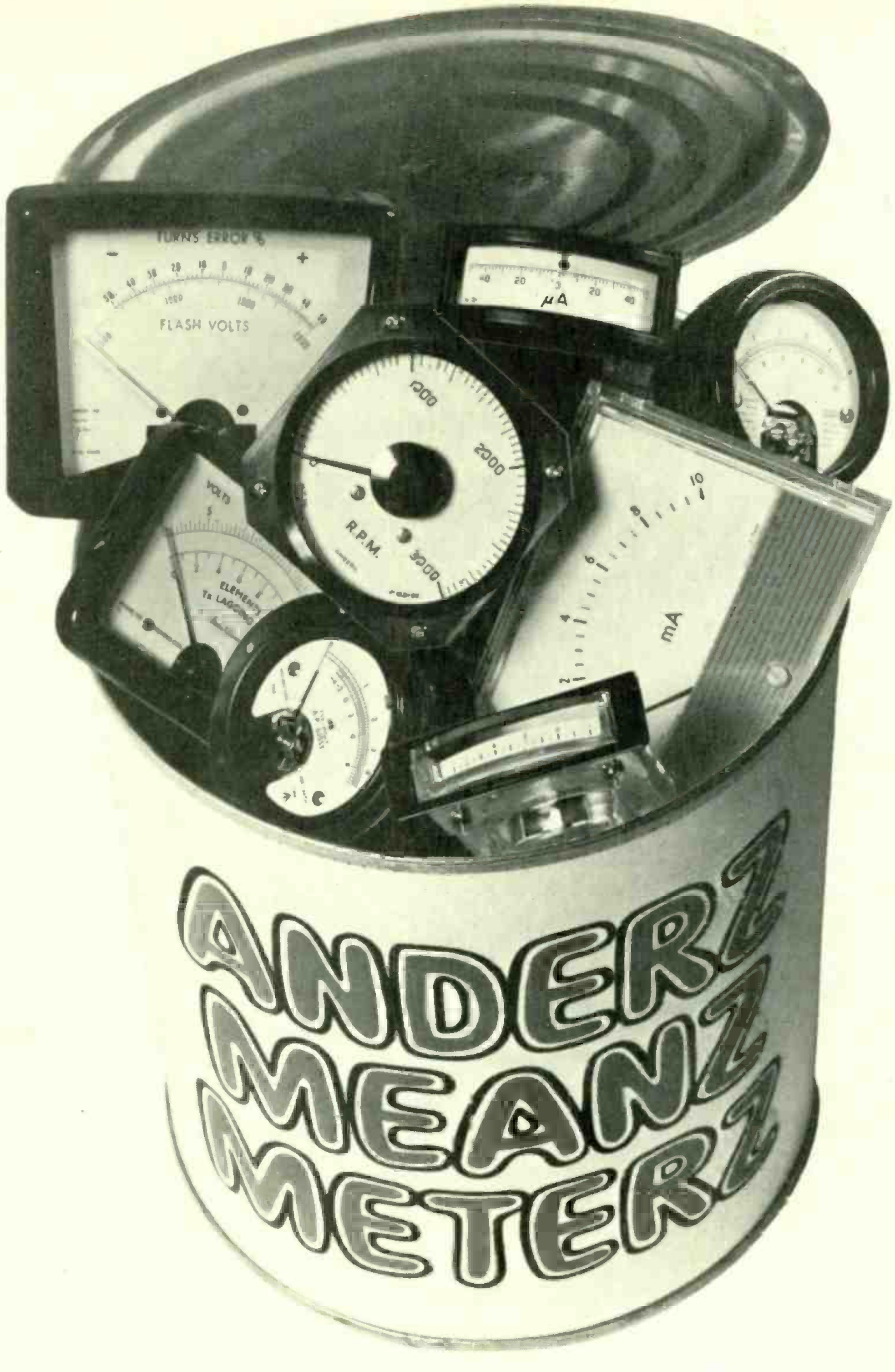
Readers interested in receiving overseas radio transmissions may like to see a specimen copy of "International Short Wave Radio" the duplicated bulletin published by the International Short Wave Club, 100 Adams Gardens Estate, London S.E.16.

The Gauge and Tool Makers' Association has published the tenth edition of its Members' Handbook and Buyers' Guide Index. This may be obtained from The Gauge and Tool Makers' Association, Standbrook House, 2-5 Old Bond Street, London W1X 4LS WW430

A leaflet is available from Mullard Ltd, Mullard House, Torrington Place, London W.C.1, which lists all the publications available from their Educational Service.

Hoover Ltd, Perivale, Greenford, Middlesex, have published a booklet called "Decimal Money for the Office Worker" WW431

Two new parts of BS 3499 "School music equipment" are now available: Part 9C Electronic organs with pedal boards (8s) and Part 8B Magnetic tape recording and reproducing equipment (6s). The British Standards Institution, Sales Branch, 101/113 Pentonville Road, London N.1.



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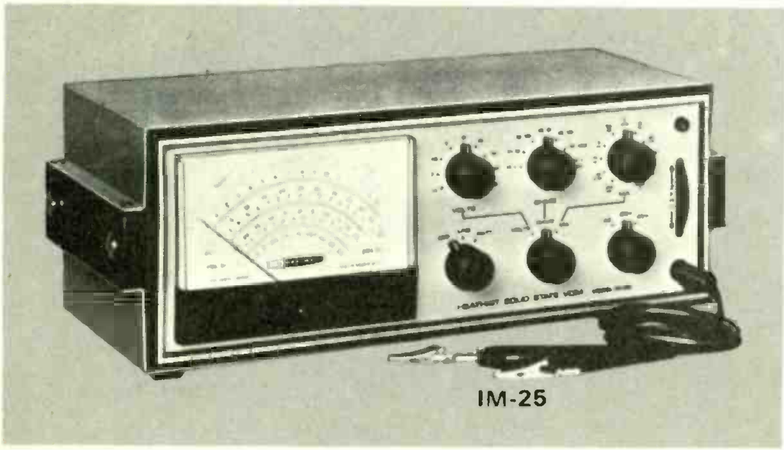

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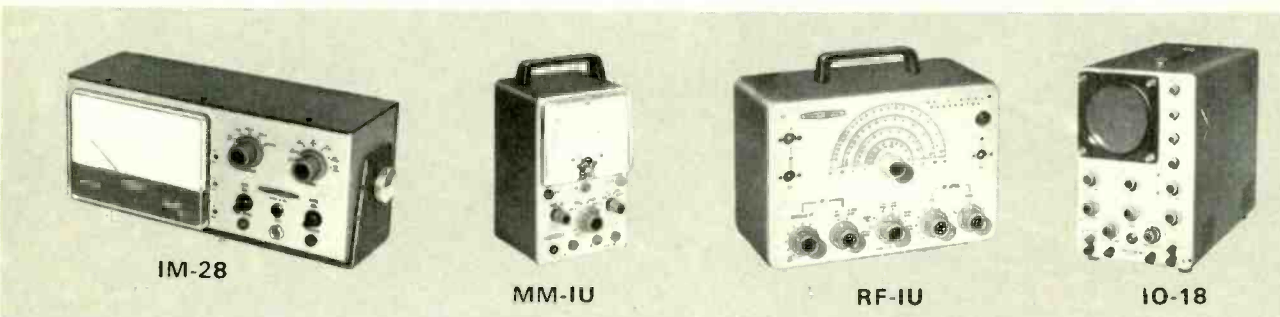
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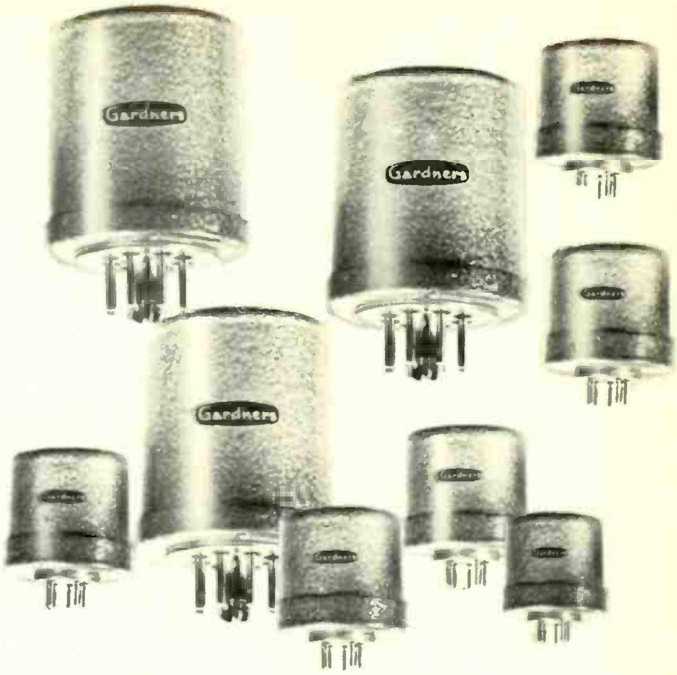

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MU.7522	3·75/15*	1-3, 2-4	100K.	6-8	82:1/164:1	Low Z. Mic/Grid
MU.7523	75/300*	1-3, 2-4	600 (C.T.)	6-7-8	1·41:1/2·82:1	Line/Line
MU.7524	150/600*	1-3, 2-4	600 (C.T.)	6-7-8	1:1/2:1	Mixing: Bal./Unbal.
MU.7525	600 (C.T.)	6-7-8	300/1·2K*	1-3, 2-4	1+1:1·41 (C.T.)	Mixing: Hybrid‡
MU.7526	600 (C.T.)	6-7-8	2·5k/10k.*	1-3, 2-4	2·04:1/4·08:1	Line/Grid
MU.7527	150/600*	1-3, 2-4	100K.	6-8	13:1/26:1	Line/Grid
MU.7528	7·5/30*	1-3, 2-4	600 (C.T.)	6-7-8	4·47:1/8·94:1	Low Z. Mic./Line
MU.7529	50/200*	1-3, 2-4	600 (C.T.)	6-7-8	1·73:1/3·46:1	Mic. or Line/Line
MU.7530	10K. (C.T.)	6-7-8	10K.	1-4	1 (C.T.):1	600 Line Bridging
MU.7532	7·5/30*	1-3, 2-4	100K.	6-8	58:1/116:1	Low Z. Mic./Grid
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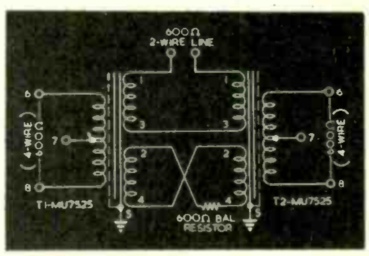

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The newest additions to the Heathkit range are two "stereo compacts". The AD-27, pictured left includes a turntable unit with a Shure magnetic cartridge, an FM stereo tuner and a 30 watt stereo amplifier. The whole is built into an attractive compact teak or walnut veneered cabinet – all for a kit price of only £82! The AD-17 compact is similar but does not have the FM radio facility and uses a simpler but still attractive cabinet. This kit only costs £54.

STEREO TUNER/AMPLIFIER, AR-14

STEREO TUNER AMPLIFIERS

If you need a Tuner-Amplifier, we can offer models to suit any pocket. Pictured on the left is the very popular Heathkit AR-14. This is a solid-state stereo Tuner-Amplifier with a sensitive FM tuner, a built-in stereo decoder and a 30 watt stereo amplifier (15 watts I.H.F.M. per channel). It is wonderful value at a kit price of £54.

STEREO TUNER TFM-IS

STEREO AMPLIFIER, TSA-12

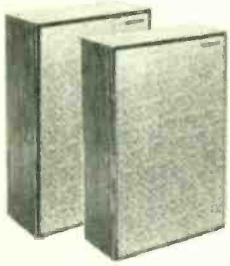
STEREO 'SEPARATES'

If your preference is "separates", or perhaps you want just a stereo amplifier without a tuner, again Heathkit offers a selection. Typical is the TSA-12 stereo amplifier, illustrated. This is a solid state stereo amplifier (15 watts I.H.F.M. per channel) at a kit price of only £32 16 0. We have radio tuners to match either for FM reception only, or for FM and Long and Medium wave. The Stereo Tuner, model TFM-IS costs only £28 14 0 in kit form.

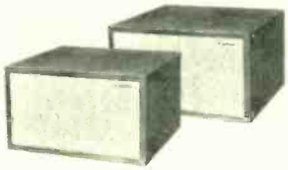
LOUDSPEAKER SYSTEMS

All the units described above can be used with any good hi-fi loudspeakers. To cover this need, the Heathkit range includes several hi-fi loudspeaker kits. The Berkeley kit features a 12 in. bass loudspeaker and a 4 in. high-frequency unit, a ready finished teak or walnut veneered cabinet, and the kit price is only £21 4 0. The 'Avon' mini kit is only £13 8 0.

A WIDE CHOICE OF SPEAKER SYSTEMS



BERKELEY



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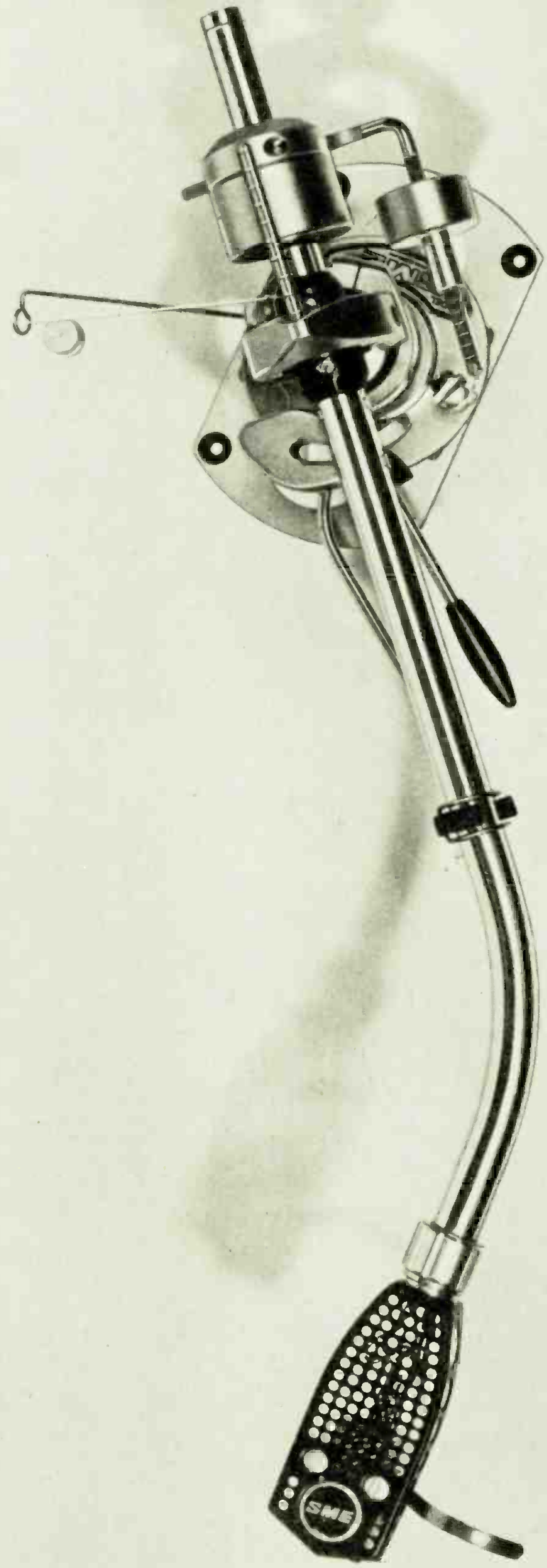

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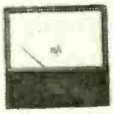
500µA	62/6	5 amp. D.C.	59/6
1mA	59/6	300V. A.C.	59/6
20V. D.C.	59/6		

BAKELITE PANEL METERS

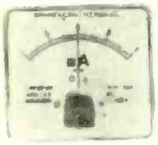
TYPE S-80
80 mm.
square fronts



50µA	62/6	50V. D.C.	49/6
100µA	59/6	1 amp. D.C.	49/6
500µA	52/6	5 amp. D.C.	49/6
1mA	49/6	300V. A.C.	52/6
20V. D.C.	49/6		

"SEW" CLEAR PLASTIC METERS

Type MR.85P. 4¾in. × 4¾in. fronts.



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100µA	62/-	100mA	52/-
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500µA	55/-	5 amp.	52/-
500-0-500µA	52/-	15 amp.	52/-
1mA	52/-	30 amp.	52/-
1-0-1mA	52/-	20V. D.C.	52/-
5mA	52/-	50V. D.C.	52/-
		150V. D.C.	52/-
		300V. D.C.	52/-
		15V. A.C.	52/-
		300V. A.C.	52/-
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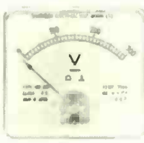
		20 amp. A.C.*	52/-
		30 amp. A.C.*	52/-

Type MR.38P. 1 21/32in. square fronts.



50µA	40/-	150mA	27/6
50-0-50µA	37/6	200mA	27/6
100µA	37/6	300mA	27/6
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200µA	35/-	750mA	27/6
500µA	30/-	1 amp.	27/6
500-0-500µA	27/6	2 amp.	27/6
1mA	27/6	5 amp.	27/6
1-0-1mA	27/6	10 amp.	27/6
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
		750V. D.C.	27/6
		15V. A.C.	27/6
		50V. A.C.	27/6
		150V. A.C.	27/6
		300V. A.C.	27/6
		500V. A.C.	27/6
		8 meter 1mA	32/-
		VU meter	42/-

Type MR.52P. 2¼in. square fronts.

50µA	62/-	10V. D.C.	40/-
50-0-50µA	52/-	20V. D.C.	40/-
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/-
5 amp.	40/-	30 amp. A.C.*	40/-

Type MR.45P. 2in. square fronts.

50µA	45/-	5 amp.	30/-
50-0-50µA	42/-	10V. D.C.	30/-
100µA	42/-	20V. D.C.	30/-
100-0-100µA	37/6	50V. D.C.	30/-
200µA	37/6	300V. D.C.	30/-
500µA	32/-	15V. A.C.	30/-
500-0-500µA	30/-	300V. A.C.	30/-
1mA	30/-	8 meter 1mA	37/6
5mA	30/-	VU meter	45/-
10mA	30/-	1 amp. A.C.*	30/-
50mA	30/-	5 amp. A.C.*	30/-
100mA	30/-	10 amp. A.C.*	30/-
500mA	30/-	20 amp. A.C.*	30/-
1 amp.	30/-	30 amp. A.C.*	30/-

Type MR.65P. 3¼in. × 3¼in. fronts.

50µA	67/6	20V. D.C.	42/-
50-0-50µA	55/-	50V. D.C.	42/-
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100-0-100µA	52/-	300V. D.C.	42/-
500µA	47/6	15V. A.C.	42/-
500-0-500µA	42/-	50V. A.C.	42/-
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5mA	42/-	300V. A.C.	42/-
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100mA	42/-	VU meter	67/6
500mA	42/-	50mA A.C.*	42/-
1 amp.	42/-	100mA A.C.*	42/-
5 amp.	42/-	200mA A.C.*	42/-
10 amp.	42/-	500mA A.C.*	42/-
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20 amp.	42/-	5 amp. A.C.*	42/-
30 amp.	42/-	10 amp. A.C.*	42/-
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10V. D.C.	42/-	30 amp. A.C.*	42/-

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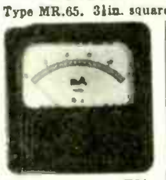
Type MR.65. 3¼in. square fronts.



25µA	70/-	500mA	35/-
50µA	47/6	1 amp.	35/-
50-0-50µA	45/-	5 amp.	35/-
100µA	45/-	15 amp.	35/-
100-0-100µA	45/-	30 amp.	35/-
500µA	42/-	50 amp.	35/-
1mA	35/-	5V. D.C.	35/-
1-0-1mA	35/-	10V. D.C.	35/-
5mA	35/-	20V. D.C.	35/-
10mA	35/-	50V. D.C.	35/-
50mA	35/-	150V. D.C.	35/-
100mA	35/-	300V. D.C.	35/-
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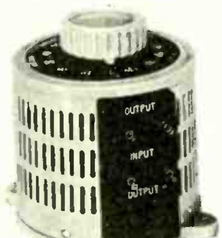

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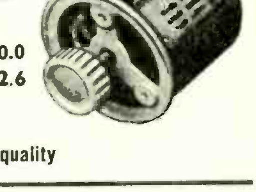

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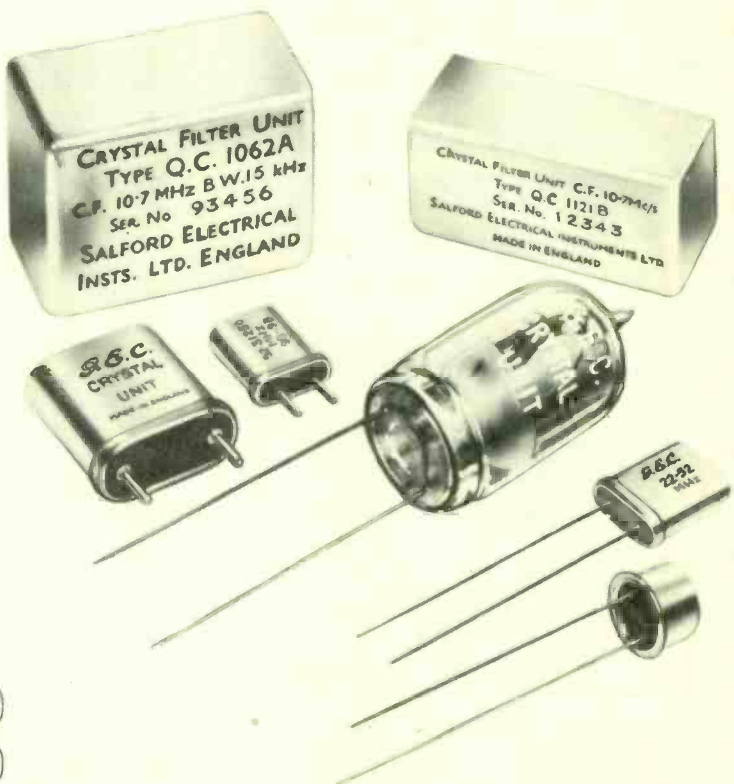

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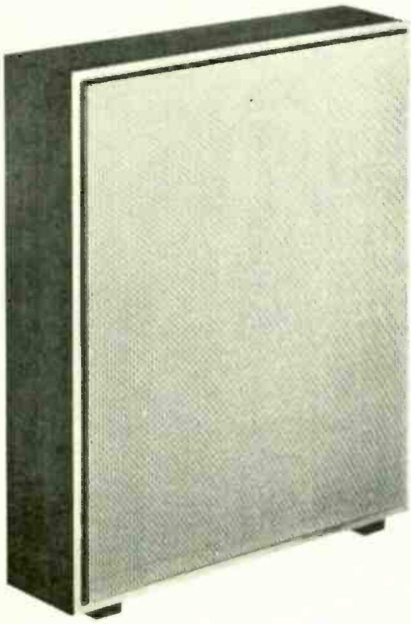
SPEAKER SYSTEMS



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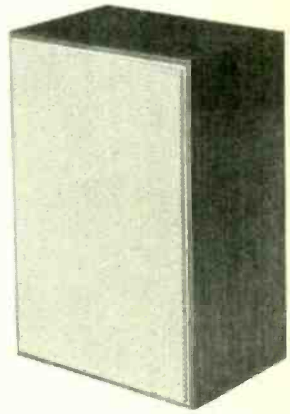
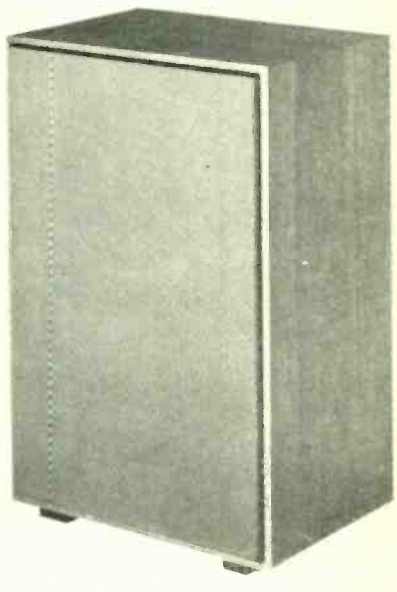


LC93

A 19″ x 12½″ x 8½″ completely enclosed acoustically loaded cabinet housing a 9″ graded melamine paper cone with siliconized cambric suspension giving a frequency response of 60Hz to 20KHz.

LC94

A 29½″ x 23¾″ x 6⅛″ acoustic Labyrinth enclosure fitted with acoustic resistance in the pipe, using the same highly efficient 9″ speaker unit used in the LC 93. Frequency response 45Hz to 20KHz.



LC95

The LC95 loudspeaker system is an acoustically loaded Bass Reflex cabinet, measuring 31½″ x 20¾″ x 13½″, fitted with two loudspeakers and a crossover network. The bass loudspeaker being used is a newly developed 12″ unit having a Melamine treated paper cone with a cambric surround. The middle and high frequency unit is a new 8″ loudspeaker having a Melamine treated paper ribbed cone and surround.

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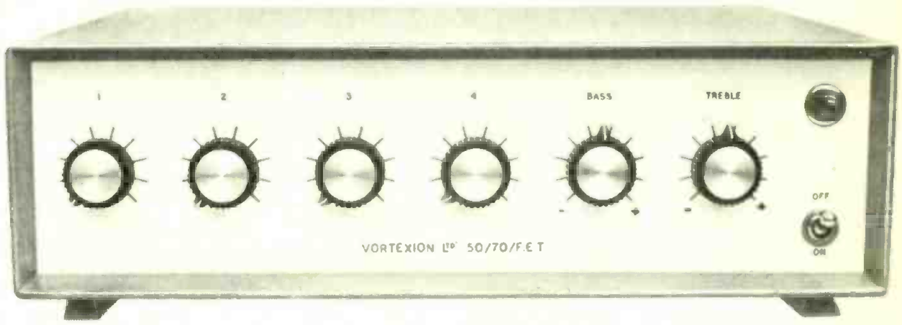

Size 14″ × 11½″ x 4½″ Weight 20lb.
100μV on 30/60 ohm mic. input.
100mV to 100 volts on gram/auxiliary input 100KΩ.

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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.

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.

20/30 WATT MIXER AMPLIFIER. High fidelity all silicon model with F.E.T. input stages to reduce intermodulation distortion to a fraction of normal transistor input circuits. The response is level 20 to 20,000 cps within 2 db and over 30 times damping factor. At 20 watts output there is less than 0.2% intermodulation even over the microphone stage at full gain with the treble and bass controls set level. Standard model 1-low mic. balanced input and Hi Z gram.

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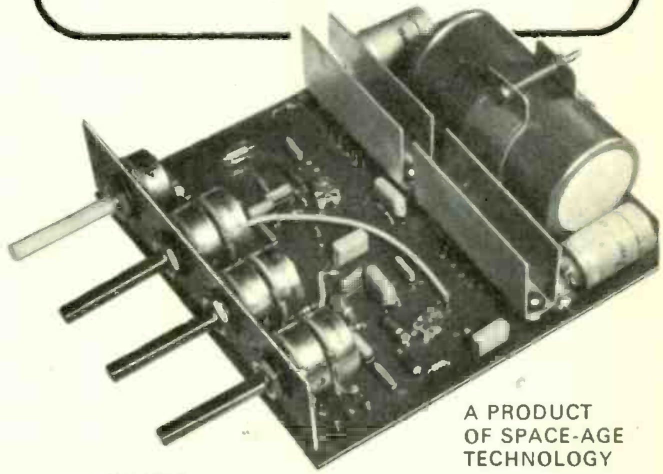
Integrated Circuit Stereo Amplifier in one package

ALL FOR
£8. 19. 6d.



A PRODUCT OF SPACE-AGE TECHNOLOGY

COMPLETE:
Integrated Circuit Stereo Amplifier System in one package—incorporating tone, balance and volume control unit, bridge rectifier and smoothing circuit. All you need now is a deck, transformer and speakers!

SMALLER:
Micro-electronic circuitry (the Plessey SL403 i.c.) means the Britmac Integrated Circuit System is smaller and more compact than ever—yet still capable of delivering 7 Wrms.

CHEAPER:
Nothing can touch the Britmac Integrated Circuit System at the price — just £8. 19. 6d complete. How? Why? Because it comes direct from manufacturer to user — no middleman's profit!

SPECIFICATION:
Power Input 14.5 V.AC
Speaker Impedance 8 Ohms/channel
Total Output — Typical 7Wrms
Distortion—0.4% Response—20Hz to 20KHz
Bass -12 to +18dB @ 20Hz
Treble -12 to +14dB @ 10KHz
I/P Sensitivity 250mV
Recommended Cartridge 9TAHC etc

By Appointment To Her Majesty Queen Elizabeth II Dorman Smith Britmac Ltd Suppliers of Electrical Accessories

Direct to you from
BRITMAC ELECTRONICS
Send the coupon today for the only COMPLETE Integrated Circuit Stereo Amplifier on the market at £8. 19. 6d — direct to you at manufacturer's price! A high quality transformer is available for £1. 5. 0d incl. P & P.

To: DORMAN SMITH BRITMAC LTD. PRESTON PR2 2DQ

NAME ....

ADDRESS ....

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I enclose cheque/postal order/money order for £ d. made payable to Dorman Smith Britmac Ltd. WW/1/70

WW—027 FOR FURTHER DETAILS

There are a couple of things you should know about the Welbrook All Silicon Stereo Amplifier

DISTORTION

0.1% at all output levels

PRICE

£42. 0. 0d.

A new and unique method of equalising impedances in the output stage enables only Welbrook to offer such true high fidelity reproduction at such low cost.

This technical breakthrough brings you the Welbrook W20 Stereo Amplifier, with no distortion rise at any level, for only £42. 0. 0d. This is a truly remarkable bargain among high quality stereo amplifiers, using Class B operation.

Performance:
Power Output:
24 watts R.M.S. (12 watts per channel) into 4 ohms load.
20 watts R.M.S. (10 watts per channel) into 8 ohms load.
14 watts R.M.S. (7 watts per channel) into 15 ohms load.
Total Harmonic Distortion:
Typically 0.1% for 10 watts per channel into 8 ohms load at 1 kHz with no increase at low levels.
Hum and Noise:
With volume control at minimum-80 dB. With volume control at maximum-55 dB.
Frequency Response:
-1 dB at 30 Hz and 15 kHz.
Inputs: Pickup:
R.I.A.A. characteristic, sensitivity adjustable up to 3 mV to suit crystal, ceramic or magnetic cartridges.
Tuner:
Flat characteristic-sensitivity 100 mV-input impedance 100 k ohms.
Tape:
Flat characteristic-sensitivity 100 mV-input impedance 100 k ohms.
Outputs:
Loudspeaker outputs to suit 4, 8 and 15 ohms. Tape output for recording-200 mV for rated input sensitivities-minimum external impedance 10 k ohms.
Tone Controls: Bass:
Ganged control giving ± 14 dB at 30 Hz
Treble:
Ganged control giving ± 14 dB at 15 kHz
Balance Control:
Facility to reduce output from either channel continuously from maximum output to zero.
Dimensions:
14¾" wide x 9" deep x 4" high (cabinet)
Price:
Recommended retail price; £42. 0. 0d. including cabinet.

For full details of the Welbrook Stereo Amplifier post the coupon to:

WELBROOK ENGINEERING & ELECTRONICS LIMITED,
BROOKS STREET, STOCKPORT, CHESHIRE, SK1 3HT

To: Welbrook Engineering & Electronics Limited;
Please send me full details of the Welbrook Stereo Amplifier.

NAME ....

ADDRESS ....

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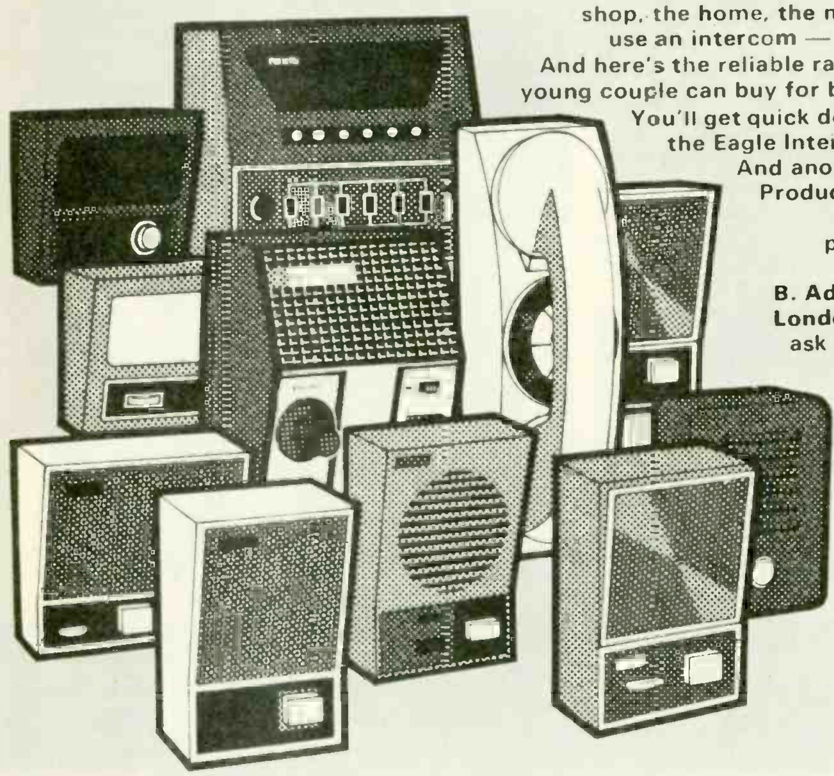
.... (WW2)

WW—029 FOR FURTHER DETAILS

EAGLE INTERCOMS



There's a vast market here — in the office, the factory, the workshop, the home, the nursery. Almost everyone in the country could use an intercom — if the trade would just push them a little bit! And here's the reliable range you can push! From an inexpensive set a young couple can buy for baby-listening to a full-scale 12-station model You'll get quick delivery, too — and you'll need it, if you display the Eagle Intercoms with their powerful colour showcards! And another attractive thing about the range of Eagle Products is the rate at which fast-selling new items are added! See our new catalogue, which proves the point! Send the coupon to the Sole Distributors of Eagle Products — **B. Adler and Sons (Radio) Limited, Coptic Street, London, W.C.1** or quicker still, dial 01-636 9606, ask for Carol Hill she'll send you one today!

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the new brenell...

MODEL ST STEREO

Probably the most important new recorder of the year!

The new ST400/200 recorders are different from all previous Brenells. All transistorized electronics; shelf-mounting cabinet; simplified controls.

Sound quality is even better than ever—as good as you can hear. Three-motor deck performance and reliability; quality components throughout. All usual facilities are available.

ST400/200 recorders are designed to give you exactly what you expect from a Brenell today.

Only the price is less than you may expect . . . £145 recommended. You pay no import duties . . . no high selling costs . . . only for a top-quality recorder, well made. It's a fine formula!

- Mono or stereo operation
- Choice of 2 or 4-track models
- 3 outer-rotor motors
- 3 tape speeds
- 2 recording level meters
- Full input/output and control facilities

A range of Brenell mono and stereo recorders is available, together with Brenell deck and tape-link.

brenell

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GD 730

WW—034 FOR FURTHER DETAILS

Plessey CT80 at the BBC

The Plessey CT80 Cartridge Recorders shown here are installed in the World Service Continuity Studio of the B.B.C. External Services Studio Centre at Bush House, London. From this centre broadcasts originate to all English speaking regions of the world including South-East Asia and Australia. The studios are in operation twenty-four hours a day and the CT80 units are used for both programme material and standby announcements.

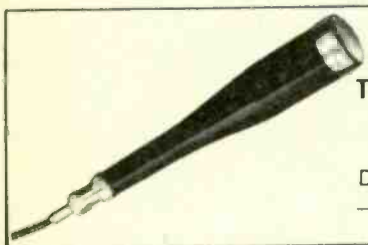
Having met the specification requirements of the B.B.C. the CT80 Recorder is now demonstrating its reliability in operational service.

PLESSEY
Electronics

Sales and Service — Rola Recording Products Department — Garrard Engineering Limited Newcastle Street Swindon Wiltshire Telephone Swindon 5381 Telex 44271 or the manufacturer Plessey Electronics Pty Limited Equipment Unit 91 Murphy Street Richmond Australia 3121 Telex 30383 Cables ROLA Melbourne

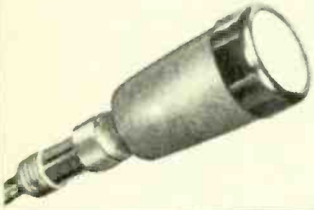
Microphones

for every purpose



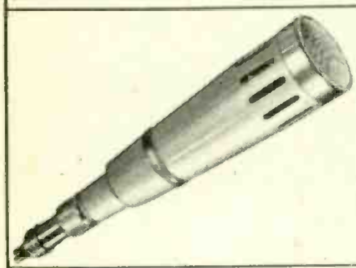
The DP4

Designed for general use —P.A., tape recording etc.



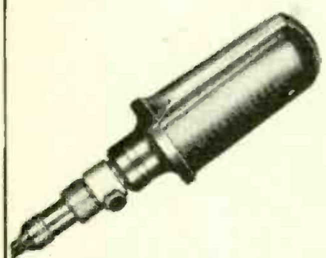
The DP6

Small in size, large in performance. As a lavalier type and for panel mounting on control units etc.



The GC/1 Cardioid

For stage and church work, P.A. use, lecture halls etc., where acoustic feedback is a serious problem.



The GR/1 and GR/2 Ribbon

Ideal for studio and similar uses, when a high standard of fidelity is essential. Easily replaceable ribbon assembly.

Other models and a full range of stands, reflectors, windshields and accessories available

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LITESOLD—the best-selling seven-model range of top-quality 'conventional' irons.

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WW—036 FOR FURTHER DETAILS

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Redcap Capacitors are ready for any assignment. As part of the Monobloc Ceramicon range, they can pack 10 to 100 times the capacitance/volume ratio of conventional components. They tolerate temperatures from −50°C to +125°C. They cover a broad range of values from 10pF to 470,000 pF (up to 2,200 pF in high stability NPO, with the remainder of the range in Hi-K Dielectric), at voltage ratings of 50 or 100 Volts d.c.

Redcaps are now made in Britain. The technique is the fusion of Thin Ceramic Films and Platinum Electrodes. The result is an inherently stable dielectric, and volumetric efficiencies as high as 380 µF per cubic inch.

Finished in Jetseal Phenolic Insulating coating, with weldable solder-coated copperclad steel leads, Redcaps are equipped to perform their tasks with complete reliability.

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ERIE MONOLITHIC CAPACITORS

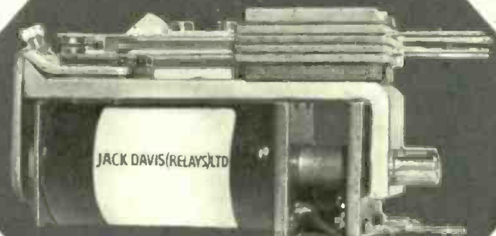
P2

RELAYS

MERCURY SWITCH 3000 TYPE

This compact Relay based on the P.O. 3000 Type is designed to switch heavy currents A.C. or D.C. even in highly inductive circuits. The enclosed contacts ensure safe operation where inflammable vapours may be present. Can also be supplied for A.C. operation.

RELAYS



A.C. OPERATED 3000 TYPE

This Relay is fitted with a full wave silicon rectifier which gives silent and chatter free operation on A.C. voltages. Dimensions and mounting are as the well proved D.C. operated P.O. 3000 Type. Can also be fitted with Mercury Switches.

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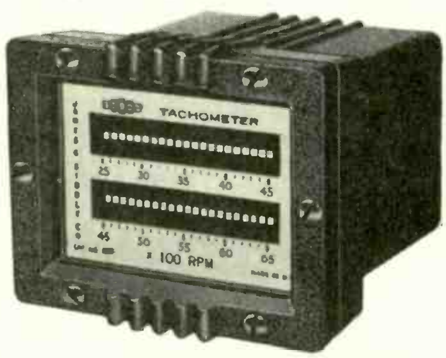
Accurate and direct measurement of speed without coupling to moving parts



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Resonant Reed TACHOMETERS

for hand use or permanent mounting.

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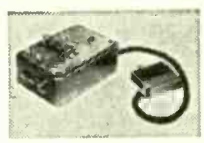
Codes: Int. No. 2 Mercury/Pegasus, Elliot 803, Binery and special purpose Codes.

2-5-6-7-8- TRACK AND MULTIWIRE EQUIPMENT

TELEGRAPH AUTOMATION AND COMPUTER PERIPHERAL ACCESSORIES DATEL MODEM TERMINALS, TELEPRINTER SWITCHBOARDS



Picture Telegraph, Desk-Fax. Morse Equipment; Pen Recorders; Switchboards; Converters and Stabilised Rectifiers; Tape Holders, Pullers and Fast winders; Governed, Sychronous and Phonic Motors; Teleprinter Tables and Cabinets; Silence Covers; Distortion and Relay Testers; Send/Receive Low and High Pass filters; Teleprinter, Morse, Teledeltos Paper, Tape and Ribbons; Polarised and specialised relays and Bases; Terminals V.F. and F.M. Equipment; Telephone Carriers and Repeaters; Diversity; Frequency Shift, Keying Equipment; Line Transformers and Noise Suppressors; Racks and Consoles; Plugs, Sockets, Key, Push, Miniature and other Switches; Cords, Wires, Cables and Switchboard Accessories; Teleprinter Tools; Stroboscopes and Electronic Forks; Cold Cathode Matrics; Test Equipment; Miscellaneous Accessories, Teleprinter and Teletype Spares.

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Cables: RAHNO TRING TELEX 82362

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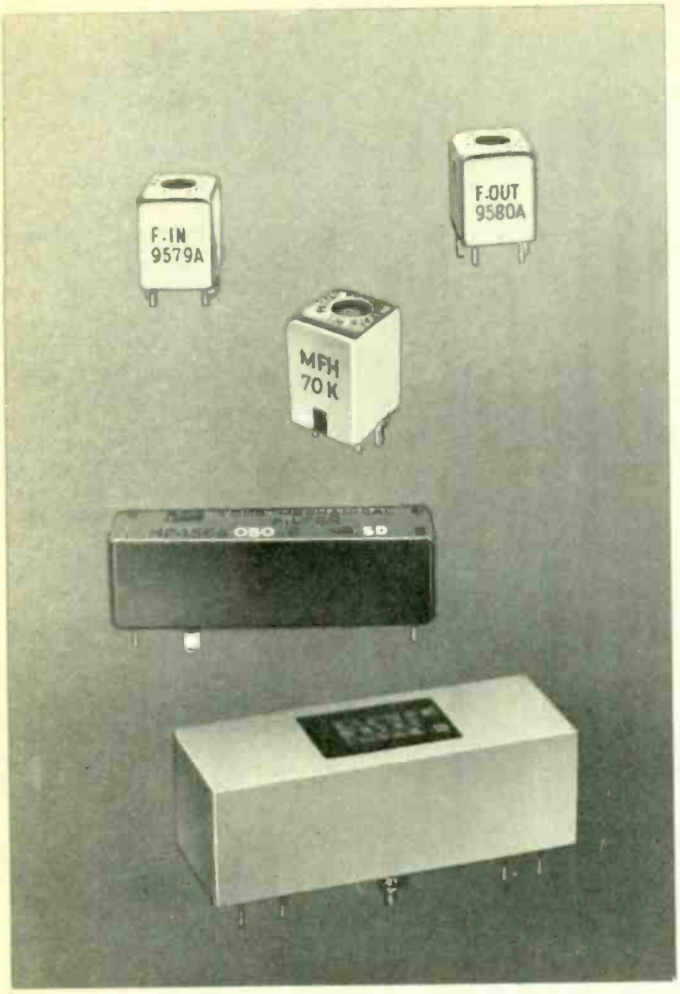

Mechanical and Crystal filters

Filters, Mechanical and Crystal for communications and broadcast applications are available in a wide series of centre frequencies and passbands.

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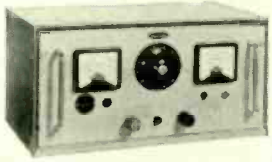
Valradio

Now available with 3 OUTPUTS making these units more versatile for:

DEVELOPMENT PRODUCTION TESTING SERVICING



Type VRU/30/20*—£131.5.0

* **OUTPUT 1, 0-30V 20A DC.**
Will provide accumulator performance from AC mains for production testing and servicing of battery operated equipment. Output continuously variable 0-30V at up to 20A.

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For the testing and development of low voltage AC equipment.

* **OUTPUT 3, 0-240V 4A.**
Continuously variable AC mains supply voltage for testing equipment at various voltages.

Send for publication WPU5.

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A SOLDER'S BEST FRIEND IS HIS GUN

From the Burgess All-electric Workshop: a light, balanced solder gun with a range of screw-in tips. The tips—and only the tips—heat up in 7 short seconds. Anti-thermal casing keeps the rest of the gun cool. Note the slim barrel—it reaches right down into confined spaces. There are spike-like extension barrels for real 'in-deep' work. A prefocused lamp pinpoints work detail. Fail-safe soldering even for delicate work! The price of this tough, modern instrument? Just £4 12 6 complete with two tips, a 6" extension barrel, a double-ended probe and solder. **FREE 24-PAGE CATALOGUE!** For details of the Burgess instant heat solder gun, plus other equipment in the Burgess All-Electric Workshop, write for a free copy of our information-packed catalogue.

BURGESS take the work out of your workshop.

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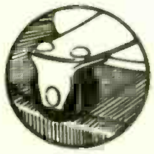
VARIABLE TRANSFORMERS



- ★ Output 0-260V
- ★ Input 230V 50/60CPS
- ★ Shrouded for Bench or Panel mounting

Inset shows latest pattern Brush gear ensuring smooth continuous adjustment.

£5.10.0 1 amp

2.5 amp £6.15.0	8 amp £14.10.0	12 amp £21.0.0
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CONSTANT VOLTAGE TRANSFORMER.

Maintain spot-on test gear readings with Automatic Mains stabilizer.

Specification:

- ★ Output 240V
- ★ Accuracy ± 1%
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- ★ Capacity 250 watts
- ★ Corrected wave

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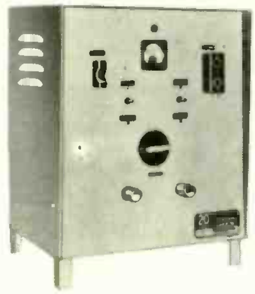

- ★ Input 240V

Output 20 amps at 24V and 12V fully adjustable

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- ★ Weight 50 lbs.

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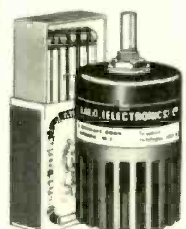

- ★ Output 25-240V
- ★ Input 240V 50 CPS
- ★ 5 amp & 10 amp models
- ★ Completely sealed

5 amp model **£8.7.6**

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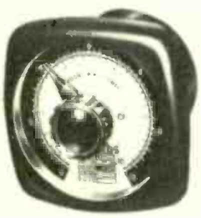

- ★ SYNCHRONOUS MOTOR & CLUTCH
- ★ 10 MILLION OPERATIONS
- ★ Instantaneous & Timed out 3 AMP contacts
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- ★ Dial ranges 0-10 secs up to 0-28 hrs. May also be used as impulse start

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Matchbox size frontal area

Automatic re-set

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TEMPERATURE CONTROLLER TYPE THP

- ★ THERMISTOR OPERATED
- ★ OCTAL BASE PLUG IN
- ★ COMPACT

Temperature ranges up to 280°c

Output contacts 4 amp

Repeat Accuracy 3% full scale

Complete with Thermistor

Approximately

£21 dependent on quantity.

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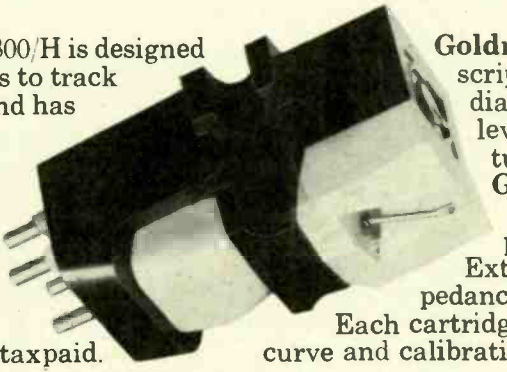
Goldring 800 magnetic cartridges track unerringly. Because that's the way we make them. They're designed to translate even the most delicate information stored in the groove back into an identical electrical signal. We call it the sound of true transduction.

Hear it for yourself. You'll know you're on the right track.



Goldring 800/H... the 800/H is designed for inexpensive changers to track between 2½—3½ grams and has a high output of at least 8mV. **£10.13.6** tax paid.

Goldring 800
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WW—046 FOR FURTHER DETAILS

Come to the

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This is the fourth practical conference on microelectronics in equipment to be sponsored by the journals "Microelectronics" and "Electronic Equipment News". The main Conference Theme will be **"The Interface between the Integrated Circuit Manufacturers and their Customers".** Emphasis will be on how to make use of ICs once the customer has them in his hand. The growing interest in, and the increased use of integrated circuits in all sections of industry are factors which make this a subject of considerable importance to all manufacturers and users.

The Conference will consist of five "workshop sessions" at which carefully selected speakers will give presentations for open discussion amongst all delegates. There will be accompanying displays of appropriate equipment.

Conference Programmes with full details and application forms are available free of charge from the Organizers.

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Please send me without obligation .... copies of the programme of the "Use of Microelectronics" Conference.

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Company .... Tel. No. ....

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81E

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Saturable Reactors
Voltmobiles—voltage regulators
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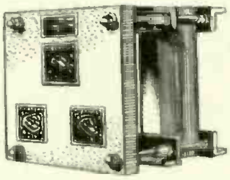
Air cooled power transformers from 0.5 to 300kVA at voltages up to 2kV. 1 or 3 phase, double or auto wound, step-up or step-down. We have manufactured transformers to over 5,000 different designs for many applications and the experience which has been accumulated from these designs is built into every Harmsworth, Townley transformer



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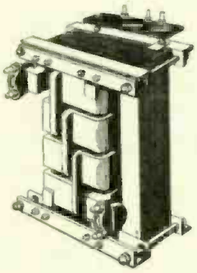
The most robust and useful control device for loads such as furnaces, ovens, bar heating and high temperature research. Our Voltmobiles are in use in their thousands to control transformers and rectifier sets or they can be used directly between supply and load. 64 step on load switching. Voltmobiles 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

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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
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Rectifiers

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2 Hare Hill, Todmorden, Lancs.
Telephone Todmorden 2601 Extension 22

WW—049 FOR FURTHER DETAILS

The flattest sweeper news for years!

With a detected system flatness within ± 0.05 dB over the full video range, and a battery of features to aid precise measurement, the new **TF 2361** provides a standard of accuracy not usually associated with general purpose sweep generators.

This powerful new instrument is designed for use with video or v.h.f. sweeper plug-ins to form accurate and comprehensive measurement systems – particularly in the TV field.

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The TF 2361 main unit, which contains common power supplies and circuitry for the plug-ins, features readily removable chassis units for straightforward servicing. Altogether an extremely comprehensive and well specified sweep generator.

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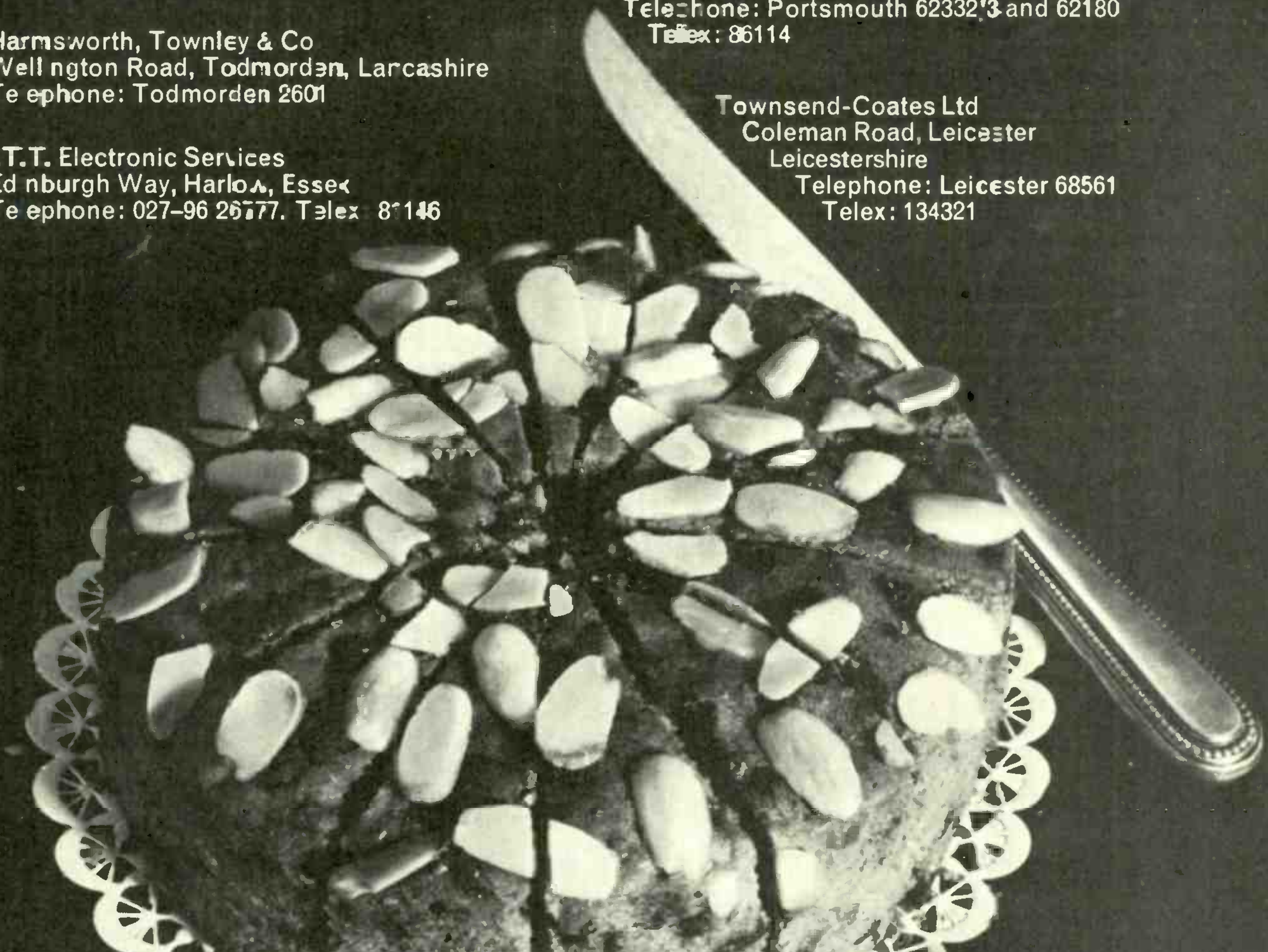

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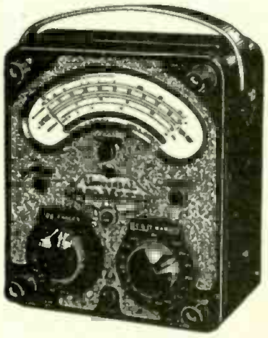

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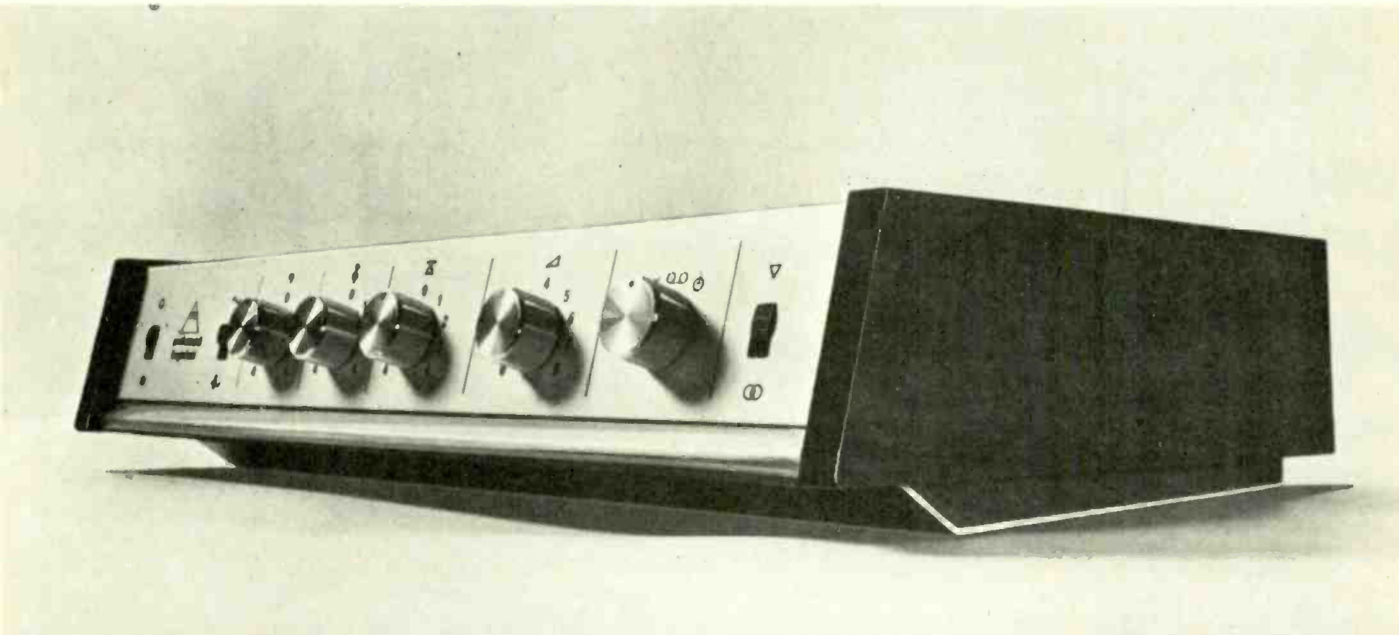

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and this is the Peak Sound Specification Guarantee

Peak Sound guarantee that their equipment meets all specifications as published by them and that these are written in the same terms as are used in equipment reviews appearing in this and other leading high fidelity journals. Audio output powers are quoted at continuous sine wave power in terms of Root Mean Square values (R.M.S.) into stated loads at stated frequencies.

THE SPECIFICATION

Using two Peak Sound PA.12-15's, driven simultaneously at 1 KHz from 240 V. mains supply.

Output per channel: 11 watts into 15 Ω: 14 watts into 8 Ω. *(see spec. guarantee).*

Frequency bandwidth: 10Hz to 45 KHz for 1dB at 1 watt.

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Controls: Volume. Treble. Bass. Low-pass Filter. Mono/Stereo: On/off; Balance.

Using two PA.25-15 amplifiers, output is then 25 watts into 15Ω or 8Ω per channel at 1 KHz.

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WW—067 FOR FURTHER DETAILS

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Supplied complete with instructions, 1 oz. New Formula dispenser, Distilled Water dispenser, spare pad cover and ribbons. Price 42/6 plus 1/3 P.T.

Replacements: 1 oz. New Formula dispenser 4/6 Distilled Water Dispenser 4/– Pad Cover and Ribbons 1/9.

STYLUS CLEANER

Available separately complete with instructions.

Price 5/–. Plus 1/3 P.T.

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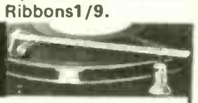
The original 'DUST BUG' Regd. (Patent No. 817598)



Automatic Record Cleaner. Easily fitted to any transcription type turntable. Provides a simple and effective method of removing static and dust while the record is being played. Surface noise and record and stylus wear is reduced, resulting in cleaner reproduction. Complete with ½ oz. New Formula Dispenser and instructions. **Price 18/9 plus 4/5 P.T.**

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Keeps new records like new. Expressly designed for use with records which have not had previous antistatic treatment. Complete with instructions. **Price 6/9.** Replacements: Packet of 4 wicks 2/–.

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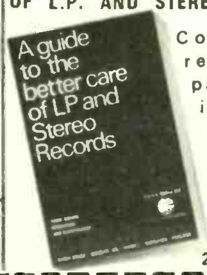

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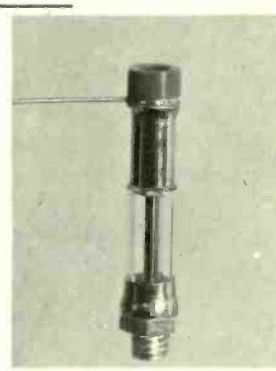

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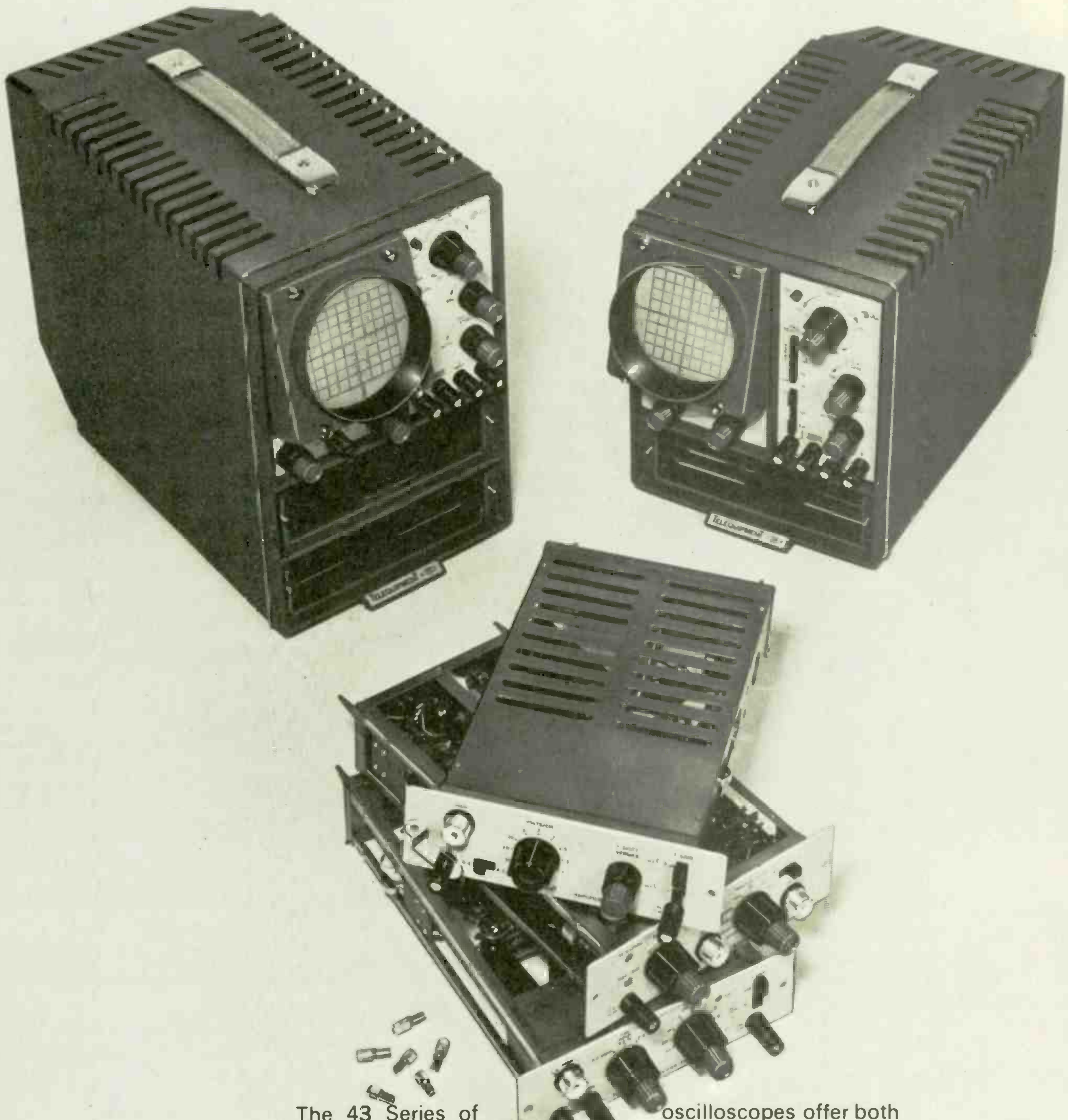
Plug-in potential



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Wireless World

Electronics, Television, Radio, Audio

Fifty-ninth year of publication **February 1970** **Volume 77 Number 1412**

This month's cover symbolizes the subject discussed by S. W. Amos on page 63.

Contents

IN OUR NEXT ISSUE

Constructional details of an **ultra-low distortion class A amplifier** with a frequency response of 15Hz to 92kHz (—3dB).
80-metre s.s.b. receiver. Full details for building this amateur band receiver.

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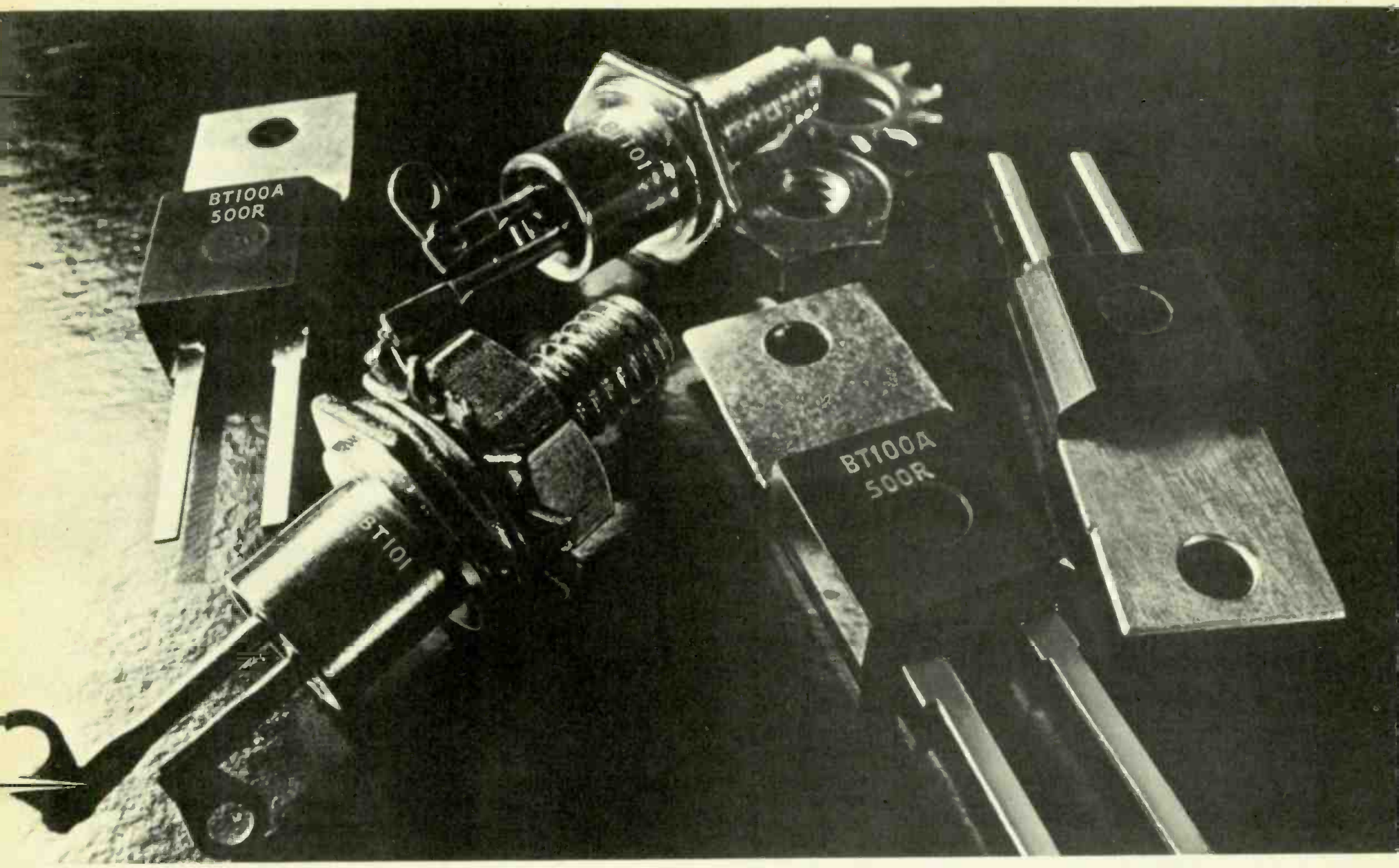

How we made thyristors a commercial proposition for consumer products

Three years ago a Mullard design team was given the problem of developing thyristors for motor speed control in washing machines and drills. Thyristors offered important advantages over conventional power control methods, but at that time, production was confined to relatively expensive industrial devices. The high unit cost was essentially due to specialist production techniques.

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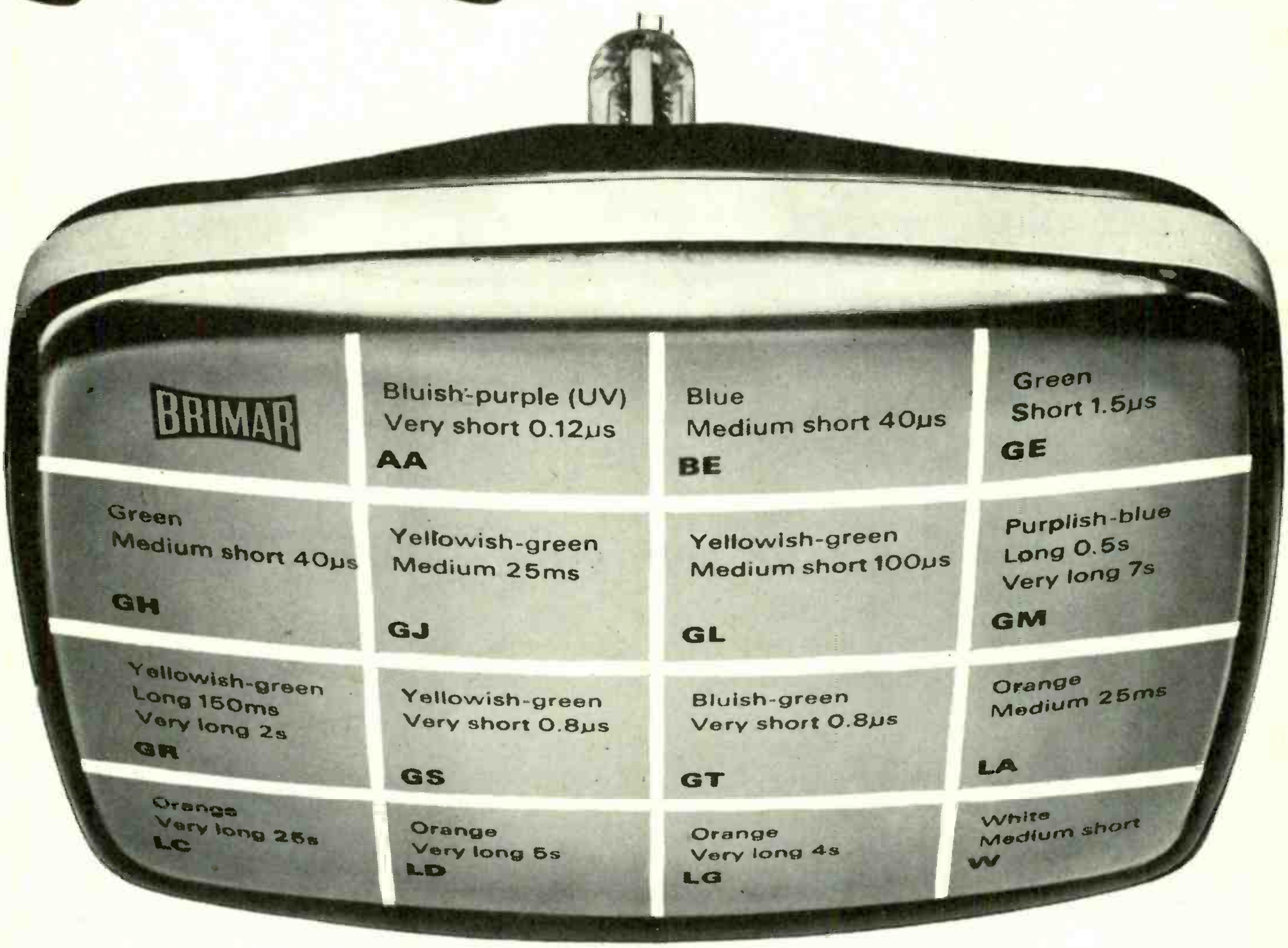

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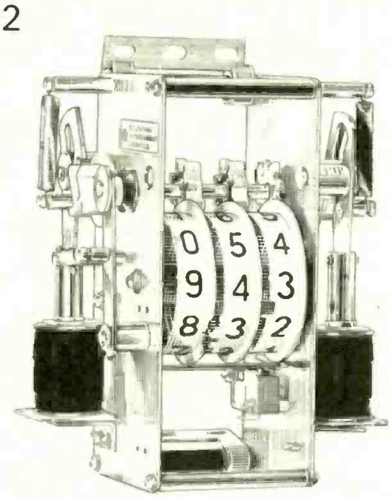

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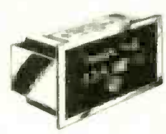

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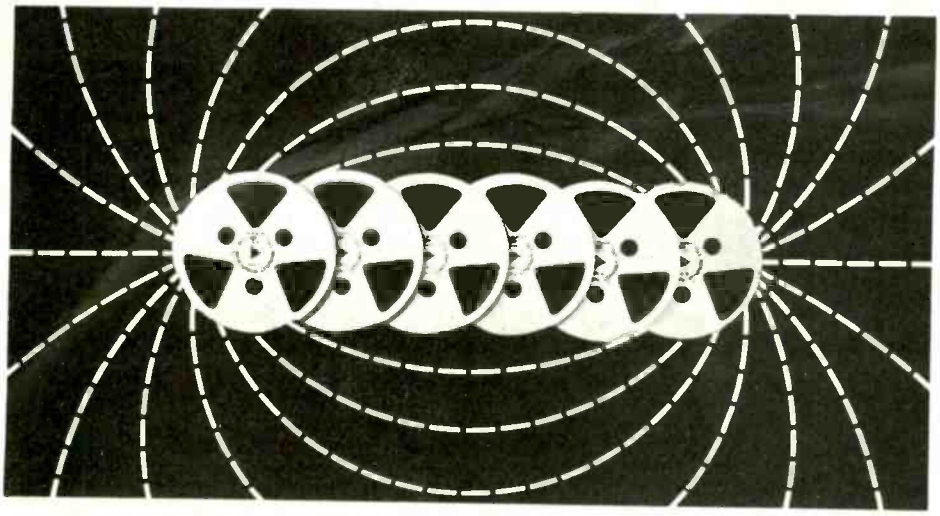
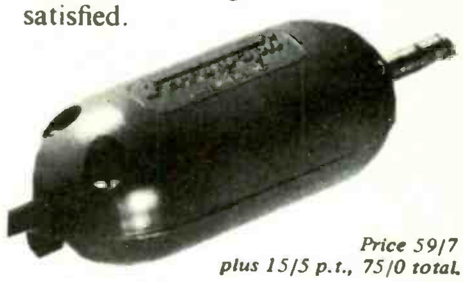


Ferrograph Defluxer is simple and quick, and can be used with practically any make of tape recorder. Once you start using it, your valuable, often irreplaceable tapes are protected against magnetization: surely it is worth just 75/- protection money! Call at your Ferrograph dealer, or send this coupon with your cheque/P.O. for a Defluxer. Money back guarantee if not satisfied.



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sweep, "B" sweep,
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omplete the control

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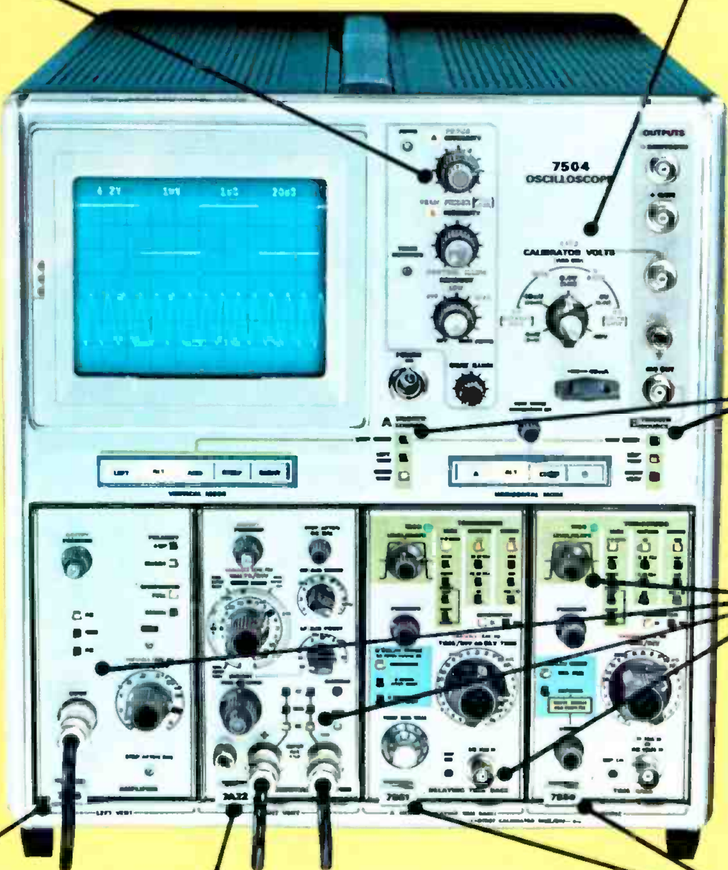

TRIGGERING

The signals from both vertical plug-ins are coupled through a mainframe logic circuit and made available to each horizontal plug-in, selectable from LEFT channel, RIGHT channel, or slaved to VERTICAL MODE. The latter frees the operator from manual source changes during single-trace operation and, in conjunction with the P-P AUTO TRIGGER MODE in the time-base units, provides true hands-off triggering during routine measurements.

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in the 7504.
at full band-

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5 ns/div maximum sweep speed. Operable singly or in combination for delaying sweep capability.

7M11 Delay Line Unit

Two 75 ns, 50-Ω delay lines. Trigger selection from either line.

7S11 Sampling Amplifier

Accepts the plug-in sampling heads for bandwidths to 14 GHz (25 ps tr).

7T11 Random Sampling Time Base

10 ps/div to 5 ms/div sweep range, accomplished with equivalent-time and real-time techniques.

Triggering to 12 GHz.

7704

AUTO SCALE FACTOR READOUT

A character generator senses the position of volts/div, amps/div, time/div, polarity, and uncalibrated variable controls, then accounts for probe attenuation and displays the correct scale factors for all channels directly on the CRT.

DISPLAY CONTR

Three intensity controls adjust "A' and READOUT brightness indep focus control, a screwdriver asti and a two-position beam finder group.

BRIGHT TRACE

The acceleration potentials are 24 kV for the 7704 and 18 kV for the 7504 for improved trace visibility. Single-shot photographic writing speed is 3300 cm/μs (7704) measured with the standard P31 phosphor, the new C-51 camera and 10,000 ASA film. The display area is 8 cm x 10 cm with a parallax-free illuminated graticule.

DUAL-TRACE SWITCHING

Both the vertical and horizontal *mainframe* amplifiers are "dual trace" providing a unique level of flexibility with plug-in combinations. A relatively small number of plug-ins can then meet a wide range of application requirements. The CHOP and ALT modes permit simultaneous displays of delaying and delayed sweep, and, through switching logic, may be "slaved" to provide a functional dual-beam type of display.

7A13 Differential Comparator Amplifier
Bandwidth—DC to 100 MHz (3.5 ns tr) in the 7704; DC to 75 MHz (4.7 ns tr) in the 7504. Min deflection factor—1 mV/div at full bandwidth.

7B71/7B70
Time-Base Units for the 7704
2 ns/div maximum sweep speed. Operable singly or in combination for delaying-sweep capability.

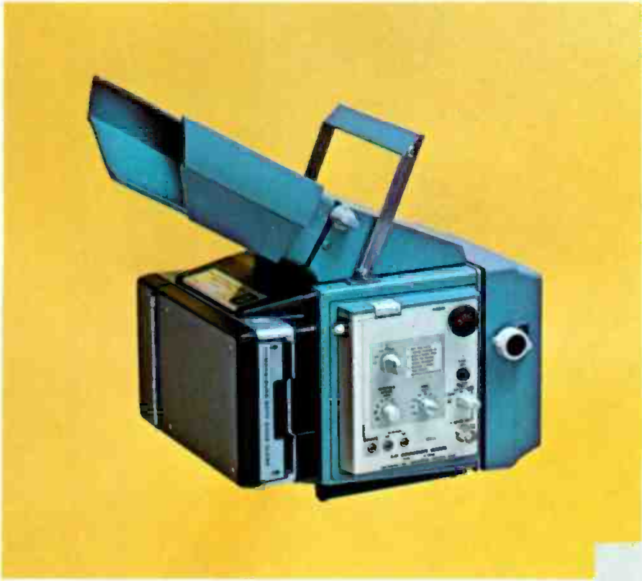
7A16 Wide-Band Ar
Bandwidth—DC to 150 MHz (2. 7704; DC to 90 MHz (3.9 ns tr) Min deflection factor—5 mV/di width.

7A11 Captive FET Probe Amplifier
Bandwidth—DC to 150 MHz (2.4 ns tr) in the 7704; DC to 90 MHz (3.9 ns tr) in the 7504. Min deflection factor—5 mV/div at full bandwidth.

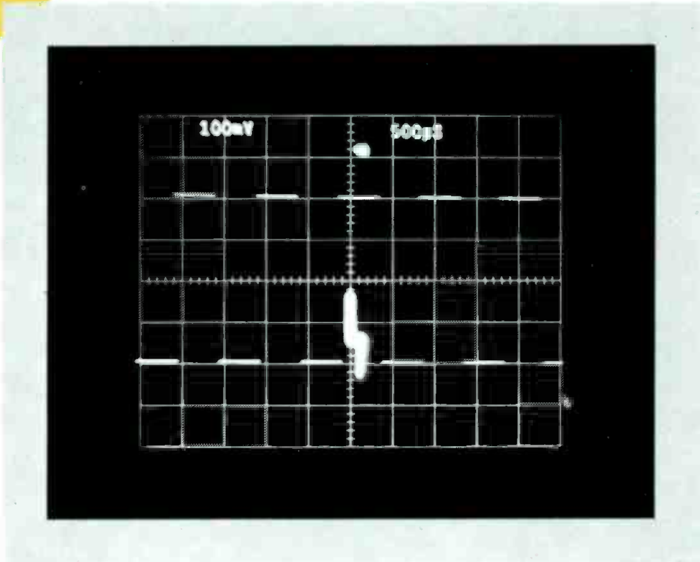
7A12 Dual-Channel Amplifier
Bandwidth—DC to 105 MHz (3.4 ns tr) in the 7704; DC to 75 MHz (4.7 ns tr) in the 7504. Min deflection factor—5 mV/div at full bandwidth.

7A14 AC Current Probe Amplifier
Bandwidth—25 Hz to 105 MHz depending on mainframe and current probe; two probes available. Min deflection factor—1 mA/div at full bandwidth.

C-51/C-50 Trace-Recording Cameras



Two new compact trace-recording cameras have been designed for direct compatibility with the 7000-Series Oscilloscopes. The C-51 and C-50 cameras are basically identical units, differing only in the lens system. The C-51 has an f/1.2, 1:0.5 lens; the C-50 uses an f/1.9, 1:0.7 lens. The C-51 is recommended for single-shot photography at the fastest sweep rates, the C-50 for more general purpose applications. Photographic writing speed of the two 7000-Series mainframes with the C-51 and 10,000 ASA film (without prefogging) is 3300 cm/μs (7704) and 2500 cm/μs (7504).



The cameras offer a new level of operational convenience for mistake-proof trace photography. The guess work normally associated with selection of f stop and shutter speed to match the ASA index and trace brightness is eliminated. After setting the ASA index, the built-in photometer allows a *visual* correlation of trace intensity to the correct f stop setting and shutter speed. After initial adjustment, a change of f stop or shutter speed will still maintain the same exposure. Focusing is accomplished by two beams of light projected on the CRT which, when superimposed, indicates optimum focus. The insert shows the photometer spot and the rangefinder focusing images.

SCOPE-MOBILE® CARTS

The 204-2 Scope-Mobile® Cart is specifically designed for the 7000-Series instruments. It provides a securing mechanism for the oscilloscope, nine positions of selectable tray tilt, a large storage drawer, storage for five 7000-Series plug-ins, and large locking-type wheels.

PROBES

The P6053 is a miniature fast-rise 10X probe designed for full compatibility with the 7000-Series instruments. Input R and C is 10 MΩ, 10.3 pF. Probe risetime is 1.2 ns or less.

The P6052 is a passive dual-attenuation probe designed for measurements below 30 MHz. A sliding collar selects 1X or 10X attenuation. Input R and C is 1 MΩ or 10 MΩ, 100 pF or 13 pF. Risetimes are 60 ns (1X) and 7 ns (10X).

7704 Oscilloscope	£1,167
7504 Oscilloscope	£933
7A11 Amplifier Plug-in	£397
7A12 Amplifier Plug-in	£327
7A13 Amplifier Plug-in	£513
7A14 Amplifier Plug-in	£268
7A16 Amplifier Plug-in	£280
7A22 Amplifier Plug-in	£233
7B71 Time-Base Plug-in	£320
7B70 Time-Base Plug-in	£280
7B51 Time-Base Plug-in	£238
7B50 Time-Base Plug-in	£210
7S11 Sampling Plug-in	£210
7T11 Sampling Time-Base Plug-in	£513
7M11 Dual Delay Line Unit	£117
204-2 Scope-Mobile ® Cart	£85+£11.6.0 duty
C-51 Trace-Recording Camera	£427+£97.4.0 duty
C-50 Trace-Recording Camera	£333+£75.16.0 duty
P6052 or P6053 Probes	£24+£3.8.0 duty

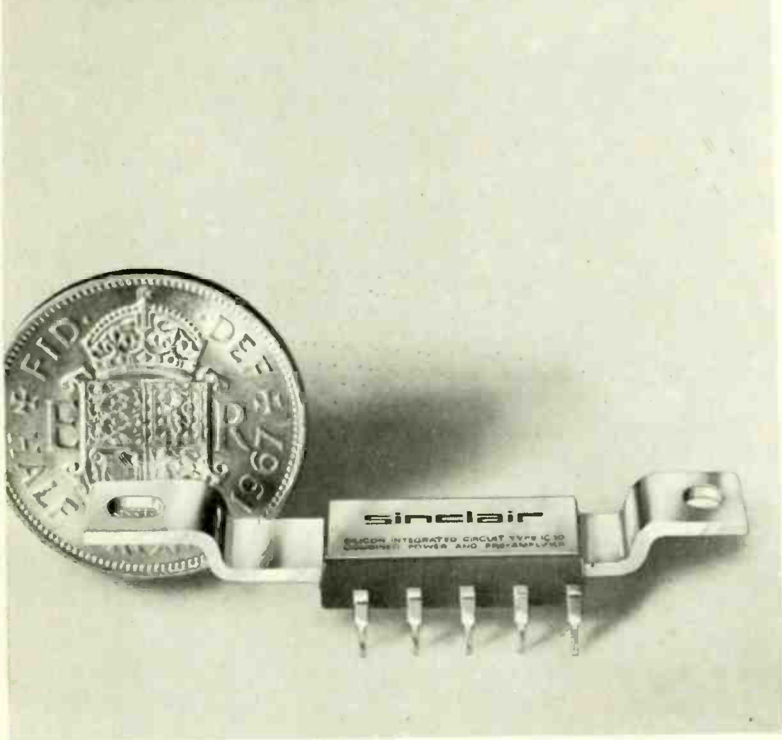
Delivered U.K.

Tektronix U.K. Ltd. *Beaverton House, P.O. Box 69, Harpenden, Herts. Telephone Harpenden 61251. Telex: 25559*

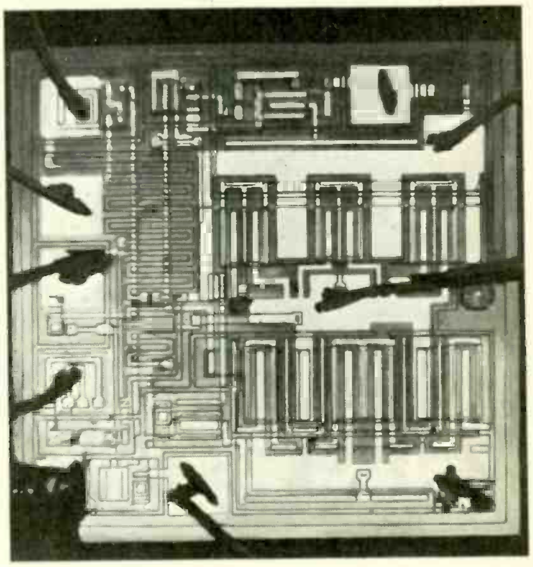
For overseas enquiries: **Australia:** Tektronix Australia Pty. Ltd., 4-14, Foster Street, Sydney, N.S.W. **Canada:** Tektronix Canada Ltd., Montreal, Toronto & Vancouver. **France:** Relations Techniques Intercontinentales, S.A., 91, Orsay, Z.I. Courtaboeuf, Route de Villejust (Boite Postale 13). **Switzerland:** Tektronix International A.G., P.O. Box 57, Zug, Switzerland. **Rest of Europe and the Middle East:** Tektronix Ltd., P.O. Box 36, St. Peter Port, Guernsey, C.I. *All other territories: Tektronix Inc., P.O. Box 500, Beaverton, Oregon, U.S.A.*

TEKTRONIX

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.

MORE SINCLAIR DESIGNS ON PAGES FOLLOWING

■ 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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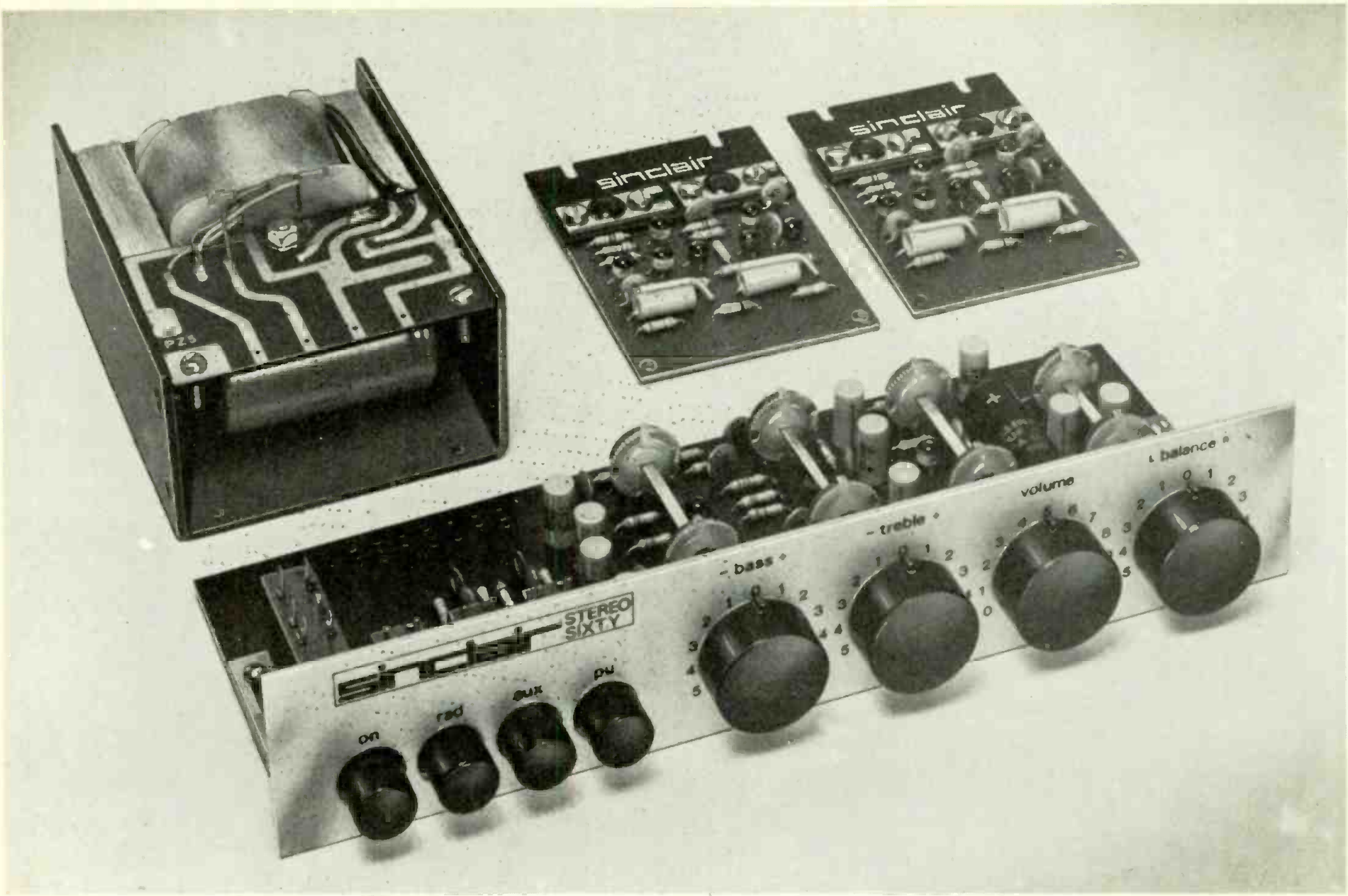
SINCLAIR RADIONICS LTD. 22 NEWMARKET ROAD, CAMBRIDGE
Telephone: 0223 52731

WW—083 FOR FURTHER DETAILS



Project 60 an exciting alternative

The buyer of an amplifier today has a remarkably wide variety to choose from. It is unlikely that a purchaser would have real difficulty in finding a unit that met all his requirements, although the price might not be as low as could be wished. The only snags are that one's needs can change and that the technically correct amplifier may be physically inconvenient. If you are confident that there is an amplifier available, of the right size and price, which will meet all your needs for the forseeable future, then that is your best buy. If not, however, we can offer you another possibility which we believe to be an exciting alternative approach. That alternative is **Project 60**.

Project 60 is 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 with it in overall performance.

The modules are: 1. The Z-30 high gain power amplifier, which is an immensely flexible unit in its own right. 2. The Stereo 60 preamplifier and control unit. 3. The PZ.5 and PZ.6 power supplies. A complete system comprises two Z-30's, one Stereo-60 and a PZ-5 or PZ-6. The power supplies differ in that the PZ-6 is stabilised whilst the PZ-5 is not. This means that the former should be used where the highest possible continuous sine wave rating is required. In a normal domestic application there will not be a significant difference between using either power unit unless loudspeakers of very low efficiency are being used.

All you need to assemble your system is a screwdriver and a 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.

Perhaps the greatest beauty of the system is that it is not only flexible now but will remain so in the future. We shall shortly be introducing additional modules which will include a comprehensive filter unit, a stereo F.M. tuner and an even more powerful amplifier for very large systems. These and all other modules we introduce will be compatible with those shown here and may be added to your system at any time.

Project 60 modules have been carefully designed to fit into virtually every known type of plinth or cabinet and templates provided enable you to position them. Only holes have to be drilled into the wood of the plinth and any slight slips here will be covered completely by the aluminium front panel of the Stereo 60. The Project 60 manual gives all the instructions you can possibly want clearly and concisely.

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Telephone: 0223 52731

Z-30 TWENTY WATT R.M.S. (40 WATT PEAK) POWER AMPLIFIER

The Z-30 is a complete power amplifier of very advanced design employing 9 silicon epitaxial planar transistors. Total harmonic distortion is incredibly low being only 0.02% at full output and all lower outputs. As far as we know, no other high fidelity amplifier made can match this specification, no matter what the price. Thus you can be utterly certain that your Project 60 system will do full justice to your other equipment however good it may be. The Z-30 is unique in that it will operate perfectly, without adjustment, from any power supply from 8 to 35 volts. It also has sufficient gain to operate directly from a crystal pickup. So in addition to its use in a high fidelity system you can use a Z-30 to advantage in your car or a battery operated gramophone for your children, for example. These, and many other applications of the Z-30, are covered in the Project 60 man

SPECIFICATIONS

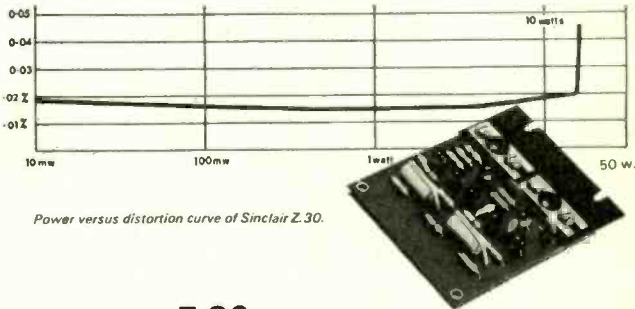
Power output—15 watts R.M.S. (30 watts peak) into 8 ohms using a 35 volt supply; 20 watts R.M.S. (40 watts peak) into 3 ohms using a 30 volt supply.

Output—Class AB.

Frequency response:	30 to 300,000 Hz ± 1dB.
Signal to noise ratio:	better than 70dB unweighted.
Distortion:	0.02% total harmonic distortion at full output into 8 ohms and at all lower output levels.
Size:	3½ x 2¼ x ½ inches.
Input sensitivity:	250mV into 100 Kohms.
Damping Factor:	>500.
Loudspeaker impedances	3 to 15 ohms.
Power requirements:	8 to 35 V.d.c.

APPLICATIONS

High fidelity amplifier; car radio amplifier; record player fed direct from pick-up; Intercom; electronic music and instruments; P.A., laboratory work, etc. Full details of these and many other applications are given in the manual supplied with your Z.30.



Power versus distortion curve of Sinclair Z.30.

Z.30

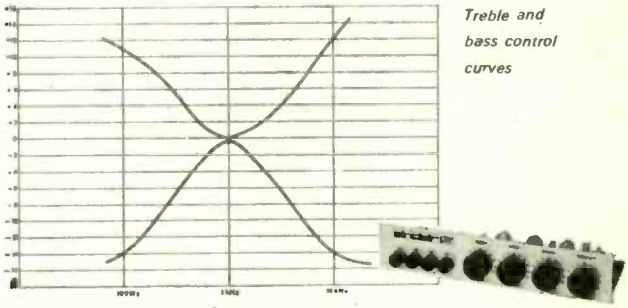
Ready built, tested and guaranteed, with Z.30 manual. **89/6**

STEREO SIXTY PREAMPLIFIER AND 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.

SPECIFICATIONS

- Input sensitivities—Radio—up to 3mV: Magnetic Pickup—3mV Correct within ± 1dB on R.I.A.A. curve. Ceramic Pickup—up to 3mV: Auxiliary—up to 3mV.
- Output—250 Mv
- 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.
- Power consumption 5mA.
- Power requirement—PZ.5 or PZ.6.
- Finish—brushed aluminium front panel with black knobs.
- Mounting—on cabinet front by spindle bushes and adjustable brackets.

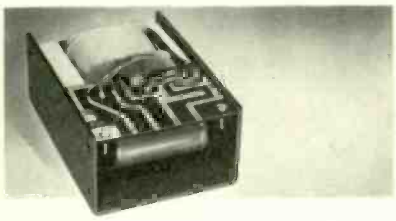


Treble and bass control curves

STEREO SIXTY

Ready built, tested and guaranteed **£9.19s.6d.**

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.

Price: £4. 19s. 6d.

PZ-6 35 volts stabilised—ideal for driving two Z-30's and a Stereo 60 when very low efficiency speakers are employed.

Price: £7. 19s. 6d.

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 service thereafter.

SINCLAIR RADIONICS LIMITED
22 NEWMARKET ROAD, CAMBRIDGE
Telephone 0223 52731

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To: SINCLAIR RADIONICS LTD., 22 NEWMARKET RD., CAMBRIDGE

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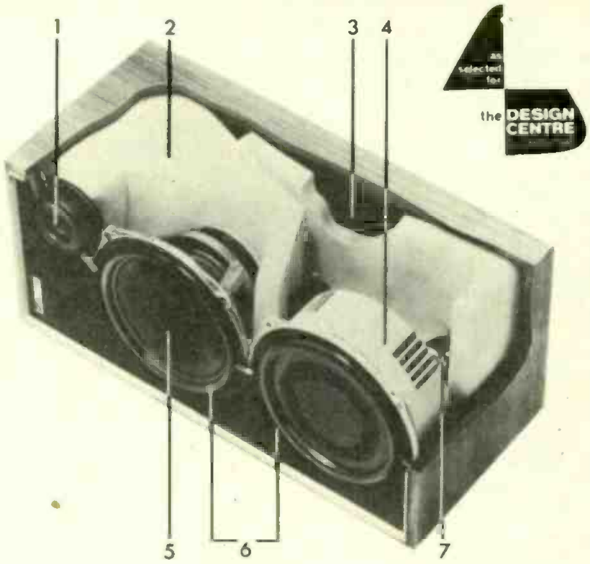
for which I enclose cash/cheque money order

WW7023

WW—085 FOR FURTHER DETAILS

Just what *is* this ABR, that makes such a vital difference to the 'DITTON 15'?

The "DITTON 15"
Now firmly established as a superb high-fidelity loudspeaker. Design features include the exclusive CELESTION ABR (auxiliary bass radiator), HF1300 treble unit—as used in B.B.C. Monitor Loudspeakers—and specially developed mid/bass unit. Low loss L/C crossover.
Power handling: 15 watts r.m.s.; 30 watts peak. Impedance 4–8 ohms.
Dimensions: 21 in. × $9\frac{1}{2}$ in. × $9\frac{1}{4}$ in.
Choice of finish: Teak or walnut.



1. Studio quality high frequency unit (HF1300 Mk. 2). As used in B.B.C. Monitors.
2. Anechoic cellular foam wedge and lining eliminates standing waves.
3. High hysteresis panel loading material to eliminate structural resonances.
4. Auxiliary Bass Radiator (ABR)—plastic foam diaphragm of high rigidity and low mass having a free air resonance of only 8 Hz, double roll suspension allowing excursions up to $\frac{3}{4}''$ with virtual absence of distortion.
5. 8″ bass unit, with free air resonance of 25 Hz, and massive Ferroba II magnet structure for optimum magnetic damping and cone treated with viscous damping layer to suppress resonances.
6. Units mounted flush to eliminate diffraction effects and tunnel resonances; covered by acoustically transparent grille cloth for maximum presence.
7. Full L-C Crossover network.

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1970 Product Guide and Directory of Manufacturers

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This month we are adding two new types of Transformers to our existing standard ranges.
1. THE 1200 SERIES
This series covers 150VA Transformers and gives a voltage range up to 110 volts at various loads.
2. THE DB SERIES
These Transformers have a high VA density (approximately 2·5VA per cu. inch) and cover a VA range up to 40VA.
Please write for further details.

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*Low Voltage

30-0-30V. 4A.	3	12	6
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20W Transistor Amplifier (W.W. Nov. 1966)

Driver	1	4	6
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L.P. Filter, Chassis Mounting		12	6
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70V & 100V Line Matching

Fitted with terminal panel, taps at 0.5, 2, 4 and 8W. into 15 ohms — 9/- each in 100 Lots
Flying leads, taps at $\frac{1}{4}$, $\frac{1}{2}$, 1, 2 and 4W. into 3 ohms — 7/3 each in 100 Lots

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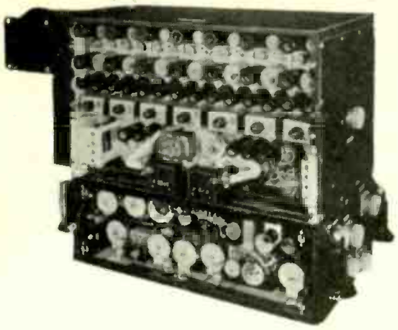
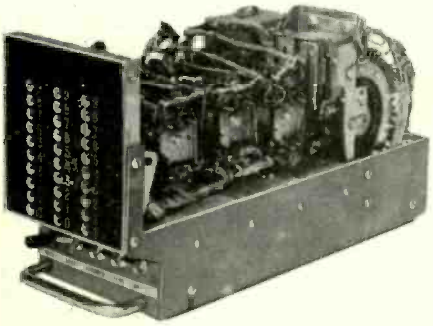


Ballistics Computers by Westinghouse. Nine servo amplifiers with associated motors and Power Packs. Brand new in sealed containers. Price on application.



Automatic Numbering Machine by Western Union. Four Uniselectors and 30 neons. Ideal basis for amateur computer. Application leaflet. £12.10s. post free.

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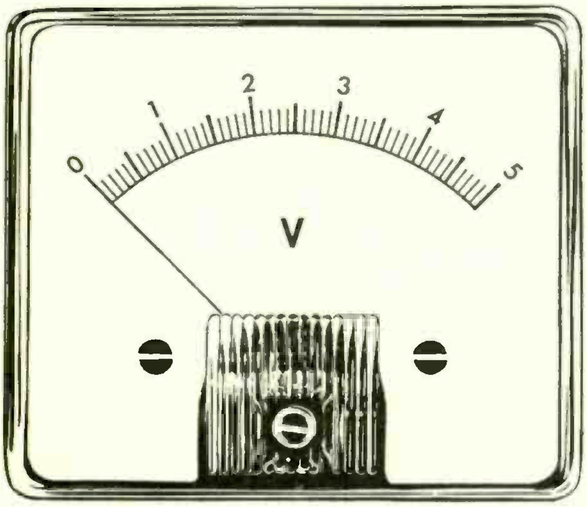

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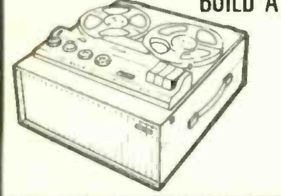
BUILD A QUALITY 4 TRACK TAPE RECORDER



To get the best out of your MAGNAVOX DECK, you need a MARTIN RECORDAKIT. This comprises a special high quality 6 valve amplifier and pre-amplifier which comes to you assembled on it s printed circuit board — in fact everything for making a superb Tape Recorder. You need no experience or technical skill to bring this about.
THE INSTFUCTIONS MANUAL MAKES BUILDING EASY, AND SUCCESS IS ASSURED.
Kit comprises: Oeck, Amplifier, Cabinet and speaker, with microphone, 7" 1200 ft. tape, and spare spool.
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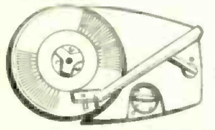

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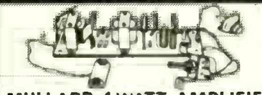

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Portable Transistor Unit-Ideal for Intercoms, Baby Alarms, Tele phone, Record Players or Guitar Practice.
9 Volt 5 transistors with volume control, output 3 ohms.
Ideal for use with STAAR RECORD DECK.
PRICE 45/-. p.p. 2/6.
OTHER ITEMS. Suitable 7 x 4 inch. 3 ohm speaker 17/6 p.p. 1/6.
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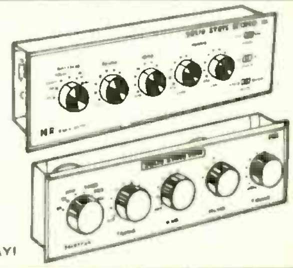
Mono or Stereo Audio equipment developed from Dinsdale Mk. II — each unit or system will compare favourably with other professional equipment selling at much higher prices.
£11.12.6. to £38.17.6. (all units available separately).
THE FINEST VALUE IN LOW COST HIGH FIDELITY — CHOOSE A SYSTEM TO SUIT YOUR NEEDS AND SAVE YOURSELF POUNDS.



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All the latest models BRAND NEW and guaranteed — TERRIFIC SAVINGS!

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*2025TC DIAMOND. 9TAH.C.	£ 9.19.6.
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*SL 55	£11.19.6.
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*Special offer base and cover available for these models at £4.15.0. Carriage 5/-.
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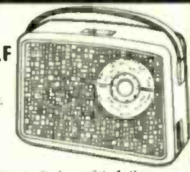

New printed circuit design with full power output. Fully tuneable on both mw/lw. bands. 7 Mullard transistors, Fitted 5" speaker, Room Filling Power. Easy to build with terrific results. All local and continental stations. Complete detailed instructions.
TOTAL COST £6.19.6. p.p. 4/6.
Ask for Leaflet No. 1.

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WE HAVE THE MOST COMPREHENSIVE STOCK IN GREAT BRITAIN.
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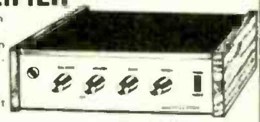
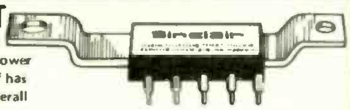
HENELEC 5–5 STEREO AMPLIFIER



Excellent low priced British designed Stereo Amplifier for use with Record Decks, Mike, Tuners.
16 transistor mains operated. Output 5+5 watts for 8- 15 ohm speakers. Black, silver and wood finish, size 13" x 3" x 6".
PRICE £13.10.0. p.p. 7/6. (Leaflet on request).
Complete Stereo System 5-5.
Garrard 2025 stereo, 5-5 Amplifier, Plinth/Cover. Two 10 watt speakers with tweeters in polished cabinets.
Usual price £47.0.0. **OUR PRICE £39.10.0. p.p. 20/-.** ASK FOR BROCHURE.13

SINCLAIR EQUIPMENT



The SINCLAIR IC-10 is the worlds first monolithic intergrated circuit high fidelity power amplifier and pre-amplifier. The circuit itself has an output power of 10 watts, yet with an overall size of 1 x 0.4 x 0.2 in.

IC-10 Integrated Circuit Amplifier	59/6
Z30	89/6
Stereo 60	£9.19.6.
PZ5 Power Supply	£4.19.6.
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Z12 Amplifier	89/6
PZ 4 Power unit	99/6
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All post paid, delivery from stock.

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RCA. CA3014	29/6
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Sinclair I C.10.	59/6
G.E. PA230*	22/6
G.E. PA234*	20/0
G.E. PA237*	37/6
G.E. PA246*	52/6
SL 402 Plessey	45/0
SL 403 Plessey	49/6
S.G.S. UL910	10/0
S.G.S. UL900	10/0
S.G.S. UL914	11/0
Mullard TAA263	15/0

*Data sheets 3/6 set for these, for others see catalogue.

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ELECTRONIC ORGANS

COMPLETE KITS FOR THE HOME CONSTRUCTOR

Start building for as little as £10

MODELS FROM £99 – £350.

STAR FEATURES:
*ALL TRANSISTOR PRINTED CIRCUIT DESIGNS. *BRITISH DESIGN. *STEP BY STEP DETAILED INSTRUCTIONS. *SAVES UP TO 50% ON COMMERCIAL EQUIVALENT. *EVERYTHING SUPPLIED DOWN TO THE LAST ITEM. *FULL AFTER-SALES SERVICE & ADVICE. *CREDIT SALE & H.P. TERMS AVAILABLE.

We are pleased to offer the choice of FOUR British designs from a single manual portable at £99 THE MAYFAIR for light or classical music — to a two manual five octave de-luxe model with OAK CONSOLE from £285 for the serious musician.

These kits are the result of years of research and design and offer the best that is essential to good organ designs, coupled with excellent value are within the reach of most pockets. No technical skill or knowledge is required in construction, with the aid of the STEP BY STEP illustrated manuals will produce an instrument that will be a delight to own and use and will give years of trouble free entertainment for the whole family.

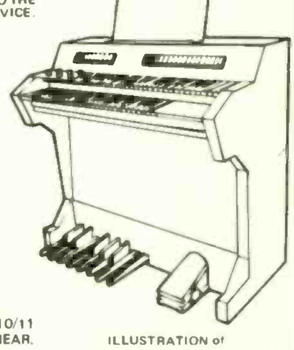
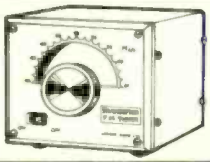


ILLUSTRATION of GROSVENOR ELECTRONIC ORGAN

SEND FOR ILLUSTRATED BROCHURES 9/10/11 TODAY! When in LONDON CALL IN—SEE. HEAR. PLAY FOR YOURSELF.
Organ Demonstration Room 1st Floor.
PRACTICAL ELECTRONICS ORGAN — ORGAN COMPONENTS
We are able to supply all items for this series, details on request. Built models available from £124.

BUILD THIS VHF FM TUNER

5 MULLARD TRANSISTORS. 300 kc/s BANDWIDTH. PRINTED CIRCUIT. HIGH FIDELITY REPRODUCTION MONO & STEREO. A popular VHF FM Tuner for quality and reception of mono and stereo. There is no doubt about it — VHF FM gives the REAL sound.



PARTS TOTAL COST £6.19.6. DECODER £5.19.6.
ASK FOR LEAFLET No. 3. (FOR STEREO)

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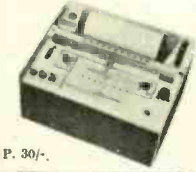
MEASURING INSTRUMENTS AND RECORDERS

NEW

6 Pen Event Recorder, 6 in. Chart width. Available in wide range of chart speeds. Rack mounted **£79/10/0**. Case to suit extra.

NEW AMERICAN 5" CHART RECORDER



Good general purpose potentiometric recorder. Suitable for research and laboratory work. Range 0-10 m.v. Variable zero set, Zenor divide reference. Input impedance. Max 100 Kohms.
Price **£69.10.0**. P.&P. 30/-.

PORTABLE AC/DC PEN RECORDER

A most versatile pen recorder. Produces a trace on a curvilinear 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 n 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**. Postage and packing £1 5s. 0d.

STRIP-CHART INDICATING RECORDER

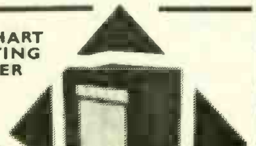


Chart width 9¾ in. 10 mV. Sensitivity ± 0.17 of full scale. Source impedance 100 ohms. Speed of operation 33 sec. for full-scale travel. Chart speed ½ in., 3 in., 6 in. per hour. Single point. **£49.10.0**. P. & P. 30/-.

RECORDER SP 20 Series

General Purpose Single Pen potentiometric instrument for continuous recording for any input signal from 0-10mV D.C. Suitable for use with Spectrophotometer and other laboratory instruments. Chart speed 0.5 to 8.4 cm/min. Linearity ±0.25%. Fully transistorised. Chart width 200 mm. Input impedance 10K ohms max. Available S.P. 20 Plain Linear. S.P. 21 Flat Bed. S.P. 22 Linear/Log. From **£135** each. P. & P. 40/-.

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.

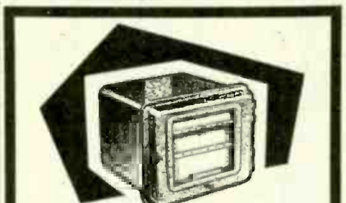
ULTRA VIOLET RECORDER 12 Channel NEP 1050 with 6 galvanometers **£280**.

ULTRA VIOLET PHOTOGRAPHIC RECORDER 12 Channel mirror Galvanometer Honeywell 1000 with 6 galvos **£280**.
24 Channel Siesmic Recorder by Film & Equipments **£325**. Carriage extra.

E H T INSULATION TESTER
From 1 - 5 Kv A.C. and D.C. Complete with probes. New equipment. Price **£52/10/0**. Carr. £2/10/0.

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 × 163 w × 245mm. Weight: 5.5kg. List price £65. Our price **£35**.



POTENTIOMETRIC 6 POINT STRIP CHART RECORDER BRAND NEW

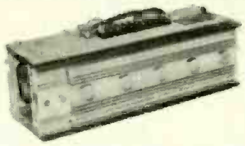
For use with thermocouplers, pyrometers and other e.m.f. sources. 6 point. Range (—100) —0—(+100) mV; 0—1,600 deg. C. 6¼ in. chart width; pen speed 8 secs. Accuracy ±0.5%; 10 chart speeds 20-720mm/hr. Tropicalised. Including tools and spares. Listed at over £200. Our price **£79.10.0**. Also available 0-100mW F.S.D. **£89.10.0**.

POWER SUPPLIES

AIRMEC 698B KLYSTRON POWER SUPPLY

Rack mounted (19 in.). Mains operated. Cathode volts from 1.0 to 2.4 kv. negative. Grid Volts, 0 to 220V negative. Reflector Volts, 0 - 500V negative. Cathode Current, 0.18mA max. Heater 4V at 1.5A. Internal Modulation—Square wave 2 - 4 KHz 7V p-p. Saw Tooth 150 - 600 Hg 0 - 30V peak. Price **£45**. P. & P. 40/-.

★ HIGH PRECISION ★ FULLY STABILISED TRANSISTORISED LOW VOLTAGE POWER SUPPLIES



incorporating
- S.C.R. Panel for overload projection.
- OVERLOAD & CIRCUIT BREAKER WITH MANUAL RESET button.
- RIPPLE better, better than 3000 : 1.
- CHOKE OF CAPACITOR transistorised 120/130 volt A.C. INPUT.

Available in the following types:

6 Volt 9 Amp	£12.10.0
6 Volt 12 Amp	£17.10.0
6 Volt 16 Amp	£22.10.0
12 Volt 8 Amp	£22.10.0
12 Volt 16 Amp	£25. 0.0
12 Volt 22 Amp	£25. 0.0
20 Volt 16 Amp	£25. 0.0
24 Volt 4 Amp	£22.10.0
30 Volt 8 Amp	£18.10.0
56 Volt 7 Amp	£25. 0.0

Ex-equipment but fully tested in our laboratory. Carr. 30/-

ADVANCE TRANSISTORISED DC POWER UNITS

	Imput Volts	Output Volts	Amps	Price
DC 4	200-245±15%	12	4	£17/10/-

METERS

2 in. dia. mounting A.C. voltmeter 0-300 V. A.C. **£1.15.0**. Carriage 6/-.
3½ in. dia. Electrostatic Kilo Voltmeter in wooden case. **£2.15.0**. Carriage 10/-.
Precision A.C. & D.C. Wattmeter. Model S.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/-.

INDICATING MEASURING AMPLIFIER PR 7410

Suitable for vibration and frequency analysis. Frequency response 10-1,000 Hz. **£45**. Carr. 40/-.

BRAND NEW S.E. LABORATORIES TRANSDUCER

complete with encapsulated Amplifier/demodulator S.E. 441/2
Frequency D.C.—60 c.p.s.
Available in the following ranges:
SE150, SE50 or SE165A.

0 - 50 p.s.i.	0 - 500 p.s.i.	0 - 3000 p.s.i.
0 - 200 p.s.i.	0 - 750 p.s.i.	0 - 4000 p.s.i.
0 - 350 p.s.i.	0 - 2000 p.s.i	

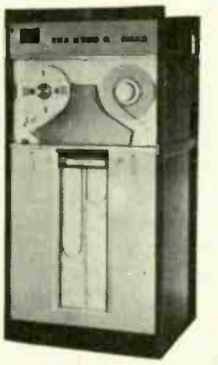
Also available differential types ± 10 p.s.i.
Also available differential types, + 10 p.s.i.
List price £70+. Our price **£15**

COMPUTER AND PERIPHERAL EQUIPMENT

7 TRACK DIGITAL MAGNETIC TAPE STORAGE DECK

These machines originally ex-computer, are multi-track recording units, ideal for data storage. Record and Replay heads encased in one common unit. Low resistance heads. Frequency response approximately 30 Kc/s. to 50 Kc/s. Bit density 557 b.p.i. ½ in., 10½ in. spools 230 V. to 380 V. A.C. Capstan Motor speed 1,500 r.p.m. 48 V. D.C. Rewind motors complete with vacuum Assembly. Finished in brush aluminium and matt-black. Size 27 in. × 26 in. × 8 in. Weight 90 lb. Price **£72.10.0**. Carriage extra.

MODEL 72 MAGNETIC TAPE DATA STORAGE UNIT



This unit consists of ½ in. 8 channel read-write heads. Can be used to record any 6 bit code. Data can be read in either a forward or backward direction plus giving search facilities. The unit consists circuits for receiving and storing instruction signals. Recording density 250 characters per inch. Tape speed 100 in. per second, price **£190**. Excellent condition.

½" 7 TRACK
Ex-computer record/replay head complete with guides. Little used. Price **£12.10.0** Carriage 15/-.

BRAND NEW
Gresham Lion 1 in. 1 + 7 track record/replay heads. Of the highest professional quality. Cost **£100** plus price **£12.10.0**. Carr. 15/-.

9 TRACK 1 in. Record/replay heads with sprocket drive, driven by synchronous motor. Mounted with integrated head assembly eliminating alignment problems. This can be fitted to any suitable type of transport system. Price **£8.10.0**. Carriage 15/-.

BRAND NEW COMPUTER TAPES AND EMPTY SPOOLS

Made by well known manufacturers

½ in. certified 2,400 ft. 800 b.p.i.	£8.10.0
½ in. 2,400 ft.	£6.10.0
½ in. Highest grade 2,400 ft.	£3. 0.0
½ in. 10½ in. dia. spool and cassette	£1.10.0
½ in. 8½ in. dia. spool and cassette	£1.10.0
1 in. metal 10½ in. dia. spool and cassette	£2.10.0
½ in. N.A.B. centres 10½ in. spool only	£1. 0.0

TAPE PUNCH MODEL 25 7 HOLE

A multiwire tape punch designed for general application involving the conversion of parallel wire electrical impulses into punched papertape at 33 characters per second. Unit completely self-contained requiring only motor power and signal supplies.

7 HOLE NON PARITY TAPE PUNCH

New condition.

LOW SPEED 7 HOLE TAPE PUNCH

60 characters per second by well-known manufacturer.

TELETYPE 8 HOLE PAPER PUNCH MU27

Also available 5 hole punch BRPE2 as above. This model has interchangeable heads. Complete with spooler. Price **£35**.

HIGH SPEED 5/7 HOLE OPTICAL READER

20 characters per second.

CARD READERS

80 column 1500/80 model, punch
80 column 1400/80 model verifier. } **£325** Excellent condition.

HOLLERITH 80 COLUMN CARD PUNCH TYPE HO29 & VERIFIER H129 £225.

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.

PROGRAMME BOARDS BY SEALECTRO

These boards are basically a multi pole multi throw switch device consisting of a X-Y Matrix with two contact decks in the Z Plane running at 90 degrees to each other. Contact is made by either, shorting or plugging in pins. Ideal for prototype work, etc. Boards available in 24 × 60 2 plane **£12.10.0**. Pins available 1/3 each.

MEMORY PLANES

Ferrite core memory planes with wired Ferrite cores. Used for building your own computer or as an interesting exhibit in the demonstration of a computer. Mounted on plastic material, frame 5 × 8 in. Consisting of matrices 40 × 25 × 4 cores each one individually addressable and divided into 2 halves with independent sense and inhibit wires. **£8.10.0**. P. & P. 3/-.

MULLARD MATRIX CORE STORE STACKS

A.W. 510 5 planes 8×16 cores/per plane	£12/10
A.W. 511 5 planes 18×32 cores/per plane	£25
A.W. 534 20 planes 64×64 cores/per plane	£89/10
A.W. 597 8 planes 32×32 cores/per plane	£55
Single plane 40×25×4	£8/10
Flexi-writer 7 hole punch and keyboard	£199/10

MEMORY STORE

M. M. 1044 complete with logic circuits mounted in Imhof cabinet **£400**

COMPUTERS

Burroughs E 201 225 words store. **£450**
COMPUTER. 802B Hybrid computer with 1K store, in full working order. Complete with paper tape punches, and compatible for Holerith 80-Hol-card-periphery. Numerous programmes available including tes-programmes. Full supporting literature. PRICE ON APPLICATION

SYNCHRONOUS MOTORS

Model 87 1 r.p.h. and 1/60 r.p.h. Self starting complete with gearing shaft ⅛" dia. ½" long. 200/250 V 50 Hz. New Condition Ex. Equipment. **30/-**. P. & P. 3/-.

TRANSFER CASE

For sending data by personal carrier, GPO post, passenger train, etc ideal. Suitable for despatching tape **20/-**. P. & P. 5/-.

EICHNER 8 Hole Punch £49/10/0.

EICHNER 8 Hole Reader £29/10/0.

CANCELLED EXPORT ORDER

90 Column card sorter and punch type 425/0 price on application.

BRAND NEW TAPE SPOOLER

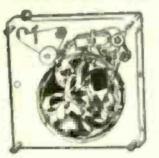
Suitable for 1 in., ½ in. and ¾ in. tapes. Fully self-contained **£99.10.0**.

FLEXIWRITERS

Both Punch and Read Type Available. One coded for Elliott 803 Computer. Price on application.

LOW COST ELECTRONIC AND SCIENTIFIC EQUIPMENT AND COMPONENTS

CONTINUOUS TAPE CASSETTE

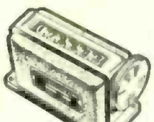


Suitable for sleep-learning, teaching programmes, programming machine tools, telephone answering etc. Complete with replay/record head and separate erase head. ¼" tape twin track. Speed 3¾" per sec. Length of tape 88 feet, but will hold three times this amount. 230V. 50 Hz supply. **£3.9.6.** p. & p. 10/-.

802D DIGITAL DESK COMPUTER

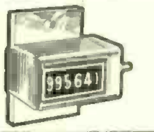
Complete with punches and reader. Compatible for 80 columns punch card system. Storage magnetic core 1,020 word of 33 binary bits each plus 4 words or 6 orders. Suitable for all types of work. Price on application.

VEEDER ROOT 6 DIGIT COUNTER



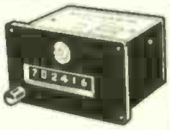
Suitable for counting all kinds of production runs, business machine operation. Mechanically driven Type KA1337. Reset manual knob. Ex-equipment but new condition. Special price **25/-** plus 5/- p. & p.

MINIATURE SQUARE COUNTER 6 DIGIT



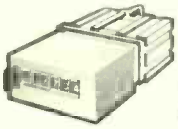
by Veeder Root. Rotary ratchet type, adds 1 count for each 36° movement of shaft **9/6** + 2/6 p. & p.

HI-SPEED QUICK RESET ELECTRO MAGNETIC COUNTERS



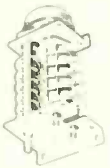
Push button reset 6 digits. 48 v. D.C. 3.5 watts. 20 counts per second. Size 3.875 × 2.625 in. Panel mounting. List £8. Our price **59/6.**

6 DIGIT ELECTRICAL IMPULSE COUNTER



With electrical and mechanical reset. Counter driven by a 110v D.C. 4,400 ohms coil. Reset 110v D.C. 800 ohm coil. Housed n plastic-alloy case The units can be interlocked with each other to give vertical or horizontal displays. Price **79/6** p. & p. 5/-.

REPEAT CYCLE TIMERS

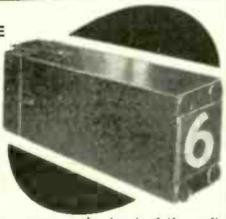


These timers repeat a set cycle of switching operations via a cam and micro switch, for as long as the motor is energised. Single Cam RB 21 in 2 min., 4 min., 5 min., 6 min. cycles @ **45/-**. Twin Cam RD 22 in 1 min., 2 min., 3 min., 4 min., 5 min. cycles @ **55/-**. 4 Cam RD 24 in 4 min., and 5 min. cycles @ **75/-**. 6 Cam RD 26 in., 2 min., 3 min., 4 min., 5 min. cycles @ **95/-**. 8 Cam RD 28 in., 3 min., 4 min. cycles @ **115/-**. All + p. & p. 5/-.

UNISELECTOR

8 and 4 Banks, 25 contact per bank, 2 sets of wipers 2 in. radius. Complete with surge capacitor. **25/-** and **45/-** respectively.

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 $\frac{3}{16}$ in. deep. 1 $\frac{5}{16}$ in. high. 3¾ oz. Character size ⅝ 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.**

LOW OHM SAFETY METER

12 milli-amps 5 ohms. suitable for testing circuits where currents must be limited **£12/10/-** p. p. 17/6.

MOTORS

HYSTERESIS REVERSIBLE MOTOR

Incorporating two coils. Each coil when energised will produce opposite rotation of output shaft. 240V 50 Hz. ⅓ 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 2 r.p.m., 1½ r.p.m., 1 r.p.m., ½ r.p.m., ¼ r.p.m., 1/3 r.p.m., 1/5 r.p.m., 1/6 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., 1/5 r.p.m., 1/15 r.p.m., 1/16 r.p.m., 1/20 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., 1440 r.p.h. **25/-** each. P. & P. 3/-.

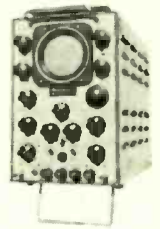
HYSTERESIS CLUTCH MOTOR

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. £1.5.0 postage and packing.

OSCILLOSCOPES



Cossor 1035. **£25.**
Cossor 1035 Mk. III. **£35.**
Cossor 1049 Mk. III. **£40.**
Solarton AD 513.2 L.F. & Servos & CD 5238.2 Long Persistent Tube. **£49.10.**
Furzehill 0.100. **£25.**
Airmec 249. **£25.**
Solartron AD 557 Pulse & Radar Field. **£55.**
Solartron Portable CD 1014 **£80.**

Philips 3230. **£85.**
Mullard L101 Double Beam **£96.10.**
Airmec 723. **£19.10.**

1200C Stroboscope for measuring rotational speeds of fans and moving mechanisms, etc. Speed Range: 600 r.p.m. - 14,500 r.p.m. PRICE: **£45.** CARRIAGE: 30/-.

UNUSED MINIATURE ¼ MILLION MAGNETIC STORAGE DRUM

Type N.S. 1389 16 write and 16 read heads 256 tracks magnetic storage drum. Each track at 800 r.p.m. Holds 1024 bits (32 words of 32 bits). Total storage 250,000 bits. Suitable for many data storage problems. 8" high, 10" dia., 21" base. **£290**, carr. extra.

A.F. GENERATOR TYPE H MODEL I.

High impedance, output from 20V. R.M.S. to 200 micro volts. Frequency Range 15c/s to 50kc/s. Distortion less than 1%. Square wave output 800 micro volts to 80 volts peak. **£25.** carr. 30/-.

PULSE AMPLITUDE ANALYSER £105

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.8	60/-
200	0.5	Beckman	A	60/-
500	0.1	Beckman	8	70/-
500		Colvern	2501	45/-
500		Foxes	PX4	40/-
500		Colvern	2610	50/-
2K	0.5	Beckman	8A1101	60/-
2K		Beckman	7216	60/-
2K		Reliance	GPM15	40/-
10K	0.5	Beckman	A	60/-
10K	0.1	Beckman X	A	70/-
15K		Foxes	GPM15	50/-
18K		Beckman	A	60/-
20K	0.5	Beckman	A	60/-
30K		Colvern	2402	30/-
30K		Beckman	8A95C	60/-
30K	0.1	Beckman	A.88	70/-
30K	0.5	Beckman	8A 1692	60/-
30K	0.25	Beckman	8A 1692	65/-
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	8A3902	70/-
300K	0.1	Beckman	A	70/-

THREE TURN 780° ROTATION

100/100	0.5	Beckman	A	60/-
300		Beckman	9303	45/-
10K	0.5	Beckman	C.88	45/-
20K/20K	0.1	Beckman	C.8	60/-
10K/10K	0.1	Beckman	C	60/-
50K	0.5	Beckman	C.8	35/-

FIFTEEN TURN 5400° ROTATION

25K/25K ....Beckman B ...10 watts £6.10s
46/K/46K ....Beckman B ...10 watts £6.10s

TWENTY TURN 7200° ROTATION

250 ohms..General Controls..PXM130 .... 80/-
1 Meg.....General Controls..PXM130 .... 80/-
50K Reliance 40/-

156 TURN 56, 160° ROTATION

460 ohms....Kelvin Hughes......KTP0701... £9.10s.

FIVE TURN 1800° ROTATION

500 ohms....Colvern...........CLR 2505 ...... 40/-
U1.5K ......Colvern...........CLR 2605 ...... 40/-

SINE COSINE

Kelvin & Hughes 8CP5..14-4K.......... £17.10.0
Colvern 8601..........30K.......... £17.10.0
CLR 9602—Cam Corrected 25K.......... £17.10.0
8CP4 ....32K £17.10.0
8CP1 ....35K £17.10.0

PRECISION BECKMAN 40 TURN 14,400° ROTATION

Wirewound Precision Potentiometer. 8E 107A 20 watts at 40°C. 3 $\frac{1}{16}$" Diameter. Servo Mounting. 200 K. Brand New **£12.10s.** List Price £30.

GENERATORS

SIGNAL GENERATOR

T.F. 801A Sine Wave, Square Wave Generator. Frequency Range: 10-310 M.c/s. Output Voltage (maximum) 200 milli-volts ± 2db. Output impedance 75 ohms. Mark/Space Ratio 50/50 on square wave. Price **£120.** Packing and carriage £2.

SIGNAL GENERATOR

T.F. 517F/1 Sine Wave, Square Wave Generator. Frequency Range: 120-300 M. C/s. Auxiliary 18-54 Meg. c/s. Output Voltage 0.2 Volts. Output impedance 75 ohms. **£85.**

MARCONI T.F. 144G

Frequency Range 85 k.c/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. **£75** + £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. **£65.**

MARCONI VALVE VOLTMETER TF 428B/1

Frequency response on probe 10Kc/s/3-100Mc/s. Five separate Voltage Ranges. Overload Protection 100-250 A.C.I.P. Input 1MΩ Acc. ±2 % or 00.2V. Size: 10 × 16½ × 9in.—15lb. **£5/19/6.**

VOLSTAT

Advance
CVN500A. Input 190-260v. 50 Hz. Output 240v. R.M.S. 500 watt P.S.I. **£25**
CV500/27. Input 95-130v. 60 Hz. Output 85v. R.M.S. Load 4 amps P.S.I. **£8/10/0**
CV25E. Input 190-260v. 50 Hz. Output 6v. 25 watts **£9/10/0**
CV50J. Input 190-260v. 50 Hz. Output 230v. 50 watts **£12/10/0**
Carriage extra 15/-.

OSCILLATORS

MUIRHEAD D729 PHASE. METER AND POWER SUPPLY

Gives direct indication of phase angle 0°-360° and difference in level between two sinusoidal voltages (transfer function) over the frequency range 2 cycles per sec. to 100 Kc/s. **£275** Carriage £2.

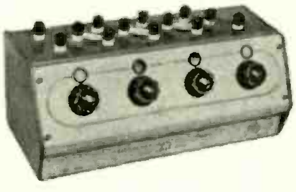
Digital Voltmeters 2003 A.C./D.C. D.C. range 1mV.-1KV. 4 Digits. **£135.** 2005 4 Digit range 10 microV. μ-2KV. Output BCD or decimal. **£260.** 2006 4 Digit D.C. range 10 microV.-1KV. Isolated output. Parallel BCD **£285.**

DAWE 444C AUTOMATIC L.F. SWEEP OSCILLATOR (NEW)

Amplitude 0 - 10V. Frequency Range 5Hz-5 KHz ±2% ±0.5 Hz. 18 Sweep Rates of 10 octaves/min. Frequency Response 0.5 dB. **£89.10.0.** Carriage extra.

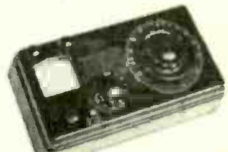
BRAND NEW LABORATORY TEST EQUIPMENT AT LESS THAN HALF PRICE

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 finished stove enamel.
List price £60. Our price **£22/10/-.**

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: 4V. Dry battery. Dimensions: 200 × 110 × 65mm. Weight: 0.9 kg.
List price £25. Our price **£9/19/6.**

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 K/cs for all decades except X1=0-15 K/cs. Maximum current: 0.5A for decades 1A for variometer (both primary and secondary dingings). Case: Polished teak. List price £65. Our price **£26.10.**

MUTUAL INDUCTANCE COIL TYPE R.7006

Specification. Value: 0.001 H. 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/-.**

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.

CARRIAGE EXTRA

ELECTRONIC BROKERS LTD., 49-53 PANCRAS ROAD, LONDON, N.W.1. Tel: 01-837 7781/2 Cables: SELELECTRO

CONVERTOR/BATTERY CHARGER. Input 240v 50 c/s, output 12v 5 amp DC. Input 12v DC, output 240v AC. 170 watt max. With fuse and indicator lamps. Size 9½ × 10 × 4½in. Weight 19lb. An extremely compact unit that will give many years' reliable service. Supplied with plug and lead. Only **£4/10/-**. P. & P. 15/- extra.
As above—fully serviceable—perfect interior but soiled exterior cases, £3. P. & P. 15/-.
G.M. TUBES. Brand new. G24/G38/G60 at **27/6** ea. G53/1, brass cased, **£6** ea.

PHOTOMULTIPLIERS. EMI 6097X at **£8/10/-** ea.

TRANSISTOR OSCILLATOR. Variable frequency 40 c/s to 5 kc/s. 5 volt square wave o/p, for 6 to 12v DC input. Size 1½ × 1½ × 1¾in. Not encapsulated. Brand new. Boxed. **11/6** ea.

TIMER UNIT. Standard primary transformer giving 18V 4 amp., G.E.C. bridge rectifier in bench or wall mounting case 10 × 10 × 5in. Complete with internal one second timer sub-chassis. Checked and tested **£2/15/0.** P. & P. 15/-.

COUNTENAY TIMER sub-chassis with 2-12AU7, transistor, relay etc. Requiring 12V. A.C. or D.C. to operate 22/6.

As above but 1, 5, 10 or 15 minutes. State which. **25/-** ea.

V.H.F. RECEIVER TYPE 715 by BCC. Complete tested and working (less crystal). 12v D.C. input. Ideal conversion 2 and 4 metres. In good condition. Supplied with conversion data. Only **£3/10/-**. P. & P. 7/6 ea.
RECEIVER UNIT TYPE 114. Freq. coverage 124-156 mc/s I.F. out 9.72 mc/s. Size 7 × 1¾ × 5½in. In original service carton, complete with valves, connections, etc. **32/6** ea. P. & P. 5/- ea.

RELAYS

Omron/Schrack octal based plug-in relays. 2 pole c/o 5A. 6v only. Brand new. Boxed. **12/6** ea.
G.E.C. 4 pole c/o 6/12v operation 180 ohms. Platinum contacts. Brand new. Boxed **12/6** ea.
Min. VARLEY type VP4. 4 pole c/o 430 ohm or 15 K/ohm. Brand new **6/6** ea.

Min. **SIEMENS.** 4 pole c/o. 24V operation. Brand new **8/-** ea.
S.T.C. sealed 2 pole c/o 48V. 2,500 ohm 48v. **3/6** ea. 12v **7/-** ea.

CARPENTERS polarised Single pole c/o 20 and 65 ohm coil as new, complete with base **7/6** ea. Single pole c/o 680, 1,110 and 1,570 ohm coil. As new **6/6** ea.
Brand New. Single Pole c/o (type 5A2). 2 × 1200 ohms. **8/6** ea.

POTENTIOMETERS

COLVERN Brand new. 5; 10; 50; 100; 250; 500 ohms; 1; 2.5; 5; 10; 25; 50k all at **2/6** ea. Special Brand new **MORGANITE** 250K 1 in. sealed. Normal price 9/-, our price **3/6** ea.

INSTRUMENT 3" Colvern. 5; 25; 50; 100 ohms; 2.5; 25K. All at **7/-** ea.

TRIM POTS. Paignton-solder lugs 5, 10 & 25K at **7/6** ea.; Pins- 10; 20; 50; 100; 200; 250; 500 ohms: 2.5; 25 and 50K at **15/-** ea.

DARSTAN-preset-sealed ½" dia. ¼ high. 1; 2 and 5K **2/-**

HIGH RESOLUTION 25K 80 turns. Complete with knob **6/6**

COLVERN 50K Ten turn complete with dial **£1** P. & P. 2/6 ea.

GENERAL CONTROLS. 100K Ten turn. Brand new. Boxed **25/-** ea.

ALMA precision resistors 100K; 400K; and 998K—0.1% **5/6** ea: 3.25K—0.1% **4/-** ea.

DALE heat sink resistors, non-inductive 50 watt. Brand new. 15 ohms—**6/6** ea.; 8.2K—**5/-**. Excellent dummy load

CAPACITORS

ERIE feed through ceramicons 1000 pf—**9d.** ea.
Sub-min. **TRIMMER** ¼ square. 8. 5pf. Brand new **2/6** ea.
Concentric **TRIMMER** 3/30 pf. Brand new **1/6** ea.

DUBILIER Electrolytic. 32mfd 350v D.C. Brand new **1/9** ea.

EHT 1000pf 20KV working, ideal transmitter blocking capacitors **6/6** ea.

VISCONOL EHT. Brand new 0.002 15kV **8/6** ea; 0.0005 25 kV, **16/-** ea.

E.H.T. 7.5kV working 0.25 mfd **8/6** ea.; Brand new 5 kV 0.25mfd **10/6** ea.; 10kV 0.05mfd **7/6** ea.

GEARED MOTORS 240v 50 c/s synchronous. Geared down to 60 rpm. Brand new **37/6** ea. P. & P. 7/6.

DIODES 1N914. Brand new **1/3** ea.; **12/-** doz.; **£4**—100; **£25**—1,000.

PHOTOCELL equivalent OCP 71 **2/6** ea.

BURGESS Micro Switches V3 5930. Brand new **2/6** ea.

BULGIN panel mounting Lamp holders. Red. Brand new **2/3** ea.

PLUGS & SOCKETS. New & ex. eq. Plessey; Paignton Cannon; Electromethods; Belling & Lee; Bulgin etc. etc. Write for lists.

MINIATURE SPEAKERS 15 ohm 100 MW 2in. diameter. Brand new. **7/-** ea. P. & P. 2/6 ea.

TRANSISTORS BC 114—NPN Low noise high gain audio, etc.; BC 116—PNP General purpose 200 mc/s. Ex brand new equipment. Guaranteed perfect. Good lead length. 2/- ea.
Also RT Micrologic L 9914 I.C. 8 lead TO-5 can. Fan out 16 dual 2 input nand nor gate, capable of F/F action at 20 mc/s or non inverting gate or gate + invert. Good length leads. Guaranteed perfect **5/-** ea.

TEST GEAR

OSCILLOSCOPES

E.M.I.	WM 8 DC—15 mc/s **£65**
E.M.I.	WM 2 DC—13 mc/s **£35**
E.M.I.	3794 DC—5 mc/s **£15**
SOLARTRON	QD 910. Storage scope **£170—£315**
SOLARTRON	7118.2 D.B. DC—9 mc/s **£60**
SOLARTRON	643 DC—15 mc/s **£80**
SOLARTRON	513/523 DC—10 mc/s **£35**
SOLARTRON	568 DC—6 mc/s **£18**
COSSOR	1035 DB. **£20**
COSSOR	1049; 1049 Mk. 3. DB. **£22/10** and **£30**
HARTLEY	13A DB. **£18/10/-**

All carefully checked and tested. Carriage 30/- extra.

MARCONI

TF 956 Audio Frequency Wattmeter **£15** Carr. 10/-
TF 886 Magnification Meter **£45** Carr. £1
TF 762C UHF Generator **£40** Carr. £1
TF 369 N. 5 Impedance Bridge **£75** Carr. 30/-
TF 144G Signal Generator, Serviceable, Clean **£18**
In Exceptional condition **£30** Carr. 30/-
TF 885 Video Oscillator Sine/Square **£40** Carr. 30/-
TF 899 Millivolt meter **£8** Carr. 10/-
TF 195M Sine wave oscillator 0/40kc/s **£14** Carr. £1
TF 517 VHF Generator 10 mc/s—300 mc/s **£6** Carr. £1
TF 428B/1 Valve voltmeter **£4** Carr. 10/-
TF 428B/2 Valve voltmeter **£10** Carr. 10/-
TF 338B Attenuator **£5** Carr. 10/-
TF 791B Carrier Deviation Meter **£45** Carr. 30/-

SOLARTRON

Pulse generator POS 100C 50 c/s—1 mc/s **£25** Carr. £1
Laboratory amplifier AWS51A. 15c/s—350kc/s **£35** Carr. £1

Stabilised P.U. SRS 151A **£20** Carr. 30/-
Stabilised P.U. SRS 152 **£15** Carr. 30/-
Stabilised P.U. AS 516 & AS 517 **£3**, and **£6** Carr. 10/-

AVO

Generator CT 368 2—225 mc/s **£50** Carr. 15/-
Generator 50kc/s—80 mc/s **£16** Carr. 15/-
Testmeter No. 1 **£14** Carr. 15/-
Electronic Testmeter CT 38. Complete **£18** Carr. £1

SPECIAL. Multimeter CT471A. Battery operated, fully transistorised, sensitivity 100 M ohm/V, measures a.c./d.c. voltage (12mV-1200V scales, +/— 3% / +/— 2% f.s.d.) a.c./d.c. current (12 microA-1.2A scales, +/— 3% / +/— 2% f.s.d.) resistance (12 ohm-120M ohm scales, +/— 3% m.s.d.), h.f./vhf/uhf. voltage with multiplier (4V-400V scales up to 50 MHz; 40 mV-4V up to 1000 MHz). Brand new **£75** Carr. 30/-
CT 471B, as above by G. & E. Bradley **£75** Carr. 30/-

CINTEL

Transistorised Nucleonic Scalers with adjustable discriminator. 6 meters display 0-9 giving count of 10 to the 5. In a new condition **£30** Carr. 15/-
Wide Range Capacitor Bridge **£25** Carr. 15/-
Sine and Pulse Generator type 1873 **£25** Carr. 15/-

AIRMEC

Valve Millivoltmeter type 264. 3MV-1V **£20** Carr. £1
Counter type 865. 6 decades. Bright Vertical display gate facilities. Very good condition **£30** Carr. 30/-
Klystron Power Supply 698B **£25** Carr. £1

SIGNAL GENERATOR/WAVEMETER type 61. 90 to 160 mc/s. Built in crystal markers. Calibrated piston attenuator. Standard mains input. Excellent condition. **£12/10/-**. Carr. 30/-.

SIGNAL GENERATOR Type 62. 95-160 mc/s in one range. 1 mc/s and 10 mc/s internal crystal markers; provision for external crystal marker. Sine and square wave mods; precision attenuator. Complete with leads, pads, etc. Nice condition. **£40**. Carr. 30/-.

SIGNAL GENERATOR type CT 478 by W. H. Sanders. Freq. range 1·3 kmc/s to 4·2 kmc/s. Output power calibrated dbb. New **£40.** Carr. £2/10/-.

AM/FM OSCILLATOR Type 1 CT 212. 85 kc/s to 32 mc/s. As new **£35.** Carr. **£1**

HEINZ GUNTHER AM/FM Generator 9—200 mc/s. **£30** Carr. £1

SIGNAL Generator CT 53. Complete with leads. Good condition. **£10** Carr. 15/-

FREQUENCY Meter BC 221. **£17/10/0**; with built-in stab. P.U. **£22/10/0** Carr. 15/- With Charts.

DIGITAL VOLTMETER type BIE 2114. 1 mV to 1kV DC. Auto decimal change. Excellent condition **£65**

MIC-O-VAC type 22 (CT54) Volts; Current; Ohms. D Cto 200 mc/s with probe, leads etc. As new **£8/10/0** P. & P. 10/-.

VIBRATING REED ELECTROMETER type N 572 by ECKO. Range 10 to the -14. Max sensitivity FSD for 1 of 0.03 Micro-microamps. **£25** ea. Carr. £1

RACAL FREQUENCY COUNTERS
SA 20 4 decades 100 kc/s **£20** ea.
SA 21 6 decades 10 mc/s **£45** ea.

SA 28 as SA 21 with convertor extending range to 30 mc/s **£65** ea.

GRAUMONT-KALEE Flutter meter type 564 **£35**

GENERAL RADIO Precision Capacitor type 722. 50 pf to 290 pf. **£75** Model 222F at **£55**

Miniature **SCOPE** type 1200B. Ideal TV servicing etc. Checked and tested **£10** P. & P. £1

ADVANCE Signal Generator type D1. 2 mc/s to 190 mc/s. Sine and square mod. With original charts. Excellent condition **£12/10/0** P. & P. £1

SERVOMEX. Stabilized D.C. Power supplies type DC3. 0-30 Volts, 0-7 amps. Separate voltage and current meters. **£35.** Type 38, bench mounting. 0-15 Volts, 0-2.5 amps. Separate voltage and current meters **£25**

TRANSISTOR Stabilised Power Unit. 48v. 4 amp. Manufactured by E.M.I. Open chassis. Brand new. Highest quality. Size 10½ × 5½ × 6½in. high. **£6** ea.

RACAL stabilizer unit 24V. raw DC in 20 volts 1amp stab and 12V. 5 MA Zener stab out. Brand new condition. Size 5 × 3 × 6 in. Complete with circuit diagram. **35/-** ea.

MAINS FREQUENCY METERS with large 270 deg. Dial calibrated 45 to 65 cycles 4in. diameter. In original service carton. **£3/10/-**. P. & P. 7/6.

19in. Rack Mounting **CABINETS** 6ft. high 2ft. deep. Side and rear doors. Fully tapped, complete with base and wheels. **£12/10/0** Carriage at cost.

EPSYLON 4 track tape recorder using 1in. tape. Metered input. Very high quality. Complete with bulk eraser and tape. **£75.**

MULLARD Transistorised Analogue to Digital Convertor Model L 281. As new. **£20** Carr. 15/-

SUNVIC DC chopper Amplifier type DCA 1. Superb condition. **£22/10/0** ea. Carr. 20/-

SEQUENCHAL TIMERS 8 individual timer circuits each with 0-100 sec calibrated dials. Ideal displays, processes, etc. Standard mains input **£25** Carr. 25/-

Ex- SOUTHERN ITV CAMERA with image orthicon tube and single lens. Mounted on tripod. Sold as seen. **£40**

ISOLATING TRANSFORMERS 240V in 240V 7 KVA out. As new. **£25** ea. Carr. £2/10/-

DESK Telephones. Current type. 3 wire red, green, white. Ideal extensions etc. As new **£3** ea.

MODERN Transistorised 10 line automatic desk top exchange. Complete with 10 A.E.I. Telephones, standard G.P.O. type dialling to call any other line. Exchange size 16 × 5 × 6 housed in attractive mahogany case. Complete set. **£55**

METERS

ELLIOTT Portable Reflecting Voltmeter. 6" dial scaled 0 to 12.5 Ranges 12.5—25—37.5 Frequency range DC to 2.5 kc/s. Accuracy 0.5 fsd. Adjustable feet, built in level, magnetic shield, movement lock. In fine quality wood case. **£20** P. & P. 15/-

EHT ELECTROSTATIC Ernest Turner, etc., 0-1.5kV. **£2** ea.; 0-3.5 KV **£2/15/0** ea.; 0-5 KV **£3/10/0** ea.; 0-7.5 KV **£4/5/0** ea.

TAYLOR 100-0-100 Micro amp scaled size 4 × 2" with internal lamp scaled 6-0-6 **1/10/0** ea.

GRIFFIN & GEORGE 3" round in sloped open ended case with terminals 3 types 0/20; 0/100. All 50 c/s. **£1** ea.

TRANSFORMERS. All standard inputs.
18v 6 amp and 12v ½ amp. Sep. windings, **18/6** ea.
18v 12 amps at **£3** ea.
3kV 4·5mA. 4v 0·5 amp × 2, 4v 1·1 amp. **£3/10/-** ea. 350-0-350 75mA. 5v 2 amps × 2, **21/-** ea.
Gardners 6·3v 2A; 6·3v 1·5A; 6·3v 0·1A. Size 3 × 1¾ × 4¾in. As new. **9/6** ea. P. & P. 3/- ea.
Gardners. Potter. Multi 6·3's combine to give 48v at 4 amps or 6·3 at 45A. With 350-0-350 at 50mA. **£2/10/-** ea.
Parmeko/Gardners. Potted. 475-60-0-60-475 at 160 mA; separate winding 215-0215 at 45mA; 6·3v 5A; 6·3v 0·75A; 5v 3A. As new. **£3** ea.
Gardners 400-350-0-350-400 at 250MA; 0/4/6·3v 4 amp × 2; 0/4/6·3 2 amp; 0/4/5 3·5A. In original boxes. **£4/10/-** inc. post. Gardiners 2kV 10MA. As new, **£3** incl. postage. Gardiners 2kV 10MA and 4 volts × 2. **£4/10/-** ea incl. postage.
Parmeko 65v 1 amp. Separate 0-18-24v at 0·5 amp. **30/-** ea. Gard/Parm/Part. 450-400-0-400-450. 180 MA. 2 × 6.3v. **£3** ea.

ADVANCE Constant Voltage Trans. 6 volts 50 watt. As new **£3** P. & P. 10/-
Gardners 4v 30 amp. Brand new **£1/10/0** incl. postage. 3 for **£3/10/0** incl. postage.
Gardners 5v 30amp. Brand new **£2** ea. incl. postage.

CHOKES. 5H; 10H; 15H; up to 120mA. **8/6** ea. Up to 250mA **12/6** ea.
Brand new. HADDON 10H 160mA. **12/6** ea.
Large quantity LT, HT, EHT transformers. Your requirements, please.
Panel switches DPDT ex eq. **2/6** ea.; DPST Brand new **3/6** ea.; DPDT twice, brand new **6/-**; heavy duty DPST brand new **6/-** ea.

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PRECISION rotary stud switches 2 pole 12W size 2" sq., ¼" shaft. **£2/10/0** ea.

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The result of the combined resources of SGS and RCA, these quasi circuits set new standards in quality and performance. Each kit is complete with circuit diagram, all semiconductors, resistors, capacitors and printed circuit board.

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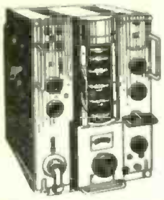
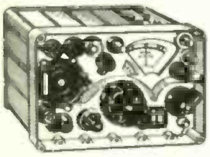
WW/270

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 × 13½ × 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/-.

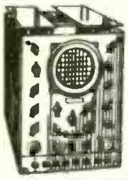


R209 Mk. II COMMUNICATION RECEIVER

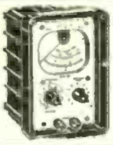


11 valve high grade communication receiver suitable for tropical use. 1-20 Mc/s. on 4 bands. AM/CW/FM operation. Incorporates precision vernier drive, B.F.O. Aerial trimmer, internal speaker and 12v. D.C. internal power supply. Supplied in excellent condition, fully tested and checked. **£15.0.0** Carr. 20/-.

TYPE 13A DOUBLE BEAM OSCILLOSCOPES BARGAIN



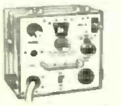
An excellent general purpose D/B oscilloscope. T.B. 2 cps-750 Kc/s. Bandwidth 5.5 Mc/s Sensitivity 33 Mv/cm. Operating voltage 0/110/200/250 v. A.C. Supplied in excellent working condition, £22/10/-. Or complete with all accessories, probe, leads, lid, etc. £25. Carriage 30/-.



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/-.

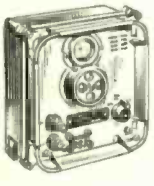
RACAL MA.168 TRANSISTORISED DIVERSITY SWITCH
Brand new condition £15. Carriage 10/-.

TO-2 PORTABLE OSCILLOSCOPE

A general purpose low cost economy oscilloscope for every-day 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.

FIELD TELEPHONES TYPE L. Generator ringing, metal cases. Operate on 2 1.5 v. batteries (not supplied.) Excellent condition. £4.10.0 per pair. Carr. 10/-.

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.

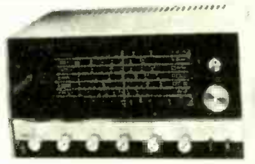
TRIO COMMUNICATION RECEIVER MODEL 9R-59DE

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.	£212 0
TRIO JR 500SE 10-80 Metre Amateur Receiver	£69 10

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.)



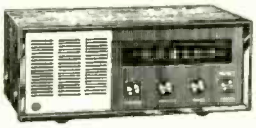
TRIO JR-310 NEW AMATEUR BAND 10-80 METER RECEIVER IN STOCK £77.10.0

RCA COMMUNICATIONS RECEIVERS AR88D

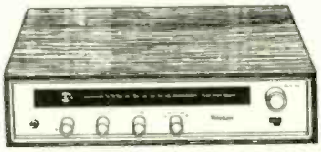
Latest release by ministry BRAND NEW in original cases. 110-250v. A.C. operation. Frequency in 6 Bands. 535 Kc/s—32 Mc/s continuous. Output impedance 2.5-600 ohms. Incorporating crystal filter, noise limiter, variable BFO, variable selectivity, etc. Price £87-10-0. Carr. £2.

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/-.



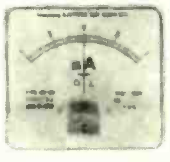
TELETON MODEL CR-10T AM/FM STEREO TUNER AMPLIFIER



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 13⅜in. × 3½in. × 9⅛in. 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		

FULL RANGE OF OTHER SIZES IN STOCK—SEND SAE FOR LEAFLET

LAFAYETTE STEREO AMPLIFIER MODEL STEREO 10

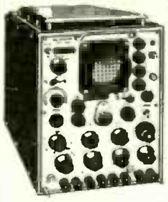
Completely transistorised 5 watts per channel I.H.F. music power. Inputs for gram and tuner. Separate volume controls and variable tone control for Bass and Treble. A compact size, big performance stereo amplifier ideal for limited space systems. Beautifully finished in grey and aluminium. Size 7⅛in. × 2 15/16 in. × 5⅛in. AC. 220/240v.

Price **£11.19.6** Carr. 7/6.

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.
25 WATT. 10/25/50/100/250/500/1000/1500/2500 or 5000 ohms. 14/6. P. & P. 1/6.
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.

SOLARTRON CD711S.2. DOUBLE BEAM OSCILLOSCOPE



An extremely high quality oscilloscope originally costing £400. Switched beam. Identical Y1, Y2 Amplifiers D.C. to 9 Mc/s. Sensitivity 3mV/CM to 100 V/CM. Time base 10μ/sec. to 10 M/secd. Calibrator. X amplifier D.C. to 2.5 Mc/s. Z Modulation. 110/250 v. A.C. Supplied in good working order. £65. Carriage 50/-.

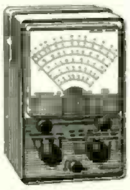
AVO 48A
Perfect order with set of shunts and resistances £12-10-0. P. & P. 7/6.

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

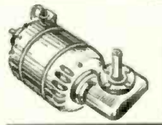


High quality instrument with 28 ranges. D.C. volts 1.5-1,500 v. A.C. volts 1.5-1,500 v. Resistance up to 1,000 megohms. 220/240v. A.C. operation. Complete with probe and instructions £17/10/0. P. & P. 6/-. Additional Probes available; R.F. 35/- H.V. 42/6.

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/-.

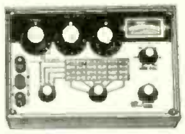


GEARED MAINS MOTOR
Parulux type SD19 230/250 v. A.C. Reversible. 30 r.p.m. 40 lb. ins. Complete with capacitor. Excellent condition. 99/6. Carr. 10/-.

TE-16A TRANSISTORISED SIGNAL GENERATOR

5 Ranges 400 KHZ-30 MHZ. An inexpensive instrument for the handy-man. Operates on 9v. battery. Wide easy to read scale. 800 KHZ modulation. 5¼" × 5¼" × 3½". Complete with instructions and leads. £7/19/6. P/P 4/-.

TRANSISTORISED L.C.R. A.C MEASURING BRIDGE

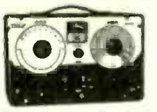


A new portable bridge offering excellent range and accuracy at low cost. Ranges: R. 1Ω—11.1 MEG Ω 6 Ranges ± 1%. L. 1μH—111 HENRIES. 6 Ranges — 2%. C. 10PF ± 1110MFD. 6 Ranges ± 2%. TURNS RATIO 1:1/1000—1:11100. 6 Ranges ± 1%. Bridge voltage at 1,000 CPS. Operated from 9 volts. 100μA. Meter indication. Attractive 2 tone metal case. Size 7¼" × 5" × 2". £20. P. & P. 5/-.

AUTO TRANSFORMERS
0/115/230v. Step up or step down. Fully shrouded
150 W. 42/6. P. & P. 3/6
300 W. 59/6. P. & P. 4/6
500 W. £4/10/0. P. & P. 6/6
1,000 W. £6/10/0. P. & P. 7/6
1,500 W. £7/19/6. P. & P. 8/6
7,500 W. £15/10/0. P. & P. 20/-.

G. W. SMITH & Co. (Radio) Ltd.
ALSO SEE OPPOSITE PAGE

ARF-100 COMBINED AF-RF SIGNAL GENERATOR



AF. SINE WAVE 20-200,000 cps. Square wave 20-30,000 cps. O/P HIGH IMP. 21 v. P/P 600Ω 3.8 v. P/P. R.F. 100 kc/s-300 Mc/s. Variable R.F. attenuation. Int./Ext. Modulation. Incorporates dual purpose meter to monitor. AF output and % mod. on R.F. 220/240 v. A.C. £32.10.0 Carr. 7/6.

VOLTAGE STABILISER TRANSFORMERS.

180-260v. input. Output 230v. Available 150w or 225w. £12.10.0. Carr. 5/-.

TE-20RF SIGNAL GENERATOR

Accurate wide range signal generator covering 120 kc/s-260 Mc/s. on 6 bands. Directly calibrated. Variable R.F. attenuator. Operation 200/240 v. A.C. Brand new with instructions. £15.

P. & P. 7/6. S.A.E. for details.

PEAK SOUND PRODUCTS

Full range of Amplifiers, kits, Speakers in stock.

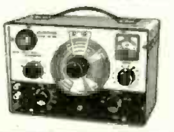
TE22 SINE SQUARE WAVE AUDIO GENERATORS

Sine: 20 cps to 200 kc/s. on 4 bands. Square 20 cps to 30 kc/s. Output impedance 5,000 ohms, 200/250 v. A.C. operation. Supplied brand new and guaranteed with instruction manual and leads. £16.10.0. Carr. 7/6.

MARCONI TF885 VIDEO OSCILLATORS

0-5 mc/s Sine Square Wave £45. Carr. 20/-.

LAFAYETTE TE-46 RESISTANCE CAPACITY ANALYSER

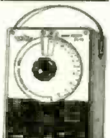


2 pf-2,000 mfd. 2 ohms-200 megohms. Also checks impedance turns ratio insulation. 200/250 v. A.C. Brand New, £17.10 Carr. 7/6.

MARCONI TF.142E DISTORTION FACTOR METERS

Excellent condition. Fully tested £20. Carr. 15/-.

TY75 AUDIO SIGNAL GENERATOR



Sine Wave 20 CPS—200 Kc/s. Square Wave 20 CPS—30 Kc/s. High and low impedance output. Output variable up to 6 volts. 220/240 volts A.C. Brand new with instructions. £16. Carr. 7/6. Size 210 × 150 × 120 mm.

MARCONI TF195M BEAT FREQUENCY OSCILLATORS

0-40 kc/s. £20. Carr. 30/-.

TE-20D RF SIGNAL GENERATOR

Accurate wide range signal generator covering 120 Kc/s—500 Mc/s on 6 bands. Directly calibrated. Variable RF. attenuator, audio output. Xtal socket for calibration. 220/240V. A.C. Brand new with instructions. £15. Carr. 7/6. Size 140 x 215 x 170 mm.

ADVANCE TEST EQUIPMENT

Brand new and boxed in original sealed cartons.

JIB. AUDIO SIGNAL GENERATOR
15 c/s to 50 Kc/s. Sine wave. Output 600 ohms or 5 ohms. £30.0.0.

VM79. UHF MILLIVOLT METER
100 Kc/s to 1,000 Mc/s. A.C. 10 mV to 3v. D.C. 10 mV. to 3v. Current 0.01 uA to 0.3 mA. Resistance 1 ohm to 10 megohm. £125.0.0.

TTIS. TRANSISTOR TESTER
Full range of facilities for testing PNP or NPN transistors in or out of circuit. £37.10.0. Carriage 10/- per item.

MODEL ZQM TRANSISTOR CHECKER

It has the fullest capacity for checking on A, B and Ico. Equally adaptable for checking diodes, etc. Spec.: A: 0.7-0.9967. B: 5-200. Ico: 0/50 micro-amps. 0.5 mA. Resistance for diode 200Ω + 1 MEG. Supplied complete with instructions, battery and leads. £5/19/6. P. & P. 2/6.

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The latest edition giving full details of a comprehensive range of HI FI EQUIPMENT, COMPONENTS, TEST EQUIPMENT and COMMUNICATIONS EQUIPMENT.... Nearly 200 pages, fully illustrated and detailing thousands of items—many at bargain prices. FREE DISCOUNT COUPONS VALUE 10/-.

SEND NOW—ONLY 7/6 P & P 1/-

GARRARD

Full current range offered brand new and guaranteed at fantastic savings

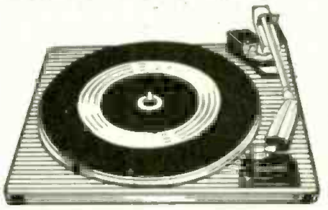
•2025 Stereo	£7.19.6	•SL55	£11.19.6
•2025T/C Mono/ Stereo	£8.17.6	A70 MKII	£11.19.6
		AP75	£17.17.0
•3000 Stereo	£9.19.6	401	£28. 7.6
•SP25 MKII	£11.19.6	SL75	£28.10.0

Carriage/insurance 7/6 extra any model.

WB4 Bases £3/19/6. Perspex cover £3/10/0

•Special offer base and cover available for these models at £4.15.0. Carr. 5/-.

Full range of Garrard accessories available



LAFAYETTE LA-224T TRANSISTOR STEREO AMPLIFIER

19 transistors, 8 diodes. IHF music power 30 watts at 8 ohms. Res. 30-20,000 ±2 dB at 1 w. Distortion 1% or less. Inputs 3 mV and 250 mV. Output 3-16 ohms. Separate L and R volume controls. Treble and bass controls. Stereo phone jack. Brushed aluminium, gold anodised extruded front panel with metal case. Size 10½in. × 3⅝ in. × 7½ in. Operation 115/230 volt A.C. £28. Carr. 7/6.

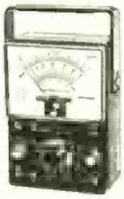
Variable Voltage TRANSFORMERS

Brand new, guaranteed and carriage paid.
High quality construction. Input 230 v. 50-60 cycles.
Output full variable from 0-260 volts. Bulk quantities available.
1 amp.—£5/10/-; 2.5 amp.—£6/15/-; 5 amp.—£9/15/-;
8 amp.—£14/10/-; 10 amp.—£18/10/-; 12 amp.—£21; 20 amp.—£37

MULTIMETERS *for EVERY purpose!*

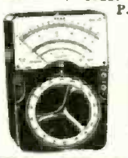
TE-900 20,000Ω/VOLT GIANT MULTIMETER Mirror scale and overload protection. 6in. full view meter. 2 colour scale. 0/2.5/10/250/1,000/5,000 v. A.C. 0/25/12.5/10/50/250/1,000/5,000 v. D.C. 0/50μA/110/100/500mA/10 amp. D.C. 02K/200K/20 MEG. OHM. £15/-/-. P. & P. 5/-.

MODEL AS-100D. 100KΩ/Volt. 5in., mirror scale. Built-in meter protection 0/3/12/60/120/300/600/1,200 v. D.C. 0/6/30/120/300/600 v. A.C. 0/10μA/6/60/300MA/12 Amp. 0/2K/200K/2M/200MΩ. —20 to +17dB. £12/10/-. P. & P. 3/6.



MODEL TE-90 50,000 O.P.V. Mirror scale overload protection. 0/3/12/60/300/600/1,200 v. D.C. 0/6/30/120/300/1,200. v D.C. .03/6/60/600 MA. D.C. 16K/160K/1.6/16 MEG Ω. —20 — + 63db. £7/10/0. P. & P. 3/-.

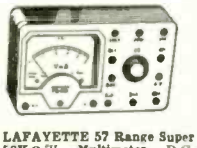
MODEL TE-70. 30,000 O.P.V. 0/3/15/60/300/600/1,200 v. D.C. 0/6/30/120/600/1,200 v. A.C. 0/30μA/3/30/300mA. 0/16K/160K/1.6M/16 MegΩ. £5/10/-. P. & P. 3/-.



MODEL TE-80. 20,000 O.P.V. 0/10/50/100/500/1,000 v. A.C. 0/5/25/50/250/500/1,000 v. D.C. 0-50μA. 5/50/500mA. 0/6K/60K/600K/6 meg. £4/17/6. P. & P. 3/-.

MODEL TE-12. 20,000 O.P.V. 0/0.6/6/30/120/600/1,200/3,000/6,000 v. D.C. 0/6/30/120/600/1,200 v. A.C. 0/60μA/6/60/600 mA. 0/6K/600K/6 Meg./60 Meg.Ω. 50 PF. .2 MFD £5/19/6. P. & P. 3/6.

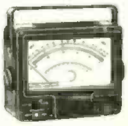
TE-51. NEW 20,000Ω/VOLT MULTIMETER, with overload protection and mirror scale, 0/6/60/120, 1,200 v. A.C. 0/3/30/60/300/600/3,000v. D.C. 0/60μA/12/300m A.D.C. 0/60K/6 meg. ohm. 92/6. P. & P. 2/6.



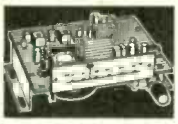
MODEL PT-34. 1,000 O.P.V. 0/10/50/250/500/1,000V. a.c. and d.c. 0/1/100/500 mA. d.c. 0/100 K Ω 39/6. P. & P. 1/6.

MODEL TE-10A. 20kΩ/Volt 5/25/50/250/500/2,500 v. D.C. 10/50/100/500/1,000 v. A.C. 0/50μA/2.5 mA/250 mA D.C. 0/6K/6 meg. ohm. —20 to +22 dB. 10-0, 100 mfd. 0.100-0.1 mfd. 69/6. P. & P. 2/6.

LAFAYETTE 57 Range Super 50KΩ/V. Multimeter. D.C. volts 125mv—1000v. A.C. volts 1.5v—1000v. D.C. Current 25μA—10 Amp. Ohms 0—10 MegΩ. D.B.—20 to +81 db. Overload protection. £12/10/-. P. & P. 3/6.



TRANSISTOR FM TUNER



6 TRANSISTOR HIGH QUALITY TUNER SIZE ONLY 6in. × 4in. × 2½in. 3 I.F. stages. Double tuned discriminator, ample output to feed most amplifiers. Operates on 9 volt battery. Coverage 88-108 Mc/s. Ready built ready for use. Fantastic value for money. £6/7/6. P. & P. 2/6.

STEREO MULTIPLEX ADAPTORS, 99/6.

SINCLAIR EQUIPMENT

Z30 amplifier 89/6.
PZ5. Power Supply Unit 99/6.
PZ6. £7/19
STERE... amplifier. £9/19/6.
Q16 Speak... £8/19/6.
Micromatic Radio Kit 49/6. Built 59/6.

NOW AVAILABLE IC10 ..59/6

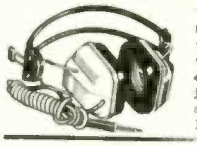
ALL POST FAI...
SPECIAL OF...

TWO Z30 amps., PZ5, Power Supply Stereo 60 pre-amplifier .... £22.

NEW SINCLAIR 2000 SYSTEM

35 watt Integrated Amp. £27.10.0 Carr. 5/-.
Self-powered FM Tuner. £25. Carr. 5/-.

ECHO HS-606 STEREO HEADPHONES



Wonderfully comfortable. Lightweight adjustable vinyl headband, 6ft. cable and stereo jack plug. 25-17,000 c.p.s. 8Ω imp. 67/6. P. & P. 2/6.

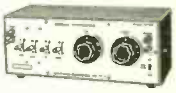
HOSIDEN DH04S 2-WAY STEREO HEADPHONES

Each headphone contains a 2½in. woofer and a ½in. tweeter. Built in individual level controls. 25-18,000 c.p.s. 8Ω imp. with cable and stereo plug. £5/19/6. P. & P. 2/6.

TRANSISTORISED TWO-WAY TELEPHONE INTERCOM

Operative over amazingly long distances. Separate call and press to talk buttons. 2-wire connection. 1000's of applications. Beautifully finished in ebony. Supplied complete with batteries and wall brackets. £6/19/6 pair. P. & P. 3/6.

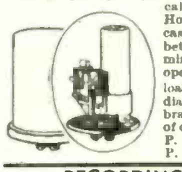
TE111 DECADE RESISTANCE ATTENUATOR



Variable range 0-111 db. Connections. Unbalanced T and Bridge T. Impedance 600 ohms. Range (0.1 db × 10) + (1 db × 10) + 10 + 20 + 30 + 40 db. Frequency: DC to 200 KHZ (—3db). Accuracy: 0.05 db. + indication db × 0.01. Maximum input less than 4 watts (50 volts). Built in 600 Ω load resistance with internal/external switch. Brand new £27/10/-. P. & P. 5/-.

CAR LIGHT FLASHERS

Heavy duty light flasher employs a condenser discharge principle operating on electro mechanical relay. (As inset.) Housed in strong plastic case. Flashing rate between 60-120 per minute. 12 volt D.C. operation. Maximum load 6 amps. Size 2⅛ in. dia. by 4in. Supplied brand new at a fraction of original cost. 6/6 each, P. & P. 2/6. (3 for 17/6. P. & P. 4/6.)



RECORDING HEADS

Cosmocord ¼ track heads: Post extra.

Record/replay. High imp.	65/-
Erase. Low imp.	20/-
Marriott ¼ track heads. Post extra.	
Record/Playback, high imp.	65/-
Erase, low imp.	20/-

AMERICAN RECORDING TAPES

First grade quality American tapes. Brand new and guaranteed. Discounts for quantities. Postage 2/-. Over £3 post paid.

3in. 225ft. L.P. Acetate	3/6
3¾in. 600ft. T.P. Mylar	10/-
5in. 600ft. Std. plastic	8/6
5in. 900ft. L.P. acetate	10/-
5in. 1,200ft. D.P. Mylar	15/-
5¾in. 1,200ft. L.P. acetate	12/6
5¾in. 1,200ft. L.P. Mylar	16/-
5¾in. 1,800ft. D.P. Mylar	22/6
5¾in. 2,400ft. T.P. Mylar	39/6
7in. 1,200ft. Std. acetate	12/6
7in. 1,800ft. L.P. acetate	15/-
7in. 1,800ft. L.P. Mylar	20/-
7in. 2,400ft. D.P. Mylar	25/-
7in. 3,600ft. T.P. Mylar	45/-

MAXELL TAPE CASSETTES

C60—10/3; C90—14/3; C120—19/6. Post extra.

G.W.SMITH & CO.(RADIO) LTD

All Mail Orders to—
147, Church Street, London, W.2
Tel: 01-262 6562
(Trade supplied)

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34, LISLE STREET, LONDON, W.C.2 Tel: 01-437 9155
311, EDGWARE ROAD, LONDON, W.2 Tel: 01-262 0387

OPEN 9-6 MONDAY TO SATURDAY (EDGWARE ROAD ½ DAY THURSDAY)

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

Stock No.	Capacity	Voltage	Price s.	Price d.	No. Required	£ s. d.
1	1 uf	6		4		
2	[illegible]	25		4		
3	4 uf	4		4		
4	6	6		4		
[illegible]	64 uf	9		4		
[illegible]	20 uf	6		4		
11	8 uf	6		4		
16	32	150		9		
17	64	2.5		3		
18	100/200/200/50	275	7	6		
19	50/80	300	3	0		
21	24	275	1	0		
22	10	25		3		
23	125	2.5		3		
25	16/32	350	2	6		
[illegible]	32	275	1	6		
[illegible]	75/75/75/75	150	2	6		
30	12.5	40		9		
[illegible]	3.000	35	7	6		
33	[illegible]000	15	3	0		
34	[illegible]000	30	7	0		
35	[illegible]0	70	2	0		
36	[illegible]00	9	2	0		
38	7[illegible]	12	1	9		
39	100 uf	275	2	6		
40	30 uf	10		3		
42	16 uf	50 REV	2	0		
43	16/16	275	2	0		
44	16	275	1	0		

Stock No.	Capacity	Voltage	Price s.	Price d.	No. Required	£ s. d.
45	350	12		9		
46	20/4	275	1	0		
47	250	50	2	0		
48	500	25	1	6		
49	400	15	1	0		
50	400	2.5		3		
51	64	275	1	9		
52	32/32	350	2	6		
53	8/8/8	275	1	9		
54	500	6		6		
55	64	275	1	3		
56	25	6		3		
57	100	9		6		
58	400	50	2	0		
59	400	30	1	6		
60	500	4		3		
61	150	30	1	6		
62	64/32/8	275	2	6		
64	40	6.4		3		
67	30	6		3		
68	100/100/50	275	5	0		
69	50/50/50	350	4	0		
70	40/40/20	275	2	0		
71	400	6.4		3		
72	320	10		3		
73	32/32 + 25	275 / 25	2	6		

Total:

RESISTORS. EXCELLENT QUALITY. MAINLY 5%. 7/6d. per 100 of any one value. 2/- per dozen of any one value. Smaller quantities 3d. each.
Tick the values required:

13 ohms	560 ohms	3.3 k ohm	10 k ohm	39 k ohm	91 k ohm	1.2 meg ohm	8.2 meg ohm
22 ohms	750 ohms	3.6 k ohm	16 k ohm	43 k ohm	130 k ohm	1.5 meg ohm	9.1 meg ohm
36 ohms	1 k ohm	4.3 k ohm	18 k ohm	47 k ohm	360 k ohm	1.8 meg ohm	10 meg ohm
47 ohms	1.5 k ohm	4.7 k ohm	22 k ohm	51 k ohm	430 k ohm	3.6 meg ohm	
91 ohms	1.8 k ohm	5.6 k ohm	24 k ohm	62 k ohm	470 k ohm	5.1 meg ohm	
220 ohms	2.2 k ohm	6.8 k ohm	27 k ohm	75 k ohm	560 k ohm	6.2 meg ohm	
470 ohms	2.4 k ohm	7.5 k ohm	30 k ohm	82 k ohm	620 k ohm	7.5 meg ohm	

or our selection (mixed) 6/6d. per 100.

Total:

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. In following values. Tick those required.

2 pf	5 pf	12 pf	25 pf	50 pf	80 pf	135 pf	180 pf	250 pf	680 pf	1,000 pf	2,500 pf
3.9 pf	6 pf	15 pf	27 pf	58 pf	82 pf	140 pf	190 pf	330 pf	800 pf	1,100 pf	2,700 pf
4 pf	8 pf	18 pf	30 pf	62 pf	100 pf	158 pf	200 pf	450 pf	820 pf	1,500 pf	3,000 pf
4.7 pf	10 pf	22 pf	39 pf	72 pf	125 pf	170 pf	240 pf	600 pf	900 pf	2,200 pf	6,200 pf

Total:

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.
50% discount lots of 1,000 per type.

TRANSISTOR BARGAIN! THEY CAN'T GET ANY CHEAPER! ! ! ! !
P.N.P. Audio. Untested, unmarked. MAINLY O.K. .. 10/- per 100
N.P.N. Silicon. R.F. types unmarked ALL USEABLE .. 10/- per 50
POWER OUTPUT (Similar OC35) ALL TESTED .. 4/- each £2 dozen

SILICON PLANAR TRANSISTORS. ALL TESTED. NO LEAKS OR SHORTS. Gain of 20/50 6d. each, 50/100 9d. each, 100/200 1/- each.

LIGHT SENSITIVE TRANSISTORS, 2/- each.

LIGHT SENSITIVE DIODES
Can be used to control any transistorised device, 1/- each.
75/- per 100. £25 per 1,000.

THYRISTORS. 400 volt BTY 79 7/6d. each. SCR 51 (10 amp) £1 each.

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.

MAINS DROPPER TYPE RESISTORS. Hundreds of types 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.

GIANT SELENIUM SOLAR CELLS. Last few to clear at half price! Circular, 67 mm. diameter 5/- each. 50 mm. × 37 mm. 3 for 10/-.

SKELETON PRESETS. Mixed. 6/- dozen.

VOLUME CONTROLS. ½ meg. 1 meg. with D.P. switch 5k. (No switch) all 2/-

RECORD PLAYER AMPLIFIERS. All transistor. Complete with screened input lead, volume control and speaker leads. This excellent unit also has built-in rectifier and smoothing components enabling same to be used direct on 6 to 9 volt A.C. supply. Small number only! Cannot be repeated at this price! 30/- ea.

TRANSISTOR RADIOS. Fantastic bargain! Tremendous value! Superb quality sound from large speaker! Excellent sensitivity! Complete with earpiece, battery and plastic carrying case, all packed in a colourful presentation box. You would expect to pay £5—but our price due to huge purchase is only 37/6d.!

CO-AXIAL CABLE. Semi-air spaced. 8d. yard. 60 yd. rolls 30/- Postage 4/6d.

CRYSTAL TAPE-RECORDER MIKES, 12/- each. **CRYSTAL EAR-PIECES WITH PLUG,** 5/- each, Magnetic earpieces. No plug. 1/6d. each.

THIN CONNECTING WIRE. 10 yds 1/-, 100 yds 7/6d., 1,000 yds. 50/-.

RECORD PLAYER CARTRIDGES
ACOS GP67/2 15/- (Mono) GP94/1 30/- (Stereo, ceramic)
ACOS GP91/3 20/- (Compatible) ACOS GP93/1 with diamond needle 32/6d.
ACOS GP93/1 25/- (Stereo) ACOS GP94/1 with diamond needle 37/6d.

TRANSISTORISED FLUORESCENT LIGHTS. 12 VOLT
8 watt 12" tube, Reflector type 59/6 15 watt 18" tube, Batten type 79/6
Complete with tube. Postage 3/-

TRANSISTORISED SIGNAL INJECTOR KIT 10/-
TRANSISTORISED SIGNAL TRACER KIT 10/-
TRANSISTORISED REV. COUNTER KIT (CAR) 10/-

VERO-BOARD

2½" × 1" × .15	1/3	17" × 3¾" × .15	14/8
3¾" × 2½" × .15	3/3	3¾" × 2½" × .1	4/2
3¾" × 3¾" × .15	3/11	3¾" × 3¾" × .1	4/9
5" × 2½" × .15	3/11	5" × 2½" × .1	4/7
5" × 3¾" × .15	5/6	5" × 3¾" × .1	5/6
17" × 2½" × .15	11/-		

Spot Face Cutter 7/6d. Pin Insert Tool 9/6d. Terminal Pins 3/6d. for 36.
Spot Face Cutter and 5 2½" × 1" boards 9/9d.

These prices cannot be repeated. Order now. Don't forget to add your name and address!
Please include suitable amount to cover post and packing. Minimum 2/-.

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Complete stereo system–£29 10s.

The new Duo general-purpose 2-way speaker system is beautifully finished in polished teak veneer, with matching vynair grille. It is ideal for wall or shelf mounting either upright or horizontally.

Type 1 SPECIFICATION

Impedance 10 ohms. It incorporates Goodmans high flux 6" × 4" speaker and 2½" tweeter. Teak finish 12" × 6¾" × 5¾". **4 guineas each.** 7/6d p. & p.

Type 2 as type 1. Size 17½" × 10¾" × 6¾". Incorporating 10½" × 6½" bass unit and 2½" tweeter. 3 ohms impedance **5½ guineas plus 15/- p. & p.**

Garrard Changers from £7.19.6d. p. & p. 7/6d.

Cover and Teak finish Plinth £4.15.0d. 7/6d. p. & p.

Duetto Integrated Transistor Stereo Amplifier **£9 10s.** plus 7/6d. p. & p.

The Duetto is a good quality amplifier, attractively styled and finished. It gives superb reproduction previously associated with amplifiers costing far more.

SPECIFICATION

R.M.S. power output: 3 watts per channel into 10 ohms speakers.

INPUT SENSITIVITY: Suitable for medium or high output crystal cartridges and tuners. Cross-talk better than 30dB at 1Kc/s.

CONTROLS: 4-position selector switch (2 pos. mono and 2 pos. stereo) dual ganged volume control.

TONE CONTROL: Treble lift and cut. Separate on off switch. A preset balance control.

These 5 Items can be purchased together for £29 10s+£1 10s p. & p.

The Classic

TEAK FINISHED CASE

£9

plus 7/6 p. & p.
Built and tested.

SPECIFICATION

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" × 6" × 2¼" 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.

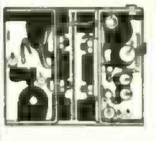
SPECIFICATION

OUTPUT: 10 watts into a 3 ohms speaker.
INPUTS: (1) for mike (10 m.v.). Input (2) for gram. radio (250 m.v.) indivdual bass and treble control.
TRANSISTORS: 4 silicone and three germanium.

MAINS INPUT: 220/250 volts.
SIZE: 10½" × 4½" × 2½".
MIKE TO SUIT (CRYSTAL): 12/6d. 1/6d. p. & p.
8" × 5" speaker 14/6d. + 3/- p. & p.
Mk. 1 £5 15s. + 7/6d. p. & p. less Teak-finished case.

X101 10w. SOLID-STATE HI-FI AMP

With Integral Pre-amp.



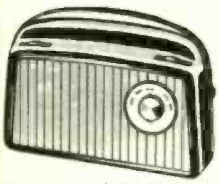
Specifications: Power Output (into 3 ohms speaker) 10 watts. Sensitivity (for rated output): 1mV into 3K ohms (0.33 microamp) Total Distortion (at 1 KHz): At 5 watts 0.35%: At rated output 1.5%. Frequency Response: Minus 3 dB points 20 Hz and 40 KHz. Speaker: 3-4 ohms. (3-15 ohms may be used). Supply 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" × 8" × 3".

ELEGANT SEVEN MK. III

(350mW Output)

£4.9.6
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—with six electronically mixed Inputs. Suitable for use with: mics. guitars. gram. tuner. organ. etc. Separate bass and treble controls. Output Impedance 3, 8 and 15 ohms.

NEW COMPLETE HI-FI STEREO SYSTEM £39

comprising SP25 Garrard MkII with diamond stereo cartridge. Viscount amplifier MkI. Two type 2 speakers, plinth and cover.

£39 plus £2 p. & p.

STEREO PRE-AMPLIFIER

Inputs—6 position rotary switch (3 position mono, 3 position stereo). Tuner 150 mV into 680k. Magnetic pick-up fully equalised and suitable for magnetic cartridges with minimising output of 4mV/cm/sec. Load 47k. Ceramic pickup 150 mV into 680k. Sensitivities taken for 200mV output. Controls—separate volume controls for each channel. Twin ganged bass. 12dB lift and 15dB cut at 60c/s. Twin ganged treble. 10dB lift and 15dB cut at 10kc/s. Voltage required 23-30v DC at 5mA. Size 12¼" × 3¾" × 2¾". In teak finished case, complete with front panel and knobs. Built and tested £7.7.0 plus 5/- p. & p.

SPECIAL OFFER

Complete stereo systems comprising BALFOUR 4 speed auto player with stereo head 2 DUO speaker systems size 12 × 6¾ × 5¾. Plinth (less cover) and the DUETTO stereo amplifier. All above items

£20 plus 20/- p. & p.

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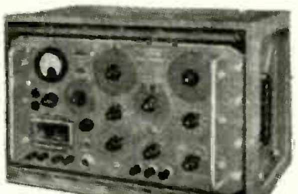
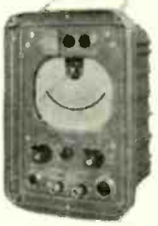
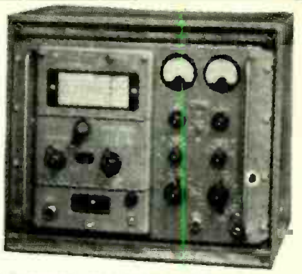
MARCONI TEST EQUIPMENT







VALVE VOLTMETER TYPE TF 958. Measures AC 100mV; 20 c/s to 100 mc/s, DC 50mV to 100V, multiplier extends ac range to 1·5kV. Balanced input and centre-zero scale for DC. AC up to 100MHz. **£32.10.0.**

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SIGNAL GENERATOR TF 801/A. 10-300 Mc/s. In 4 bands. Internal at 400 c/s. 1 kc/s. External 50 c/s to 10 kc/s. Output 0-100 db below 200 mV from 75 ohms source. **£85.** DITTO but **801/A/1** with additional high level output. **£89.** Both P. & P. 20/-. Including necessary connectors, plugs, and instruction manual.

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TF 899 VALVE VOLTMETER, 10mV to 2V, **£17.10.0.** Carriage 30/-.

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VIDEO OSCILLATOR TF 885A & 885A/1, £55 and **£85** resp. Carr. 30/-.

FM DEVIATION METER TYPE TF 791B. Frequency range: 4-250MHz, deviation 1-75kHz. Specification and price on application.

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CIRCUIT MAGNIFICATION METER TYPE TF 329F. Frequency range: 50kHz to 50MHz. Magnification 10 to 500 Q. Tuning Capacitor: 40 to 450pF with ±3pF vernier. Fully overhauled and calibrated, **£70.** Carriage 30/-.

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MODEL 524B ELECTRONIC COUNTER WITH MODEL 525B PLUG IN UNIT. Basic counter measures frequencies from 10Hz to 10MHz and time from 0 to 10 kHz. Automatic positioning of decimal point, eight place registration. Full self check facility from built in frequency standards. Plug in unit extends frequency range of basic counter to 100 to 220MHz. Full specification and price on request.

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PHASE MONITOR ME-63/U. Manufactured recently by Control Electronics Inc. Measures directly and displays on a panel meter the phase angle between two applied audio frequency signals within the range from 20-20,000 c.p.s. to an accuracy of ± 1.0°. Input signals can be sinusoidal or non-sinusoidal between 2 and 30 v. peak. In excellent condition together with handbook and necessary connector. **£45.** Carriage 30/-.

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BOONTON SIGNAL GENERATOR TS 497/B/URR, 2-400MHz. £95.

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To view **TEST EQUIPMENT** please phone for appointment

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PLEASE NOTE
Unless offered as "as seen" all equipment ordered from us is complete-ly overhauled mechanically and electrically, thus ensuring that our equipment is in "connect and use" condition.

A.F. Amps with PRE-AMP 2.5W. **£2.2.6.** 3.5W. **£2.12.6.** Mono with tone controls **£6.2.6.** Stereo with tone controls **£12.19.6.**

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MANY OTHERS IN STOCK include Cathode Ray Tubes and Special Valves. U.K. P. & P. up to 10/- 1/-; to £1 2/-; over £1 2/- in £, over £3 post free. C.O.D. 4/- extra.

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29/41FT. AERIALS each consisting of ten 3ft., ⅞in. dia. tubular screw-in sections. 11ft. (6-section) whip aerial with adaptor to fit the 7in. rod, insulated base, stay plate and stay assemblies, pegs, reamer, hammer, etc. Absolutely brand new and complete ready to erect, in canvas bag, **£3/9/6.** P. & P. 10/6.

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Just a few from our huge stock:

25μA round pj M.C. 2½"	27/6
50μA round M.C. 2½"	32/6
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100μA round M.C. 3½"	35/-
200μA round N.C. 2½"	27/6
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500-0-500μA round M.C. 2½"	22/6
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1mA round M.C. 2½"	25/-
5mA round M.C. 2" clip fit	22/-
10mA round M.C. 2½"	22/6
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50 amp round 2½" thermo.	22/6
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15V round M.I. 2½"	30/-
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RESISTORS

Code	Power	Tolerance	Range	Values available	1 to 9	10 to 99	100 up
C	1/20W	5%	100Ω–220K Ω	E12	18	16	15
C	1/8W	5%	4·7Ω–1M Ω	E24	2·5	2	1·75
C	1/4W	10%	4·7Ω10M Ω	E12	2·5	1·75	1·5
C	1/2W	5%	4·7 Ω–10M Ω	E24	3	2·25	2
MO	1/2W	2%	10 Ω–1M Ω	E24	9	8	7
C	1W	10%	4·7 Ω–10M Ω	E12	4	3·25	3
WW	1W	10% ± 1/20 Ω	0·22 Ω–3·3 Ω	E12	15d. all quantities		
WW	3W	5%	12 Ω–10K Ω	E12	15d. all quantities		
WW	7W	5%	12 Ω–10K Ω	E12	15d. all quantities		

Codes: C = carbon film, high stability, low noise.
MO = metal oxide, Electrosil TR5, ultra low noise.
WW = wire wound, Plessey.

Prices are in pence each for each ohmic value and power rating. (Ignore fractions of one penny on total resistor order.)

Values:
E12 denotes series: 1, 1·2, 1·5, 1·8, 2·2, 2·7, 3·3, 3·9, 4·7, 5·6, 6·8, 8·2 and their decades.
E24 denotes series: as E12 plus 1·1, 1·3, 1·6, 2, 2 4, 3, 3·6, 4·3, 5·1, 6·2, 7·5, 9·1 and their decades.

NEW PLESSEY INTEGRATED CIRCUIT POWER AMPLIFIER TYPE SL403A. Only 57/- each. Operates with 18V power supply. Sensitivity 20mV into 20M Ω, 3 watts into 7·5 Ω. Supplied complete with application Data on orders for 2 or more.

PE NOV. 69 STEREO AMPLIFIER KIT less metalwork .. **£11/18/- NET complete**

CARBON SKELETON PRE-SETS
Small high quality, type PR: Linear only: 100 Ω, 220 Ω, 470 Ω, 1K Ω, 2K2, 4K7, 10K, 22K, 47K, 100K, 220K, 470K, 1M Ω, 2M2, 5M, 10M Ω 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 **51/-** 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/-; 500/50 6/-; 1000/25 4/-; 1000/50 7/-; 2000/25 6/-.

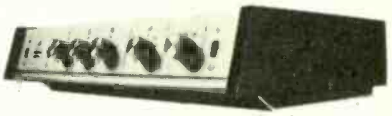
SMALL ELECTROLYTICS
Axial leads: 5/10, 10/10, 25/10, 50/10 **1/- each**
25/25, 47/25, 100/10, 220/10 .. .. **1/3 each**

COMPONENT DISCOUNTS
10% on orders for components for £5 or more.
15% on orders for components for £15 or more.
(No discount on net 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.

PEAK SOUND AMPLIFIER KITS

The new Englefield Kits



Build it 12+12 or 25+25

Brilliant new styling and available in two forms:

STEREO 15 WATTS PER CHANNEL
Supplied in kit form with complete amplifier and pre-amplifier modules and power supply components. Output per channel into 15Ω —13 watts R.M.S. **Price £38.9.0 Net**
In total kit form £32.12.6 net

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Supplied in kit form with complete amplifier, pre-amplifier and regulated power supply modules. Output per channel into 15Ω —28 watts R.M.S. **Price £58.15.0 Net**
Specifications on these amplifiers in accordance with the Specifications in Guarantee published in Peak Sound advertisements.

Inputs:
Magnetic, RIAA 3·5mV
Ceramic 35mV
Tape 100mV
Radio 100mV
Signal to noise ratios: Better than 60dB all inputs.

ENGLEFIELD CABINET to house either above assemblies (as illustrated) **£6.0.0.**
Other Peak Sound Products as advertised.

COLVERN 3 WATT WIRE-WOUND POTENTIOMETERS: 10 Ω, 15 Ω, 25 Ω, 50 Ω, 100 Ω, 150 Ω, 250 Ω, 500 Ω, 1K Ω, 1·5K Ω, 2·5K Ω, 5K Ω, 10K Ω, 15K Ω, 25K Ω, 50K Ω.
Price .. .. **only 5/6 each**

CARBON TRACK POTENTIOMETERS
Double wiper ensures minimum noise level. Long plastic spindles.

Single gang linear	220 Ω, 470 Ω, 1K, etc. to 2·2M Ω	2/6
Single gang log.	4K7, 10K, 22K, etc. to 2·2M Ω	2/6
Dual gang linear	4K7, 10K, 22K, etc. to 1M Ω	8/6
Dual gang log.	4K7, 10K, 22K, etc. to 2M2 Ω	8/6
Log/Anti-log.	10K, 47K, 1M Ω only	8/6
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Any type with ½ amp double pole mains switch .. extra 2/3

FETS n-channel
Low cost general purpose 2N5163, 25 volt .. only **5/- each**
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Transistors for one channel £7/5/6 list, with 10% discount .. .. only **£6/11/-**
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Printed circuit board free with each transistor set.
Complete unregulated power supply kit £4/17/6 mono or stereo, subject to discount.
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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.
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R.S.C. SENSATIONAL HIGH FIDELITY STEREO 'PACKAGE' OFFERS

Matching as recommended for optimum performance. Compare prices with equipment and cabinets purchased individually.

30 Watt Output

★ Goldring Transcription Turntable on Plinth.
★ Shure or Goldring G800H Magnetic Pick-up Cartridge.
★ Super 30 Amplifier in veneered housing.
★ Pair of Stanway II Loudspeaker Units.

Special total price. Four fully wired units ready to "plug-in". Really superb performance. Send S.A.E. for leaflet. **86 Gns.** Carr. 30/-

'Package' prices apply providing all individual units are purchased from any branch within 3 months (see leaflet).

30 Watt Output

★ Garrard SP25 Mk. II Turntable on Plinth.
★ Goldring CS90 Ceramic diamond tipped Cartridge.
★ Super 30 Amplifier in veneered housing.
★ Pair of Stanway II Loudspeaker Units.

Extremely Attractive Plinths finished in Teak or Afrormosia veneer. Tinted Transparent Plastic "roll over" cover with handle.

Special total price. Four fully wired units ready to "plug-in." **76 Gns.** Carr. 30/-

13 Watt Output

★ Garrard SP25 Mk. II 4-speed Player Unit, on Plinth. ★ Goldring CS90 Ceramic P.U. Cartridge with diamond stylus. ★ TA12 Amplifier in veneered housing. ★ Pair of Dorchester Loudspeaker Units.

Special total price. Transparent Plastic cover 3 gns extra. **53 Gns.** Terms Dep. £10.0.3 and 9 monthly payments £5.15.5 (Total 59 Gns.) Carr. 25/-

13 WATT 'PACKAGE' as above but with Garrard 3000 and Sonotone 9TA cartridge in lieu of SP25 and CS90. Special total price **47½ Gns.** Transparent cover 3 gns. extra. Carr. 25/-

AUDIOTRINE HIGH FIDELITY LOUDSPEAKERS

Heavy construction. Latest high efficiency ceramic magnets. Treated Cone surround for low fundamental resonance. "D" indicates Tweeter Cone providing extended frequency range up to 15,000 c.p.s. Exceptional performance at low cost. Impedance 3 or 15 ohms.

Prices include carriage. PLEASE STATE IMPEDANCE

HF 510L	5" 10W	57/9	HF 120	12"	15W	79/9
HF 801D	8" 8W	59/9	HF 120D	12"	15W	89/9
HF 811D	8" 10W	£4/4	HF 126	12"	15W	£5/5/-
HF 102D	10" 10W	65/-	HF 126D	12"	15W	£5/15/-
HF 100D	10" 15W	£5/15				

AUDIOTRINE HI-FI SPEAKER SYSTEMS

Consisting of matched 12in. 11,000 line 15 watt 15 ohm high quality speaker, cross-over unit and tweeter. Smooth response and extended frequency range ensure surprisingly realistic reproduction. **£5.15.0**
Or SENIOR 15 watt inc. HF 126 15,000 line Speaker £6/15. Carr. 6/6. Carr. 5/9

HI-FI 'SPEAKER ENCLOSURES

Teak or Afrormosia veneer finish. Modern design. Acoustically lined. All sizes approx. Prices inc. carr.
JE8 Size 16 × 11 × 9in. Pressurised. Gives pleasing results with any 8in. Hi-Fi speaker. **£4.14.6**
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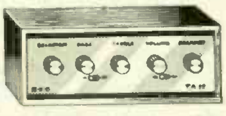
SE12 For high performance with 12in. Hi-Fi speaker and Tweeter. Size 25 × 16 × 10½in. Pressurised. **£6.19.9**

RSC TA12 Mk II 13 WATT STEREO AMPLIFIER

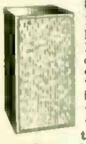
FULLY TRANSISTORISED, SOLID STATE CONSTRUCTION HIGH FIDELITY OUTPUT OF 6.5 WATTS PER CHANNEL



Designed for optimum performance with any crystal or ceramic Gram P.U. cartridge, Radio tuner, Tape recorder, 'Mike' etc. ★ 3 separate switched input sockets on each channel ★ Separate Bass and Treble controls ★ Slide Switch for mono use ★ Speaker Output 3-15 ohms ★ For 200-250 v. A.C. mains ★ Frequency Response 30-20,000 c.p.s. —2dB ★ Harmonic Distortion 0.3% at 1000 c.p.s. Hum and Noise —70dB ★ Sensitivities (1) 300 mV (2) 50 mV (3) 100 mV (4) 2 mV ★ Handsome brushed silver finish Facia and Knobs. Output rating I.H.F.M. Complete kit of parts with full wiring diagrams and instructions. 13½ GNS. Carr. 7/9. Factory built with 12 mth. gntee. 17 GNS. Or Dep. £5/2/6 and 9 mthly pymts. 34/- (Total £20/8/6). Or in Teak or Afrormosia veneer housing 20½ GNS. or Dep. £5/10/6 and 9 mthly. pymts. £2/1/7 (Total £24/4/9).

HIGH FIDELITY LOUDSPEAKER UNITS

Cabinets of latest styling Satin Teak or Afrormosia veneer. Acoustically lined or filled with acoustic damping material. Ported where appropriate. Credit terms available.

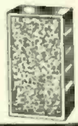


DORCHESTER Size 16 × 11 × 9in. Appr. Range 45-15,000 c.p.s. Rating 8-10 watts. Fitted High flux 13 × 8in. Dual cone speaker. Impedance 3 or 15 ohms. **£8.19.9** Carr. 7/6

STANWAY II Size 20 × 10½ × 9½in. Rating 10 watts. Inc. Fane 13 × 8in. speaker with highly flexible cone surround, long throw voice coil and 11,000 line magnet. High flux tweeter. Handsome Scandinavian design cabinet. Range 35-20,000 c.p.s. Impedance 15 Ω. Gives smooth realistic sound output. Inc. carr. **16Gns.**

GLOUCESTER Size 25 × 16 × 10in. 12in. High flux 12,000 line speaker. Cross-over unit and Tweeter. Rating 10 watts. Frequency range 40-20,000 c.p.s. Impedance 15 ohms. **12½ Gns.**

THE 'YORK' HIGH FIDELITY 3 'SPEAKER SYSTEM



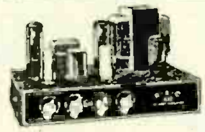
•Moderate size approx. 25 × 14 × 10 in. •Range 30-20,000 c.p.s. Impedance 15 ohms. • Performance comparable with units costing considerably more. Complete kit. **20 Gns.** Consists of (1) 12 in. 15 watt Bass unit with cast chassis. Roll rubber cone surround for ultra low resonance, and ceramic magnet. (2) 3-way quarter section series cross-over system. (3) 8 × 5in. high flux middle range speaker (4) High efficiency tweeter. (5) Appropriate quantity acoustic damping material. (6) Teak veneered cabinet. (7) Circuit and full instructions.
REMARKABLE VALUE HEAR IT AT ANY BRANCH

R.S.C. BATTERY/MAINS CONVERSION UNITS

Type BM1. An all-dry battery eliminator. Size 5½ × 4½ × 2in. approx. Completely replaces batteries supplying 1.5 v. and 90 v. where A.C. mains 200/250 v. 50 c/s. is available. Complete kit with diagram 52/6 or, Ready for use. 3 GNS.

SELENIUM RECTIFIERS
F.W. Bridged 6/12v. D.C. Output Input Max. 18v. A.C. 1a.. 4/3; 2a.. 6/11; 3a.. 9/9; 4a.. 12/9; 6a.. 15/9.

R.S.C. A10 30 WATT ULTRA LINEAR HI-FI AMPLIFIER



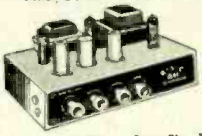
Highly sensitive. Push-Pull high output, with Pre-amp./Tone Control Stages. Performance figures: Hum level —70dB. Frequency response ±3dB 30-20,000 c/s. Sectionally wound output transformer. All high grade components. Valves EF86, EF86, ECC83, 807, 807, GZ34. Separate Bass and Treble Controls. Sensitivity 36 millivolts. Suitable for High Impedance mic. or pick-ups. Designed for Clubs, Schools, Theatres, Dance Halls or Outdoor Functions, etc. For use with Electronic Organ, Guitar, String Bass, etc. Gram. Radio or Tape. Reserve L.T. and H.T. for Radio Tuner. Two inputs with associated volume controls so that two separate inputs such as Gram and "Mike" can be mixed. 200-250 v., 50 c/s. A.C. mains. For 3 and 15 ohm speakers. Complete Kit parts wiring diags., instructions. Twin-handled perforated cover 27/6. Or factory built with EL34 output valves and 12 months' guarantee for 18 gns. Tech. figs. apply to factory built units. Carr. 12/6. **15 Gns.**
TERMS: Deposit £6.3.0 and 9 monthly payments of 34/- (Total £21/9/0.) Send S.A.E. for leaflet.

R.S.C. TA6 6 Watt HIGH FIDELITY SOLID STATE AMPLIFIER

200-250v. A.C. mains operated Frequency Response 30-20,000 c.p.s. —2dB. Harmonic Distortion 0.3% at 1,000 c.p.s. Separate Bass and Treble 'lift' and 'cut' controls. 3 input sockets for Mike, Gram. Radio or Tape. Input selector switch. Output for 3-15 ohm speakers. Max. sensitivity 5mV. Output rating I.H.F.M. In fully enclosed enamelled case. 9¼ × 2½ × 5¼in. Attractive brushed silver finish facia plate 10½ × 3½in. and matching knobs. Complete kit of parts with full wiring diagrams and instructions. **7 Gns.** Or factory built with 12 months' guarantee. £8.19.9. Carr. 7/6.

INTEREST CHARGES REFUNDED On Credit Sales settled in 3 months.

R.S.C. A11 HIGH FIDELITY 12-14 WATT AMPLIFIER



Push-pull ultra linear output "built-in" tone control pre-amp. Two input sockets with associated controls allowing mixing of "mike" and gram. etc. etc. High sensitivity. 5 valves—ECC83 (2), EL84 (2), EZ81. High quality sectionally wound output transformer. IND. BASS AND TREBLE CONTROLS. Frequency response ±3dB 30-20,000 c/s. Hum level—60dB. SENSITIVITY 40 millivolts. For Crystal or Ceramic PUs. High Impedance "mikes". For Musical Instruments such as String Bass, Electronic Guitars, etc. Size approx. 12 × 9 × 7in. For AC mains 200-250v. 50 cps. Output for 3 and 15 ohm spkrs. S.A.E. for leaflet. Complete kit **9½ Gns.** Full instructions and point-to-point wiring diagrams. Carr. 11/6 (or factory built 12½ Gns.) Twin handled metal cover 27/6. Terms on assembled units. Deposit 99/6 and 9 monthly payments of 23/-. (Total £15/6/6. RSC A11T transistorised version of above complete kit 9 Gns. (Assembled 13 gns.)

R.S.C. COLUMN SPEAKERS

Covered in two-tone Rexine/Vynair. Ideal for vocalists and Public Address. 15 ohm matching. TYPE C57 15 watts inc. five 7 × 4in. spkrs. £7/19/11. TYPE C48S, 30 watts. Fitted four 8in. high flux 8 watt speakers. Overall size approx. 42 × 10 × 5in. 16 Gns. Or deposit 67/- and 9 mthly pmts. 34/9 (Total £18/19/9). Carr. 10/-.
TYPE C4128, 50 watts. Fitted four 12in. 11,000 lines 15 watt speakers. Overall size 56 × 14 × 9in. approx. 26 Gns. Or deposit £5/17/6 and 9 monthly payments Carr. 15/- of 54/6 (Total £30/7/-).

R.S.C. MAINS TRANSFORMERS

FULLY GUARANTEED. Interleaved and Impregnated. Primaries 200-250 v. 50 c/s. Screened

MIDGET CLAMPED TYPE 2½ × 2½ × 2½in.

250 v., 60 mA, 6.3 v. 2 a.	17/11
250-0-250v., 60mA. 6.3v. 2a.	18/11

FULLY SHROUDED UPRIGHT MOUNTING

250-0-250v. 60mA., 6.3v. 2a., 0-5-6.3v. 2a.	24/9
250-0-250v. 100mA. 6.3v. 4a., 0-5-6.3v. 3a.	39/9
300-0-300v. 100mA. 6.3v. 4a., 0-5-6.3v. 3a.	39/9
300-0-300v. 130mA. 6.3v. 4a. c.t., 6.3v. 1a. For Mullard 510 Amplifier	47/11
350-0-350v. 100mA., 6.3v. 4a., 0-5-6.3v. 3a.	39/9
350-0-350v. 150mA. 6.3v. 4a., 0-5-6.3v. 3a.	47/9
425-0-425v. 200mA. 6.3v. 4a. c.t., 5v. 3a	89/9
425-0-425v. 200mA. 6.3v. 4a., 6.3v. 3a. 5v. 3a	93/9
450-0-450v. 250mA. 6.3v. 4a., ct., 5v. 3a.	99/9

TOP SHROUDED DROP-THROUGH TYPE

250-0-250v. 70mA. 6.3v. 2a., 0-5-6.3v. 2a.	23/9
250-0-250v. 100mA. 6.3v. 3.5a.	27/9
250-0-250v. 100mA. 6.3v. 2a., 6.3v. 1a.	28/9
350-0-350v. 80mA. 6.3v. 2a., 0-5-6.3v. 2a	29/11
250-0-250v. 100mA. 6.3v. 4a., 0-5-6.3v. 3a.	39/9
300-0-300v. 100mA. 6.3v. 4a., 0-5-6.3v. 3a.	39/9
300-0-300v. 130mA. 6.3v. 4a., 0-5-6.3v. 1a. Suitable for Mullard 510 Amplifier	46/9
350-0-350v. 100mA., 6.3v. 4a., 0-5-6.3v. 3a.	39/9
350-0-350v. 150mA., 6.3v. 4a., 0-5-6.3v. 3a.	46/11

FILAMENT or TRANSISTOR POWER PACK Types 6.3 v. 1.5a. 8/9; 6.3v. 2a. 9/9; 6.3v. 3a. 13/9; 6.3v 6a, 22/9; 12v. 1a. 9/11; 12v. 3a. or 24v. 1.5a. 23/9; 0-9-18v. 1½a. 19/11; 0-12-25-42v. 2a. 31/9.

CHARGER TRANSFORMERS 0-9-15v. 1½a. 18/9; 2½a 19/11; 3a. 21/11; 5a. 25/11; 6a. 29/9; 8a. 36/9.

AUTO (Step UP/Step DOWN) TRANSFORMERS
0-110/120v.-200-230-250v. 50-80 watts 19/9
150 watts, 33/6; 250 watts 49/9; 500 watts 105/-

OUTPUT TRANSFORMERS

Standard Pentode 5,000Ω or 7,000Ω to 3Ω	8/9
Push-Pull 8 watts EL84 to 3Ω or 15Ω	14/9
Push-Pull 10 watts 6V6 ECL86 to 3, 5, 8 or 15Ω	24/9
Push-Pull EL84 to 3 or 15Ω 10-12 watts	23/9
Push-Pull Ultra Linear for Mullard 510, etc.	39/9
Push-Pull 15-18 watts, sectionally wound 6L6 KT66, etc., for 3 or 15Ω	35/9
Push-Pull 20 watt high quality sectionally wound EL34, 6L6, KT66, etc. to 3 or 15Ω	59/9

SMOOTHING CHOKES
150mA. 7-10H, 250Ω 12/9; 100mA, 10H, 200Ω 10/9; 80mA, 10H, 350Ω, 8/9; 60mA, 10H, 400Ω 4/11.

R.S.C. TFM1 SOLID STATE VHF/FM RADIO TUNER

Total cost of parts with detailed wiring diagrams and instructions. **14 Gns.**
Or factory built 18gns. Or in Teak finished cabinet as illustrated 21 gns. Terms: Deposit £6/1/- and 9 monthly payments £2/2/-. Total £24/19/-. All above prices include carriage.

★ High-sensitivity ★ 200-250v. A.C. Mains operation. ★ Sharp A.M. Rejection. ★ Drift-free reception. ★ Output ample for any amplifier (approx. 500 m.v.). ★ Simple alignment instructions. ★ Output available for feeding tuning meter. ★ Output for feeding Stereo Multiplexer. ★ Tuner head using silicon Planar Transistors. ★ Designed for standard 80 ohm co-axial input.
Visually matching our Super 15 and 30 amplifiers and of the same high standard of performance and reliability. The pre-wired tuning head facilitates speed and simplicity of construction. Printed circuitry. Only high grade transistors and components used. A quality product at considerably less than the cost of comparable units. Stereo version. All parts 20 gns. Inc. Carr. Assembled 23½ gns. Inc. Carr.

High Quality LOUDSPEAKERS

In teak or afrormosia veneered cabinets. L13 13" × 8" 10 Watt Model. Gauss 10,000 lines, 3 or 15 ohms. **£4/19/9** Carr. 7/6
L12 12" 20 Watt Model. 15 ohm. Size 18 × 18 × 10in. Gauss 10,000 lines. Rexine covered 10/- extra. Carr. 8/9 **£8/19/9**

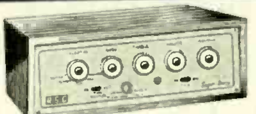
TWO-WAY 'PHONE AMPLIFIER

Listen and speak with both hands free. Handsome black case. Battery operated. **59/9**

R.S.C. SUPER 30 Mk II HIGH FIDELITY STEREO AMPLIFIER

HIGH GRADE COMPONENTS. SPECIFICATIONS COMPARABLE WITH UNITS COSTING CONSIDERABLY MORE

Employing Twin Printed Circuits 200/250v. A.C. mains operation.
TRANSISTORS: 9 high-quality types per channel.
OUTPUT: 10 Watts R.M.S. continuous into 15 Ω (Per channel) 15 Watts R.M.S. continuous into 3 Ω
INPUT SENSITIVITIES: Mag. P.U. 4 m.v. Ceramic P.U. 35 m.v. Tape Amp. 400 m.v. Aux. 100 m.v. Mic. 5 m.v. Tape Head 2.5 m.v.
FREQUENCY RESPONSE: ±2dB. 10-20,000 c.p.s.
TREBLE CONTROL: +17 dB to —14 dB at 10 Kc/s.
BASS CONTROL: +17 dB to —15 dB at 50 c/s.
HUM LEVEL: —80 dB.
HARMONIC DISTORTION: 0.1% at 10 Watts 1,000 c.p.s.
CROSS TALK: 52 dB at 1,000 c.p.s.



CONTROLS: 5-position Input Selector, Bass, Treble, Vol., Bal., Stereo/Mono Sw., Tape Monitor Sw., Mains Sw.
INPUT SOCKETS: (1) P.U. (2) Tape Amp. (3) Radio (4) Mic. or Tape Head. (Operation of Input Selector assures appropriate equalisation.)
CHASSIS: Strong Steel construction. Approx. 12 × 3 × 8 in.
FACIA PLATE: Attractive design in rigid Perspex. Spun silver matching control knobs as available.

COMPLETE KIT OF PARTS, point to point wiring diagrams and detailed instructions. **22Gns.** Carr. 15/-.

EMINENTLY SUITABLE FOR USE WITH ANY MAKE OF PICK-UP OR MIC. (Ceramic or Magnetic Moving Coil, Ribbon or Crystal.) CURRENTLY AVAILABLE. SUPERB SOUND OUTPUT QUALITY CAN BE OBTAINED BY USE WITH FIRST-RATE ANCILLARY EQUIPMENT. Unit factory built 29 gns. or Deposit £7/5/- and 9 mthly. payments 58/9 (Total £33/13/9) or in Teak or Afrormosia veneer housing 32 gns. Carr. 15/-. Terms: Deposit £7/3/6 and 9 mthly. payments 66/6 (Total £37/2/-.) Send S.A.E. for leaflet.

R.S.C. SUPER 15 HIGH FIDELITY AMPLIFIER

Solid state. Approx. as Super 30 but single channel. Complete kit with full constructional details and point to point wiring diagrams. Carr. 12/6. **12½ Gns.**
Or factory built: 15½ Gns., Carr. 12/6. Terms: Deposit 4 Gns. and 9 monthly payments 31/1 (Total £18/3/9): or in Teak or Afrormosia veneered housing 19 Gns.

R.S.C. PLINTHS for Record Playing units.

Cut for Garrard 1025, 2025, 3000, AT60, SP25 etc. etc. 59/9 Available with Transparent plastic cover. Inc. carr. **6 Gns.**

Record Playing Units

MONEY SAVING UNITS
Ready to plug into Amplifier.
RP2C Consisting of Garrard SP25 Mk. II (with heavy turntable fitted Goldring CS90 high compliance ceramic Stereo/Mono cartridge with diamond stylus. Mounted on plinth. Transparent plastic cover included. Inc. carr. **23Gns.**
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Other types available with magnetic cartridges and with alternative design plinths.

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1 WATT TRANSISTOR AMPLIFIERS
Miniature size battery operated For 3-5Ω L/speakers. Brand new boxed. 37/9

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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
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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	2½lb	£1 19 6	5/6
2	150	4 lb	£2 12 6	6/6
3	300	6½lb	£3 12 6	6/6
4	500	8½lb	£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.

ISOLATION TRANSFORMERS
Built into metal case, size 8×7×7ins., with on/off switch, neon indicator. 13A 3-pin socket outlet. Pri. 220–240v. Sec. 220–240v. 1000 watts **£16.10.0.** Carr. 15/–. 750 watts **£14.10.0.** Carr. 12/6.

DAVENSET ISOLATION TRANSFORMERS
Built into metal case, size 12×8½×7ins. Pri. 240v. Sec. 110v. 1500 watts. 13A 3-pin socket outlet. **£12.19.6.** Carr. 15/–.

HEAVY DUTY L.T. TRANSFORMERS
Pri. 220–240v. Sec. 12v. 90A. Open frame type. Flying leads. Size 7½×6½×6ins. **£15.0.0.** Carr. 15/–.

Pri. 200–220–240v. Sec. tapped 14v., 15·5v., 28v., 31v., 20A. Open frame type. Table top connections. **£12.0.0.** Carr. 12/6.

Pri. 240v. Sec. tapped 4v., 6v., 11v., 200A. Size 11×9×7 ins. **£15.10.0.** Carr. 15/–.

Pri. 110–120v.–200–240v. Sec. tapped 12v., 18v., 24v., 30v., 8A. Table top connections. Fully tropicalised. **79/6.** Carr. 8/6.

Pri. tapped 200–250v. Sec. 46v. Very conservatively rated at 29A. Size 11×7×7ins. Weight 75 lbs. approx. Manufactured by Partridge. **£15.** Carr. 15/–.

Pri. tapped 110v., 220–250v. Sec. 55v. 24A, 14v. 10A, 60v. 2A. All windings very conservatively rated. Tropically finished. Terminal connections. Size 9×7½×7ins. Weight 65 lbs. **£12. 19. 6.** Carr. 15/-.

Pri. 200–250v. Sec. 17v., 24v., 31v., 38v., conservatively rated at 2·4A twice. Open frame type. Table top connections. Size 6½×4½×4½ins. **£3.15.0.** P. & P. 10/6.

RADIO SPARES—H.T. TRANSFORMERS
Pri. 200–250v. Sec. 350–0–350v. 150M/A. 6·3v., 3A CT. 6·3v. 2·5A CT. 5v. 3·5A. Half shrouded. Flying leads. **59/6.** Carr. 8/6.

PARMEKO POTTED TRANSFORMERS
Sec. 6·3v. Sec. 2–0–2v. 4A 5kv. Wkg. "C" core potted type. **17/6.** P. & P. 3/6.

SCOTCH MAGNETIC TAPE
Type 3M 459 ½in. 3,600 feet. Supplied new in maker's cartons. List price £18.10.0. **Our price £3.19.6.** P. & P. 5/-.

HIGH GRADE POTTED CHOKES BY FAMOUS MAKERS. NEW. GUARANTEED
20 H. 200 m/a. **30/-.** P. & P. 7/6. 20 H. 180 m/a. **27/6.** P. & P. 7/6. 15 H. 180 m/a. **25/-.** P. & P. 7/6. 12 H. 200 m/a. **25/-.** P. & P. 7/6. 10 H. 180 m/a. **22/6.** P. & P. 7/6. 5 H. 300 m/a. **15/-.** P. & P. 6/6. 30 H. 50 m/a. **25/-.** P. & P. 7/6. 10 H. 75 m/a. **10/6.** P. & P. 2/6. 50 H. 25 m/a. **8/6.** P. & P. 2/-. 10H. 120 m/a. **12/6.** P. & P. 3/6. 15 H. 75 m/a. **12/6.** P. & P. 3/6. 5 H. 100 m/a. **6/6.** P. & P. 2/-. 0·75 H. 450 m/a. **15/-.** P. & P. 4/6.

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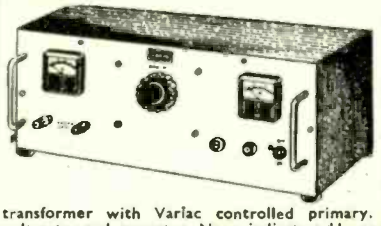
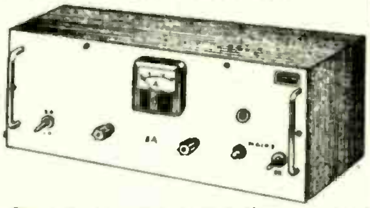
VARIABLE D.C. SUPPLY UNITS TYPE S.E.4



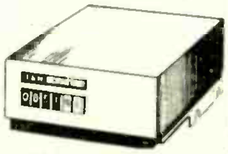
0–48 volt 10 amps, continuous from 240 volts A.C. Silicon full wave bridge rectification, isolated transformer with Variac controlled primary. 3in. scale voltmeter and ammeter. Neon indicator. Housed in strong metal case. Size 17×7×6½in. **£32.10.0.** Carr. 15/-.

L.T. SUPPLY UNITS TYPE S.E.5



A.C. Input 220–240 volts. D.C. output 12 or 24 volts 10 amps continuous rating. Selenium full wave bridge rectification. 3in. scale ammeter, neon indicator. Housed in strong metal case. **£17.10.0.** Carr. 15/-.

DIGITAL HOUR METERS



6 figs inc. 1/10ths, 1/100ths 40v. A.C. but complete with transformer for 240v. A.C. operation. All in plastic case. Size 6½ × 6½ × 3in. Condition as new **45/-.** P. & P. 5/-.

GARDNERS "C" CORE TRANSFORMERS
Pri. tapped 200v., 220–240v. Sec. 1, 300v. 210M/A. Sec. 2, 400v. 262M/A and 6·3v. 3·5A, 6·3v. 2A, 6·3v. 1A. Conservatively rated. **79/6.** Carr. 10/-. Pri. T. 200–240v. Sec. 6·3v. 3A, 6·3v. 2A. **17/6.** P. & P. 4/6. Pri. T. 200–240v. Sec. 400v. 25 M/A and 25v. 25M/A. **15/-.** P. & P. 19/6. Pri. T. 200–240v. Sec. T. 370v., 390v., 340v. 6M/A. **10/-.** P. & P. 4/6. Pri. T. 200–240v. Sec. 6·3v. 1·5A, 6·3v. 1A, 6·3v. 2·5A, 6·3v. 2·5A, 6·3v. 0·5A. **27/6.** P. & P. 6/6. Pri. T. 200–240v. Sec. 500–450–0–0450 500v. 215M/A. **65/-.**

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PARMEKO 200–240v. Sec. 300v. 37M/A twice. 4v. 1A, 4v. 0·3A. Pri. 200–240v. Sec. tapped 65v., 130v., 195v. 85M/A, 6·3v. 5A, 6·3v. 1A. **22/6.** P. & P. 5/-. Pri. 230v. Sec. tapped 325–150–0–150–325v. 75M/A, 12·6v. 1A. **22/6.** P. & P. 5/-.

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Pri. tapped 200–250v. Sec. 200v. 50M/A, 20kv., wkg. Size 7ins. high plus 4in. terminals, by 6×6ins. **85/-** Carr. 10/6.

BERCO
HEAVY DUTY WIRE WOUND RESISTORS
Single tube slider 1000Ω 1A. **47/6.** Carr. 8/6. 30Ω 1·25A, right-angled geared drive. **19/6.** P. & P. 4/6. Single tube geared drive 782Ω 1A. **52/6.** Carr. 8/6. Single tube fixed 45+12Ω 6·5/4A. **27/6.** P. & P. 6/6. Single tube adjustable 57·2Ω 2/8A. **27/6.** P. & P. 5/6. Single tube fixed 71·5Ω 2·8A. **25/-.** P. & P. 5/6. Single tube adjustable 0·6Ω 16A. **15/-.** P. & P. 5/-. Vitreous fixed 1KΩ 70 watts. **5/-.** P. & P. 1/6.

TEDDINGTON AIR PRESSURE SWITCHES. Type T8/A/A3. Single pole change over 15 amp. 250v. A.C. switch contacts, approx. ½ lb. pressure. 3in. dia. **17/6.** P. & P. 3/6.

TEDDINGTON REFRIGERATION THERMOSTATS. Type QJ with control knob. **15/-.** P. & P. 3/6.

SMITHS SYNCHRONOUS MOTORS. 22–28v. A.C. 1 rev. per day. **10/6.** P. & P. 2/6.

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CRAMER CONTROLS SYNCHRONOUS GEARED MOTORS. 220–240v. A.C. 6 revs. per minute. **17/6.** P. & P. 2/6.

TRANSFORMERS, VARIABLE TRANSFORMERS, CHOKES, CAPACITORS, L.T. SUPPLY UNITS. Send 6d. stamp for latest 12-page Price List.

A.E.I. ADJUSTABLE THERMOSTATS TYPE TS2
Stem 6ins. Contacts N.O. 60°C. New and boxed. **27/6.** P. & P. 3/6. 12in. stem. **32/6.** P. & P. 4/6.

MINIATURE RELAYS
250Ω 1 make contact. Size 1½in. Inc. fixing screw×⅝in.×½in. **6/-.** P. & P. 1/6. 170Ω 4 C.O. contacts. Size 1½ins. inc. fixing screw×1½×⅞ins. **8/6.** P. & P. 1/6. Diamond H sealed type. 4 PDT. 150Ω 1in. dia. Length 2½ins. **8/6.** P. & P. 2/-. G.E.C. sealed type 6945–99. 670Ω 1 C.O. contact. **7/6.** P. & P. 2/-. ADS A.C. 230v. 2 C.O. contacts. Size 1⅞×1½×1½ins. **10/6.** P. & P. 2/-.

SPECIAL OFFER. BLOCK CAPACITORS
G.E.C. 8 mfd. 600v. D.C. wkg. Six for **29/6.** Carr. 7/6. Dubliner. 1 mfd. 600v. wkg. Six for **9/-.** F. & P. 3/6. T.C.C. 2 mfd. 500v. wkg. Three for **7/6.** P. & P. 2/6. T.C.C. 0·1 mfd. 500v. wkg. Six for **6/6.** P. & P. 2/6.

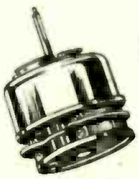
NEW GUARANTEED OIL-FILLED BLOCK CAPACITORS. ALL BY FAMOUS MAKERS
8 mfd. 2,500v. D.C. wkg. 70°C. **37/6.** P. & P. 7/6. 8 mfd. 1,500v. D.C. wkg. 70°C. **22/6.** P. & P. 5/-. 8 mfd. 750v. D.C. wkg. 60°C. **10 6.** P. & P. 3/6. 8 mfd. 400v. D.C. wkg. 60°C. **7/6.** P. & P. 3/6. 4 mfd. 400v. D.C. wkg. 70°C sub chassis mtg. **6/6.** P. & P. 3/-. 2 mfd. 1,500v. D.C. wkg. 70°C. **10/6.** P. & P. 3/6. 2 mfd. 1,000v. D.C. wkg. 70°C. **6/6.** P. & P. 2/6. 0·5 mfd. 2,000v. wkg. 60°C. **5/6.** P. & P. 2/-. 2 mfd. 2,000v. D.C. wkg. 60°C. **8/6.** F. & P. 3/6. 8 mfd. 250v. wkg. 71°C. **4/-.** P. & P. 2/-. 2 mfd. 500v. D.C. wkg. 60°C. **3/6.** P. & P. 1/6. 1 mfd. 600v. D.C. wkg. 70°C. 0·1 mfd. 7,500v. D.C. wkg. 70°C. **15/-.** P. & P. 3/6. 0·1 mfd. 5,000v. D.C. wkg. 70°C. **7/6.** P. & P. 1/6. 0·01 mfd. 8kV. D.C. wkg. 70°C, tubular. **3/9.** P. & P. 1/6.

AMERICAN TYPES
8 mfd. 600v. wkg. **7/6.** P. & P. 3/6. 8 mfd. 1,000v. wkg. **12/6.** P. & P. 3/6. 4 mfd. 600v., tubular S.H. fixing. **6/6.** P. & P. 2/6.

A.C. WKG. BLOCK CAPACITORS
60 mfd. 275v. wkg. **45/-.** P. & P. 7/6. 25 mfd. 300v. wkg. **25/-.** P. & P. 5/-. 25 mfd. 275v. wkg. **22/6.** P. & P. 5/-. 18 mfd. 300v. wkg. **17/6.** P. & P. 3/6. 12 mfd. 400v. wkg. **15/-.** P. & P. 5/-. 7·19 mfd. 400v. wkg., 3-ph. Delta connection. **45/-.** P. & P. 8/6.

A.E.I. LIGHTING CAPACITORS
12 mfd. 250v. A.C. wkg. **5/-.** P. & P. 2/6. 13 mfd. 250v. A.C. wkg. 2·85 mfd. 440v. wkg., tubular. **5/-.** P. & P. 2/-. T.C.C. Type LC52, 0·01 mfd. 15 amps max. 2kV rms max. 20kVA max. 10kV P.K. (A.C.+D.C.). **27/6.** P. & P. 7/6.

3 INCH SQ FLUSH 0-80V. D.C. METERS
2½in. hole. By famous maker. Brand new. Boxed. **19/6.** P. & P. 2/6.



NEWMARK SYNCHRONOUS MOTORS
220/240v. A.C. 50C. 3 watts. 6 R.P.M. Size 2½×2×1½ ins. **12/6.** P. & P. 5/-.

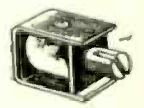
WESTERSTRAND CLOCKWORK TIMERS
Switch contacts, 15 amps., 250 volts A.C. Control knob can be set between 30 secs. and 6 mins. **Brand new 17/6.** P. & P. 2/6.

AMERICAN WILLARD, miniature accumulators 6v. 1·2 A.H. Size ⅞×1½×4in. Weight 4oz. **7/6.** P. & P. 1/6.

LONDEX PLUG-IN RELAYS
Sealed type, 28v. D.C. Three heavy duty silver contacts. Size 2×2×1in. Complete with base. **8/6.** P. & P. 2/-.

G.P.O. 3000 TYPE RELAY (New and Boxed)
20,000 ohms Heavy Duty Contacts. 2CO, 2M. **15/-.** P. & P. 2/-. 75 ohms Normal Contacts. 3M, 1B, 1CO. **6/-.** P. & P. 2/-. 500 ohms Heavy Duty Contacts. 3M, 3B. **8/6.** P. & P. 2/-. 150 ohms Heavy Duty Contacts. 2M. **6/-.** P. & P. 2/-.

MAGNETIC DEVICES SOLENOIDS



180v. D.C. Approx. ½in. pull. Size 1½×1½×1½ins. **5/-.** P. & P. 1/6. 50v. D.C. **7/6.** P. & P. 1/6.

A.C. 220-240v. SHADED POLE MOTORS
1,500 r.p.m. Double spindle. Length 0·9in. and 0·6in. Overall size 3×3½×2ins. New and Boxed. **10/6.** P. & P. 3/6.

PULLEN SHUNT WOUND 24. D.C. REVERSIBLE MOTORS
Type 610 H.P. 1/75 r.p.m. 3,500 Cont./R. New and boxed. **15/-.** P. & P. 3/6...

BURGESS MICRO SWITCHES
Type MK 3BR/74. Norm closed or Norm open. ½in. raised Press Button. 8/6 for three. P. & P. 2/6.

HONEYWELL 250v. 10A. A.C. Lever operated. Make or break (3 tags). Three for **12/6.** P. & P. 2/-. Many other types available.

MINIATURE LOW VOLTAGE P.S.U. Variable between 6-14 V. D.C.
These P.S.U. are transistorised and stabilised, fused and protected output is at 400 mA., 240 v. A.C. Input size 4 × 3 × 2½ in. Ideal unit for building into equipment. Price 75/-. P. & P. 2/6.

LANGBOURNE DYNAMICS TYPE 4B
Low Voltage/Highly Stabilised POWER SUPPLY UNIT
Variable between 3-30 v. D.C. at 1 A. Fully transistorised and current limiting offered. BRAND NEW at only £13.10 inclusive of P. & P.

ADVANCE VOLT STAT CV500/31
Input 162-276 v. A.C., 50 c/s. 1 phase output 115 v. constant at 410 watt. Offered BRAND NEW at only £8. P. & P. 15/-.

ADVANCE D.C. SERIES
Output 24 v. D.C. at 5 amps. Input 200-245 v. A.C. ± 15%. Fully smoothed and protected. BRAND NEW units at only £10 each.

HIGH VOLTAGE TRANSFORMERS
Input 240 v., output 2560 v. and 2820 v. at 1 amp. Weight 75 lb. Price £15.

TRANSFORMERS
Suitable for P.S.U. high grade unit with 2 5000 v. smoothing capacitors. 8 Mullard BYZ 13 Zeners. 2 Mullard BY114 diodes. Transformer incorporates tapped primary 100-250. Output is 17-24-31-38 v. twice at 2·4 amp. Offered BRAND NEW ONLY 80/-. P. & P. 10/6.

NICKEL-CADMIUM BATTERIES
D.E.A.C. manufacture RS 3·5 rating 3·5 Ah 1·24 v. Size as British U2, fully rechargeable. Offered BRAND NEW 19/6 each. P. & P. 1/6.

MALLORY DURACELL MERCURY BATTERIES TYPE TR153R. 4·05 V.
Size 1⅝ × 7/16 in. dia. Price 4/-. P. & P. 6d. Also TR152R 2·7 v. Size 1⅛ × ½ in. dia. Price 3/-. P. & P. 6d.

LEAD ACID BATTERIES 12 v. 4 Ah.
Non spillable type supplied NEW. Boxed with charging instructions. Size 4 × 4 × 4 in. Price 45/-. P. & P. 4/6.

OHMITE RHEOSTATS
40 ohms, 500 watts. Torodial wound on ceramic formers. BRAND NEW high quality units. Size 5 in. dia. Price 35/- each. P. & P. 5/-.

MULLARD HIGH SPEED VALVE TESTER
With approx. 500 cards. Good, used condition. Ready to work. Price £45. Carriage extra.

BERCO RHEOSTATS 3000 Ω AT 100 Watts
Torodial wound on ceramic former with control knob. BRAND NEW at 12/6. P. & P. 1/6.

AUDIO OSCILLATORS AMERICAN TS-382/U
Covers 20 c/s-200 Kc/s in four ranges. Output voltage 1 micro volt to 10 v. in seven ranges. Built in calibrator. Sine wave O.P. is excellent over complete range. Supplied with transit case adaptors and circuits and transformer for 240 A.C. AS NEW. £30. P. & P. 20/-.

RF WATTMETERS U.S.A. PATTERN ME-11/U
Power range 0-60 watts in 2 ranges. Impedance 50 ohms. Frequency range to 500 MHz. Type of reception AM-CW-FM. Supplied with small transit case in first class condition.

WE HAVE FULL RANGE OF HIGH QUALITY OSCILLOSCOPES
Offered in FIRST CLASS condition

	Price
Solartron CD711S/2	£75
Solartron CD513	£47
Solartron CD614	£47
Solartron CD1015·2	£85
Solartron CD1012	£125
Solartron QD910 Storage Scope Cossor 1049	£35
Remscope Storage Scope Cossor 1076 with four plug ins. Waterman USM-24	£65

Also Scopes by EMI, Marconi, Furzhill, Naggard, Telequipment. All instruments have been carefully overhauled, pre-calibrated and are offered guaranteed condition.

CAPACITANCE BRIDGE ELECTROLYTIC
B.P.L. Cat. No. ZD00506. Measures capacitance under full working loads (variable voltage selection). Easy to operate. C/W voltmeter, leakage current meter, balance indicator, discharge switch, etc. Range 2 mfd. to 2,200 mfd, A modern instrument in new condition. and guaranteed accurate. Price £35. P. & P. 20/-.

MARCONI AUDIO TESTER TYPE TF894
This directly calibrated AF oscillator from 50c/s to 12kc/s has a maximum output of 300mW. Into 600 ohm and is fitted with an output level meter and 600 ohm ladder attenuator of 0-50dB. An alternative 5,000 ohm outlet is provided and the level in each case is continuously variable. AF measurements: the voltmeter may be used for AF inputs (external) over the ranges of 0 to 80 v. in 4 ranges, providing a very useful facility. Supplied in excellent condition and working order for only £18.10. Power supply 240 v. A.C. (internal).

WESTON RF AMP METERS O-3A
Two inch flush round panel mounting, black scale white pointer these first grade meters are offered NEW BOXED Price 25/-. P. & P. 2/6.

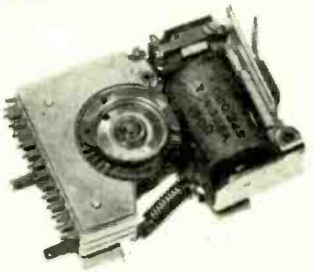
HIVOLT PORTABLE E.H.T. GENERATOR
Variable output from 0 to 10 kv. D.C., Megohms range 200 to 10³. A small modern completely portable instrument. Fully transistorised C/W batteries. Weight complete 21 lb. New condition. £35.

SPECIAL EQUIPMENT COOLING BLOWERS
Manufactured by Woods of Colchester. Totally-enclosed type with good airflow makes these blowers suitable for cooling T/X valves and equipment. For 115 v. A.C. operation. Supplied new and boxed. Price 60/-. P. & P. 5/-.

AVO METER CALIBRATION TEST UNIT TYPE CT155
A modern precision instrument, giving 7 standard voltages. 1 v. A.C.-2·5 v. A.C.-10 v. A.C.-25 v. A.C.-100 v. A.C.- and 250 mV. A.C. Also 250 mv. D.C. from internal standard cell. Internal power supply 110-240 v. A.C., contained in portable carrying case. Size 11 × 8 × 7 in. Brand new equipment. £12.10. P. & P. 10/6.

TUNING UNITS ANAPR4
Complete RF tuning head for the APR4 receiver two types available frequency range 38-95 Mc/s. Price £15. Also Type 3. Frequency range 300-1,000 Mc/s. Price £25. Both types are supplied with Auto Sweep Mechanism and circuit diagrams. Reduced price £10 either type.

A.E.I. MINIATURE UNISELECTOR SWITCHES
No waiting, straight off the shelf and into your equipment the Catalogue Nos. are 2202A, 4/33A63/1; coil resistance is 250 ohms. Complete with base, and the price is £4.19.6. Limited quantity only available.



MARCONI STANDARD SIGNAL GENERATOR T.F.867
Frequency range 15 kHz.-30 mHz. output variable from 4 micro volts to 4 volts at 75 ohms. Built in crystal calibrator. Calibration accurancy 1%. Supplied like NEW GUARANTEED.

HEWLETT PACKARD 616A. U.H.F. SIGNAL GENERATOR
Frequency range 1·8-4 G.Hz. variable output 0·1 micro volt to 0·223 v. into 50 ohm load. Pulse CW. or FM. modulation. Directly calibrated. OFFERED LIKE NEW.

RHODE & SCHWARZ SPECIAL EQUIPMENTS

UHF Receiver USVD BN1523. Range 280-4600 MHz.

R. & S. Signal Generator. Frequency range 1000-1900 MHz. type BN41026.

R. & S. ZDD Diagraph BN 3562.

R. & S. Signal Generator and Klystron P.S.U. Type SMPC. Range 1·7-5000 MHz.

R. & S. Signal Generator, range 300-1000 MHz.

Schomandle Frequency Meter. Type FDI with FDMI adaptor. Frequency range 30-900 Mc/s. Recalibrated to makers' specification.

Digital voltmeters. Digital Frequency Meters to 220 MHz. Digital Wheatstone Bridges. A.C. and D.C. Millivolt meter. D.C. Voltage Calibrators. Precision Crystal Calibrators.

Solartron 2 phase and 4 phase oscillators and associated equipment.

UHF Receiver R216. 19-157 MHz. FM/AM/GW C/W. P.S.U. and cables.

AR880 Receiver like new. Redifon Receiver R50M. Like new.

SOLARTRON LABORATORY OSCILLOSCOPE TYPE 711/S2
This magnificent scope will take pride of place in any service dept., college or university, offered at one fifth of the manufacturer's price, in perfect working order and excellent condition. Brief specification: bandwidth DC-7Mc/s.; sensitivity 3mV/cm to 100V/cm; sweep velocity, 0·33cm/sec. to 3·3cm/μsec.; × expansion variable up to × 10; size 16in. × 13in. × 27in. deep. Price £75.

AUDIO AMPLIFIER EXECUTIVE SIXTY
All solid state professional amplifier designed for studios and discotheques and P.A. systems. Supplied brand NEW and GUARANTEED 6 MONTHS. Please write for details.

HEWLETT PACKARD RF. POWER METER—Type 431B
Measures RF. power in 7 ranges, from 0·01 MW to 10 MW. This instrument is fully completely solid state, small portable, current series equipment. Mains or battery powered C/W thermistor mount either 478A 10 Mc/s to 10 K.Mc/s. Supplied in good used condition with thermistor mounts.

"PERISTALTIC PUMPS" HR FLOW INDUCER TYPE MHRE 72 L WATSON MARLOW LTD.
These very versatile pumps have facilities for two feed lines. The pumps are standard type but less variable speed control. Ideally suitable for highly corrosive liquids. Offered as new for A.C. mains operation, at the greatly reduced price of £24.10. Post/packing 10/-.

HIGH VALUE RESISTANCE BOX TYPE R.7003
Specification:
Range: 0·01-11·10 Megohm in 0·01 Megohm divisions. Accuracy: 0·05%. Maximum power rating: 0·1W. per step. Case: Hammer finished stove enamel. List price £60. OUR PRICE £22.10.

MUTUAL INDUCTANCE BOX TYPE R.7005
Specification:
Range: 0-11·110 mH in 0·002 mH divisions.
Accuracy:
$$\pm(0{\cdot}3 \times \frac{0{\cdot}012}{M})\%$$
where M = value of mutual inductance in mH set on the box. Frequency range: 0-2·5 Kc/s for all decades except X1 = 0-1·5 Kc/s. Maximum current: 0·5A for decades 1A for variometer (both primary and secondary windings). Case: Polished teak. List price £65. OUR PRICE £26.10.

PORTABLE WHEATSTONE BRIDGE
Specification:
Type: Moving Coil Galvanometer. Ranges: 1 0·05 to 5 ohms 20·5 to 50 ohms 35 to 500 ohms 450 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: 4 v., dry battery. Operating temperature: + 10 to + 35° C. Operating Humidity: Up to 80% R.H. Dimensions: 200 × 110 × 65mm. Weight: 0·9 kg. List price £25. OUR PRICE £9.19.6.

HUGE SELECTION OF TRANS-RADIO R.F. CONNECTORS, ALL NEW AND BOXED • SEND S.A.E. FOR LIST

ALSO B.N.C. AND PLESSEY CONNECTORS

P. F. RALFE 10 CHAPEL STREET, LONDON, N.W.1

Phone: 01-723 8753

HRO RECEIVER. Model 5T. This is a famous American High Frequency superhet, suitable for CW, and MCW, reception crystal filter, with phasing control. AVC and signal strength meter. Complete HRO 5T SET (Receiver, Set of 5 Coils & Power Unit) for £27/10/-, carr. 30/-.

COMMAND RECEIVERS; Model 6-9 Mc/s., as new, price £5/10/- each, post 5/-.

COMMAND TRANSMITTERS, BC-458: 5.3-7 Mc/s., approx. 25W output, directly calibrated. Valves 2 × 1625 PA; 1 × 1626 osc.; 1 × 1629 Tuning Indicator; Crystal 6,200 Kc/s. New condition—£3/10/- each, 10/- post.
(Conversion as per "Surplus Radio Conversion Manual, Vol. No. 2," by R. C. Evenson and O. R. Beach.)

AIRCRAFT RECEIVER ARR. 2: Valve line-up 7 × 9001; 3 × 6AK5; and 1 × 12A6. Switch tuned 234-258 Mc/s. Rec. only £3 each, 7/6 post; or Rec. with 24 v. power unit and mounting tray £3/10/- each, 10/- post.

RECEIVERS: Type BC-348, operates from 24 v D.C., freq. range 200-500 Kc/s, 1.5-18 Mc/s. (New) £35.0.0 each; (second hand) £20.0.0 each, good condition, carr. 15/- both types.

MARCONI RECEIVER 1475 type 88: 1.5-20 Mc/s, second-hand condition £10.0.0 each. New condition £25.0.0 each, carr. 15/-.

RACAL EQUIPMENT: Frequency Meter type SA20: £35 each, carr. £1. Frequency Counter type SA21: £65 each, carr. 30/-. Diversity Switching Unit type MA168: £35 each, post 10/-. Converter Frequency Electronic VHF Type SA.80 (for use with the SA.20): 25 Mc/s-160 Mc/s, £40 each, carr. £1.

ROTARY CONVERTERS: Type 8a, 24 v D.C., 115 v A.C. @ 1.8 amps, 400 c/s 3 phase, £6/10/- each, 8/- post. 24 v D.C. input, 175 v D.C. @ 40mA output, 25/- each, post 2/-.

CONDENSERS: 150 mfd, 300 v A.C., £7/10/- each, carr. 15/-. 40 mfd, 440 v A.C. wkg., £5 each, 10/- post. 30 mfd, 600 v wkg. D.C., £3/10/- each, post 10/-. 15 mfd, 330 v A.C. wkg., 15/- each, post 5/-. 10 mfd, 1000 v, 12/6 each, post 2/6. 10 mfd, 600 v, 8/6 each, post 5/-. 8 mfd, 1200 v, 12/6 each, post 3/-. 8 mfd, 600 v, 8/6 each, post 2/6. 4 mfd, 3000 v wkg., £3 each, post 7/6. 2 mfd, 3000 v wkg., £2 each, post 7/6. 0.25 mfd, 2Kv, 4/- each, 1/6 post. 0.01 mfd. MICA 2.5 Kv. Price £1 for 5. Post 2/6. Capacitor: 0.125 mfd, 27,000v wkg. £3.15.0 each, 10/- post.

AVO MULTIRANGE No. 1 ELECTRONIC TEST SET: £25 each, carr. £1.

OSCILLOSCOPE Type 13A, 100/250 v. A.C. Time base 2 c/s.-750 Kc/s. Bandwidth up to 5 Mc/s. Calibration markers 100 Kc/s. and 1 Mc/s. Double Beam tube. Reliable general purpose scope, £22/10/- each, 30/- carr.
COSSOR 1035 OSCILLOSCOPE, £30 each, 30/- carr.
COSSOR 1049 Mk. 111, £45 each, 30/- carr.

RELAYS: GPO Type 600, 10 relays @ 300 ohms with 2M and 10 relays @ 50 ohms with 1M., £2 each, 6/- post.
12 Small American Relays, mixed types £2, post 4/-.
Many types of American Relays available, i.e., Sigma; Allied Controls; Leach; etc. Prices and further details on request 6d.

GEARED MOTORS: 24 v. D.C., current 150 mA, output 1 r.p.m., 30/- each, 4/- post. Assembly unit with Letcherbar Tuning Mechanism and potentiometer, 3 r.p.m., £2 each, 5/- post.

Actuator Type SR-43: 28 v. D.C. 2,000 r.p.m., output 26 watts, 5 inch screw thrust, reversible, torque approx. 25 lbs., rating intermittent, price £3 each, post 5/-.

SYNCHROS: and other special purpose motors available. British and American ex stock. List available 6d.

TCS MODULATION TRANSFORMERS, 20 watts, pr. 6,000 C.T., sec. 6,000 ohms. Price 25/-, post 5/-.

AUTOMATIC PILOT UNIT Mk. 2. This complex unit of diodes and valves, relays, magnetic clutches, motors and plug-in amplifiers, with many other items, price £7/10/-, £1 carriage.

FOR EXPORT ONLY: B.44 Trans-ceiver Mk. III. Crystal control, 60-95 Mc/s. **AMERICAN EQUIPMENT:** BC-640 Transmitter, 100-156 Mc/s., 50 watt output. For 110 or 230 v. operation. ARC 27 trans-ceivers, 28 v. D.C. input. Also have associated equipment. BC-375 Transmitter. BC-778 Dinghy transmitter. SCR-522 trans-ceiver. Power supply, PP893/GRC 32A; Filter D.C. Power Supply F-170/GRC 32A: Cabinet Electrical CY 1288/GRC 32A; Antenna Box Base and Cables CY 728/GRC; Mast Erection Kits, 1186/GRC; Directional Antenna CRD.6; Comparator Unit, CM.23; Directional Control CRD.6, 567/CRD and 568/CRD; Azimuth Control Units, 260/CRD. Test Set URM.44, complete with Signal Generator TS.622/U.

SOLENOID UNIT: 230 v. A.C. input, 2 pole, 15 amp contacts, £2/10/- each post 6/-.

CONTROL PANEL: 230 v. A.C., 24 v. D.C. @ 2 amps., £2/10/- each, carr. 12/6.

AUTO TRANSFORMER: 230-115 v.; 1,000 w. £5 each, carr. 12/6. 230-115 v.; 300VA, £3 each, carr. 10/-.

OHMITE VARIABLE RESISTOR: 5 ohms, 5½ amps; or 2.6 ohms at 4 amps. Price (either type) £2 each, 4/6 post each.

POWER SUPPLY UNIT PN-12B: 230 v. A.C. input, 395-0-395 v. output @ 300 mA. Complete with two × 9H chokes and 10 mfd. oil filled capacitors. Mounted in 19in. panel, £6/10/- each, £1 carr.

TX DRIVER UNIT: Freq. 100-156 Mc/s. Valves 3 × 3C24's; complete with filament transformer 230 v. A.C. Mounted in 19in. panel, £4/10/- each, 15/- carr.

POWER UNIT: 110 v. or 230 v. input switched; 28 v. @ 45 amps. D.C. output. Wt. approx. 100 lbs., £17/10/- each, 30/- carr. SMOOTHING UNITS suitable for above £7/10/- each, 15/- carr.

DE-ICER CONTROLLER MK. III: Contains 10 relays D.P. changeover heavy duty contacts, 1 relay 4P, C/O. (235 ohms coil). Stud switch 30-way relay operated, one five-way ditto, D.C. timing motor with Chronometric governor 20-30 v., 12 r.p.m.; geared to two 30-way stud switches and two Ledex solenoids, 1 delay relay etc., sealed in steel case (4 × 5 × 7 ins.) £3 each, post 7/6.

MODULATOR UNIT: 50 watt, part of BC-640, complete with 2 × 811 valves, microphone and modulator transformers etc. £7/10/- each, 15/- carr.

ADVANCE TEST EQUIPMENT: TT1S Transistor Tester (CT472) £37/10/- each; VM77C Valve Voltmeter £40 each. Carr. 10/- extra per item.

NIFE BATTERIES: 4 v. 160 amps, new, in cases, £20 each, £1 10/- carr.

FUEL INDICATOR Type 113R: 24 v. complete with 2 magnetic counters 0-9999, with locking and reset controls mounted in a 3in. diameter case. Price 30/- each, postage 5/-.

UNISELECTORS (ex equipment): 5 Bank, 50 Way, 75 ohm Coil, alternate wipe, £2/5/- each, post 4/-.

FREQUENCY METERS: BC-221, meter only £30 each, BC-221 complete with stabilised power supply £35 each, carr. 15/-. LM13, 125-20,000 Kc/s., £25 each, carr. 15/-. TS.175/U, £75 each, carr. £1. TS323/UR, 20-450 Mc/s., £75 each, carr. 15/-. FR-67/U: This instrument is direct reading and the results are presented directly in digital form. Counting rate: 20-100,000 events per sec. Time Base Crystal Freq.: 100 Kc/s. per sec. Power supply: 115 v., 50/60 c/s., £100 each, carr. £1.

CT.49 ABSORPTION AUDIO FREQUENCY METER: freq. range 450 c/s-22 Kc/s., directly calibrated. Power supply 1.5 v.-22 v. D.C. £12/10/- each, carr. 15/-.

CATHODE RAY TUBE UNIT: With 3in. tube, colour green, medium persistence complete with nu-metal screen, £3/10/- each, post 7/6.

APNI ALTIMETER TRANS./REC., suitable for conversion 420 Mc/s., complete with all valves 28 v. D.C. 3 relays, 11 valves, price £3 each, carr. 10/-.

TEST EQUIPMENT

MARCONI	TF-1274	VHF Bridge Oscillator	£75 each
	TF-1275	VHF Bridge Detector	£75 each
	TF-1067/1	Heterodyne Frequency Meter	£85 each
	TF-899	Valve Millivoltmeter	£35 each
	TF-978	VHF Admittance Bridge	£85 each
	TF-894A	Audio Tester	£55 each
	TF-329G	Circuit Magnification Meter	£45 each
	TF-428/2	Valve Voltmeter	£12/10/- each
	TF-428/1	Valve Voltmeter	£8/10/- each
	TF-726C	UHF Signal Generator	£65 each
	TF-934	Deviation Test Meter	£35 each
	6075A	Deviation Test Meter	£65 each
	TF-987/1	Noise Generator	£20 each
	TF-956	(CT.44) A.F. Absorption Wattmeter	£20 each
FIRZ HILL	V.200	Sensitive Valve Voltmeter	£35 each
	B.810	Incremental Inductance Bridge	£75 each
SOLATRON	CD-513	Oscilloscope	£45 each
	CD-513-2	Oscilloscope	£47/10/- each
	AW-553	Power Amplifier	£30 each
AIRMEC	Type 701	Signal Generator	£50 each
PHILLIPS	Type GM-6008	Valve Voltmeter	£35 each
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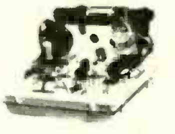

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100	9d	1/6	2/3	4/6
200	1/3	2/-	2/9	5/-
400	2/-	2/6	4/-	8/-
600	—	3/-	4/6	9/6
800	—	3/9	5/-	11/3
1000	—	6/-	6/6	14/-

THYRISTORS-SCRs

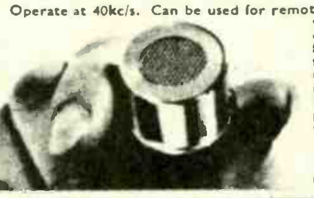
PIV	1A	3A	10A	30A	100A
50	7/6	9/-	7/6	25/-	20/-
100	—	10/-	10/-	30/-	22/-
200	8/6	—	12/6	42/-	35/-
300	—	11/-	—	51/-	—
400	9/6	12/6	15/-	60/-	45/-
600	—	—	20/-	84/-	120/-
800	—	—	—	—	—

NEW SPECIAL ITEMS!!

40602— Dual Gate MOS-FET 9/- each
L14B— Photo-Darlington Amplifier 26/6
MGA100—Gallium Arsenide Infra Red Light Source 35/-
31F2— Infra Red Detector Diode 28/6
3N84— Silicon Controlled Switch 29/6
TAA320—Monolithic IC with MOS-FET input followed by Bi-Polar transistor 13/6
Data sheets 1/- on request—free with above items.

ULTRASONIC TRANSDUCERS

Operate at 40kc/s. Can be used for remote control systems without cables or electronic links. Type 1404 trans-ducers can transmit and receive.
FREE: With each pair our complete transmitter and receiver circuit.
PRICE £5.18.0 Pair
(Sold only in pairs)

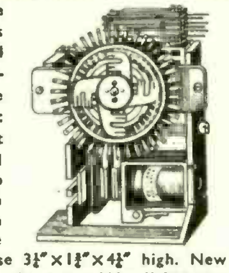


Prices quoted are current at time of going to press and may be subject to variation.
Semiconductors offered bear Manufacturers' original markings and are subject to our full replacement guarantee if not to published specifications.
WE DO NOT offer "Re-marked" Semiconductors.
Our 1969/70 Catalogue is available FREE on request.
Trade: Quantity Prices on application.
Please enclose a stamped addressed envelope with any queries.
Retail: Cash with order, please.
Trade: Please furnish usual references if Credit facilities required.
Post & Packing 1/- per order (FIRST CLASS).

MAIL ORDER DEPT. & RETAIL SHOP:—
LST, 7 Coptfold Road, Brentwood, Essex
Telephone: 226470/1 (Sales Department)
EXPORT ENQUIRIES PARTICULARLY WELCOME

Electro-Tech Sales

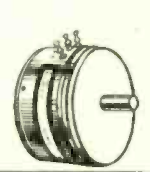
SCHRACK ROTARY STEPPING RELAY RT304 48v. coil (28 ohm). The relay has 48 basic segments shorted in step by the 4 sweep contacts to 4 pole-plates (banks of 12). There are 2 secondary switches: (1) one c/o H/Duty contact set which changes over and back with each step; (2) two H/Duty changeovers which changeover on each 12th step and return on the following pulse. Size: Base 3½"×1¾"×4½" high. New in maker's packing, also, as above, but 110v. (1,290 ohm coil). **£4.15.0** each.



Welwyn high value Resistors Type GA 36501. Values between 9.4 and 10.9 kilo-meg ± 1%, glass encapsulated 15/-.

Victoreen "Hi-Meg" Resistors. One value only 50,000 meg ± 2%, glass encapsulated **15/-.**

Precision Motor-driven Potentiometer By "Precision Line" (U.S.A.). Continuous track with 2 platinum contact wipers set at 90° C.W. resistance 300 ohm only, ± 5% LIN ±0·5%, ball bearing spindle column. Size: dia. 1 13/32", height 1 1/32", spindle length 11/32" by ⅛" dia. These potentiometers were purchased by the importer at a cost of approx. £25 each. Our price **£4.10.0.**



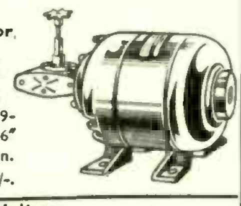
English Electric ¼ h.p. Motors. 240v. single-phase, standard foot mounted, 1,425 r.p.m., continuous rating. **£4.15.0.** Carriage 20/-.

Isolation Transformers. 1 to 1 ratio. 240v. input, 240v. centre tapped out, at 2 K.V.A., mounted in metal case measuring 8½"×8½"×11" high. Weight 65lb. **£16.10.0.** Plus £1 carriage.

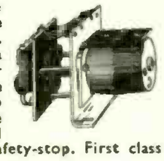
NEW HYSTERESIS MOTORS BY WALTER JONES. Type 14050/12, 240v. 50 c/s 1500 RPM cont. rating, output 2.0 oz./in. Size: Length (less spindle) 3½". Width 2½"×2½". Spindle 1"×3/16". Weight 3 lb. Maker's price in region of £22.10.0. Our price **£6.10.0.** each.

K.L.G. Sealed Terminals. Type TLSI AA, overall length 11/16", box of 100, **25s.**
Type TLSI BB, overall length 1", box of 100, **35s.**

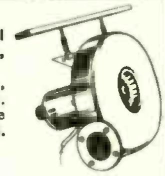
"Parvalux" Reversible 100 RPM Geared Motor. Type S.D.14, 230/250v. A.C. 22 lb./in. Standard foot mounted, variable angle final drive. Removable 9-tooth chain spiggot on 3/16" spindle. 1st class condition. **£7.10.0** each. P. & P. 10/-.



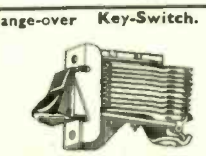
Motor Driven Variable Voltage Transformers by Ohmite (U.S.A.). Input 120/240v., 50/60. c.p.s. Output 0-240v. at 480 v.a A reversible 115v. a.c. geared motor drives the contact sweep arm in the direction required. There is a micro switch mounted at each end of the track which is cam-operated and intended to be connected as a safety-stop. First class condition. **£8.15.0.** P. & P. 10/-.



Brand new "Discus" Centrifugal Blower by Watkins & Watson, 240v. A.E.I. motor, cont. 2,850 r.p.m., overall diam. 10", outlet flange 2" I.D. additional coupling mounting flange supplied. Limited supply. **£9.10.0.** Carriage £1.0.0.

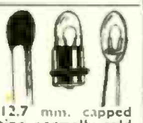


New beautifully-made 3 change-over **Key-Switch.** Neat action, either locking or spring-return, as required determined by reversing fixing-plate. Attractive plastic prestle. Available red, green, grey, cream. Limited number only. **17/6** each.

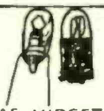


THORN DIGITAL INDICATOR designed as a modular unit for easy mounting where 1st class numerical readout is required. Easily read through a wide angle of view and under bright ambient lighting. 12 characters, 0 to 9, decimal point and minus sign. Characters 13/16" high engraved on acrylic slides and individually edge-lit by 1 watt midget-panel lamps. Overall size of front panel 4½" high × 1⅞" overall depth 1" finished in matt black supplied with 12 lamps, choice of following ratings—6v. .1A. or 12-14 v. .08A. **£4.0.0** each, spare lamps **24/-** per dozen.

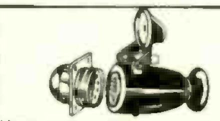
ATLAS SUB-MINIATURE LAMPS type L1122 and L1123—a high efficient light-source with excellent light-output and low power demand. Ratings 5v. 60 ma. .35± 25% lumens. Life expectancy 60,000 hours or at 6 v. 70 ma. .75± 25% lumens 5,000 hours. Dimensions: Uncapped 6.3 x 3.1 mm. leads 12.7 mm. capped 9.1 x 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. .25 A., 6v. .1 A., 6v. .2A. 24/- per dozen or boxes of 50 at £4 per box. Indicator lamp holders and caps for **ATLAS MIDGET PANEL LAMPS** (as above) available red, orange, green, blue, 2/6 each (complete) minimum order 4 units.

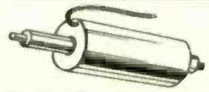


THORN TRAILER CONNECTORS—These special 12 way connectors are for heavy vehicle applications and allow uncoupling by strain on the cable. Spring loaded protection caps give a full weather insulation sealing immediately on uncoupling. Heavy rubber sleeve on plug ensures maximum safety **£3.0.0** per pair (plug and socket).



THORN ILLUMINATED PRESS SWITCH for 250v. operation. M.E.S. Pressure on cap completes a second circuit. Very robust. Length 44.5 mm. dia. 30.5 mm. in amber, green or red. **10/6** each.

4½v. to 9v. Solenoid. 1" pull. Very powerful, length 1½", dia. 11/16". **10/-** each.



"Tansitor" (U.S.A.) Tantalum, Wet Sintered Anode Polarised Capacitors. 1200 UF. 6v. D.C. size: 1⅞" long × ⅝" dia. 200 UF. 25v. D.C. size: ⅞" long × ⅜" dia. 180 UF. 25v. D.C. size: ⅞" long × ⅜" dia. 150 UF. 30v. D.C. ⅞" long × ⅜" dia. 33UF. .75v. D.C. size: ⅜" long × 9/32" dia. One wire each end. All types 5/- each. Also few only, Tansistor "MICRO-MODULE" capacitors 0.2 Mfd. 15v. wire-ended, size: 3/32" dia. (disc) **7/-** each.

American "Powerstat" Variable Voltage Transformer by Superior Electric Co. Input 120v. 50/60 c.p.s. Output 0–120v. at 2·25 amps. ¼" spindle with alternative pre-set locking device. Size (approx.) 3" dia. × 2" long. First class condition. **£2.15.0.** P. & P. 5/-.

Berco Rotary "Regavolt," variable voltage transformers input 240v. 50/60 cps., output 240v. C.T. at 6 amps. Not new, but in 1st class condition. Few only, **£8.10.0.** P. & C. 10/-.

Gardner Transformer Type I.T.N. 876 (new). Enclosed in ventilated metal case. Prim 200/250, sec. 2×12v. windings rated 4 amps each (96 v.a. in series/parallel). **£3.2.6.**

S.T.C. Midget Relay Type 4190 GC. (new). 2 changeovers, 12v. 40 m.a. coil (170 ohms). **10/6** each.

Jackson Air-Spaced Trimmers Type C803. Preset locking type, ceramic end-plate, 2-hole fixing. 3–10 p.f., **2/6.** 4–20 p.f., **2/6.** 4–60 p.f., **4/-.** 5–100 p.f., **4/-.** (Minimum order any 4 pieces.)

Advance Constant Voltage Transformer (new). Input 190–260v. Output volts 12 R.M.S. at 50 v.a. **£4.19.6.** Carriage 10/-.

Mullard Geiger Muller Tubes Type MX115 (new) Max. threshold voltage 370. Min. plateau length (volts) 100. Active length 44mm. Wall thickness 375 M.G./sq. cm. Two-pin base. **£3.10.0.**

Dubilier Nitrogol Capacitors. 24 mfd. at 350v. D.C. Size (approx.) 4½" high × 3½" × 2½". **10/-** each.

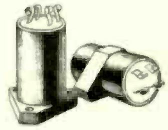
Mallory Tubular Capacitor, with mounting clip. 1,000 mfd. 45v. D.C. Size 2½" long by 1½" dia. **7/6** each.

WHERE NO CARRIAGE CHARGE IS INDICATED PRICE IS INCLUSIVE. PERSONAL CALLERS WELCOME.

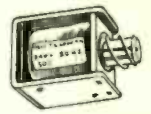
SYLVANIA MAGNETIC SWITCH—a magnetically activated switch operating in a vacuum. Switch speed—4ms. temperature −54 to + 200° C. Silver contacts normally closed rated 3 amps. at 120v. 1.5 amp. at 240v. **10/-** each. **£4.10.0** per dozen. Special quotations for 100 or over. Reference Magnets available **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 **£4.10.0** per dozen.

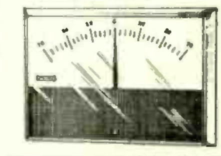
MINIATURE "LATCH-MASTER" RELAY 6, 12, or 24v. D.C. operation. One make one break, contacts rated 5 amps. at 30v. Once current is applied, relay remains latched until input polarity is reversed. Manufactured for high acceleration requirements by Sperry Gyroscope Co. Size: Length ⅞", dia. 9/16" (including mount). Please state vertical or horizontal mount and voltage. **£2.5.0** each.



New "Magnetic Devices" solenoid 240v. A.C. Type 42117, 1 to 3 lb. pull, frame size 1½"× 1⅝"×1". **20/-** each.

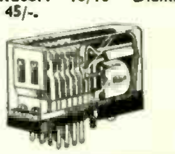


New 75-0-75 Micro-ammeter by Sifam. 750 ohm movement, clear reading, 5μa divisions × ⅛"; plastic front, projection ½" (tapering forward). Size: 4¾"×3¾", **57/6** each.

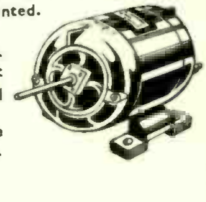


MINIATURE B.P.L. 500-0/500 Micro-Ammeter. 13/16" Diam. scale. Through-Panel mounting, **45/-.**

"AUTOMATIC ELECTRIC" ENCLOSED RELAYS
6v. 50Ω 2 c/o, **12/6**
24v. 470Ω 4 c/o, **13/6**
48v. 2,780Ω 4 c/o, **13/6**
48v. 1,260Ω 6 c/o, **15/-**



New "Croydon" 1/50th HP, cont. rating 240v. A.C. motor, 1500 RPM, foot mounted. Size: 3⅜" high × 5" long + spindle length 1⅝"×¼" dia. A really reversible motor at less than half maker's original price. Also available identical to above but 750 r.p.m. 1/100th h.p. both types **£6.10.0** each.



BRAND NEW ALTERNATORS MANUFACTURED BY ENGLISH ELECTRIC CO.

Type	Motor V.	Ph.	Input C.P.S.	R.P.M.
1	220	3	50	3000
2	380/440	3	60	3600
3	115	3	60	3600
4	220	3	60	3600
5	220 D.C.			
6	110 D.C.			

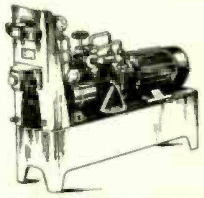
All types give the same Dual outputs as below.

V.	Ph.	C.P.S.	V.A.
115	3	400/20	50
85	1	400/20	300

£47.10.0 Each Carriage extra.

Also in stock several types of heavier duty units. Full Details upon request.

VICKERS-SPERRY-RAND Hydraulic Power Units as illustrated. Full details upon request. Approx. 60% below makers price at **£150.0.0** each.



ELECTRO-TECH SALES
264 PENTONVILLE ROAD, LONDON, N.1
(ONE MIN. FROM KINGS X STATION) **Tel. 01-837 7401**

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., 5th FEB. for the MARCH issue, subject to space being available.

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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:

C & G Final Certificate in Electronic Radio/TV Servicing
or
Telecommunications Technicians Intermediate Certificate.

The Company is the UK's leading manufacturer of radio-telephone equipment and is engaged in a major expansion programme designed to double present turnover over the next five years. Opportunities for promotion are therefore excellent.
The factory is situated in an expanding town and assistance with Housing through the Local Council is possible, together with relocation expenses where appropriate.
The successful applicants will join our permanent staff and will enjoy the benefits of a Company which is offering first class financial rewards, pension and sick schemes.
Please apply to:

Mrs C. M. Dawe, Personnel Officer
PYE TELECOMMUNICATIONS LTD
Colne Valley Road, Haverhill, Suffolk.
Telephone: Haverhill 2321 Ext. 26

Pye Telecommunications Ltd

1966

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.

2834

TELECOMMUNICATIONS MAINTENANCE

WEST MIDLANDS GAS

The development of telecommunications services in the Board has created vacancies for experienced Maintenance Technicians.

The work is extremely interesting and covers microwave and single channel radio links, telephone multiplexing equipment, mobile and personal radio systems. Data transmission systems are now being introduced and sophisticated mobile radio control systems are planned.

Candidates should have relevant experience in one or more of the above fields; knowledge of digital systems and the ability to work effectively over a wide range of equipment is desirable. They should have obtained City and Guilds (Intermediate Telecommunications) or O.N.C. as a minimum qualification. Possession of a current driving licence is necessary.

The salary ranges are:

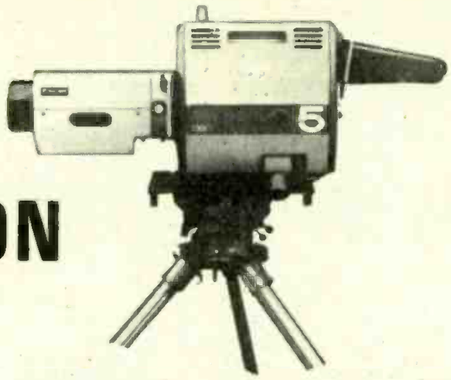
TECHNICIAN (II)
£1,035 to £1,355 per annum

TECHNICIAN (I)
£1,210 to £1,565 per annum

Opportunities exist for progression to scales rising to £1,790 per annum and for participation in budget engineering and system planning duties. Please apply in writing quoting reference number A 950 to the Senior Personnel Officer (Headquarters), West Midlands Gas Board, 5 Wharf Lane, Solihull.

2831

COLOUR TELEVISION



COMMISSIONING, INSTALLATION AND MAINTENANCE ENGINEERS

BASED IN

BIRMINGHAM, GLASGOW, MANCHESTER, LEEDS, CROYDON or ROYSTON

To keep pace with our current expansion programme, we have established additional vacancies for TV engineers to join our existing teams working on a wide range of professional TV broadcast equipment, such as colour/monochrome TV cameras and monitors, telecine, large screen TV projectors, videotape recorders, etc.

If you are of O.N.C. standard, are prepared to travel and have recent practical experience of professional TV equipment or colour TV receivers, we would like to hear from you. Product training will be given. Good career prospects.

Conditions of employment are attractive. Excellent and progressive salaries will be offered to competent applicants.

Apply with brief details of your experience to:

Personnel Officer
PYE TVT LIMITED
Addlestone Road,
Weybridge, Surrey.

Area interviews will be arranged.

2808

WW.21.

SENIOR DEVELOPMENT ENGINEER. £1900.

Our clients seek electronics engineer of at least H.N.C. standard with additional qualifications in control or digital techniques preferably around 30 years and living, or prepared to work, in the Hertfordshire area. The applicants should have shown some administrative ability in project coordination, possibly in avionics, military control systems, or high speed digital control circuits. *Please apply in writing and in strict confidence, quoting the above reference to:*

ELECTRONICS APPOINTMENTS LTD.
NORMAN HOUSE · 105/109 STRAND · LONDON · W.C.2
TEL · 01-836 5557

LIVERPOOL CLINIC
1 MYRTLE STREET, LIVERPOOL

Applicants are invited for the post of

MEDICAL PHYSICS TECHNICIAN Grade II

in the DEPARTMENT OF NUCLEAR MEDICINE. Person appointed will be required to maintain nucleonic and electronic equipment and would be expected to assist in the design and building of new equipment and modifications of existing apparatus. Duties are principally in the Liverpool Clinic, but at times extend to other hospitals in the region. Possession of Higher National Certificate or equivalent is desirable. Whitley Council Conditions of Service. Salary scale £1,313 rising to £1,671 per annum.

Application forms obtainable from Personnel Section, Clatterbridge Hospital, Bebington, Wirral, Cheshire.

2788

INTERTEL COLOUR TELEVISION
LIMITED

have the following vacancies at their Studio at 66 Dean St., London, W.1

Engineer in Charge of Operations
Supervisory Engineer—VTR
Senior Engineers—VTR
Engineers—VTR
Senior Engineer—Vision
Senior Engineer—Sound
Junior Lighting Director
No. 2 Cameraman
No. 3 Cameraman

Applications should be forwarded to:

The Chief Engineer, Intertel Colour Television Ltd., Wycombe Road, Wembley, Middlesex

2800

HACKER

ELECTRONIC TEST ENGINEERS

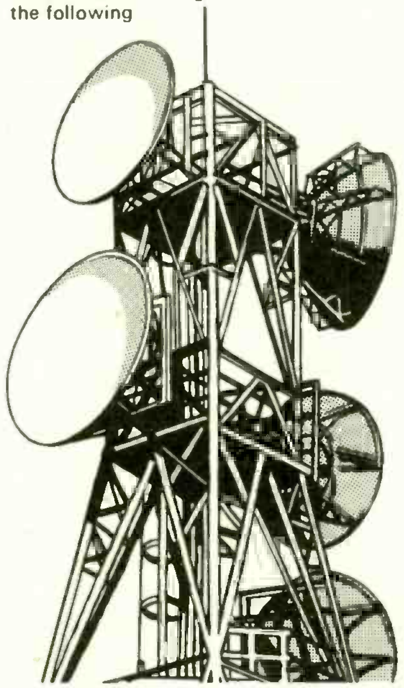
required for advanced test equipment under contract to the Atomic Energy Authority. Full staff status. Excellent working conditions and every opportunity for advancement.

Write or telephone:
The Personnel Manager, Hacker Radio Limited,
Norreys Drive, Cox Green, Maidenhead, Berks.
Telephone: Maidenhead 22261

2805

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

Government of ZAMBIA

REQUIRES

RADIO SPECIALIST

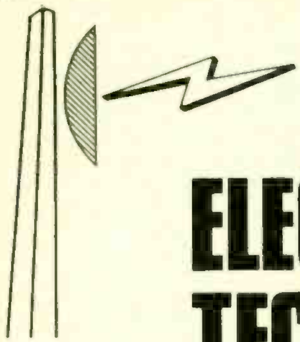
on contract for one tour of 36 months in the first instance. Salary according to experience in the Scale Kwacha 2460 to 3000 (Approx. £. Stg. 1435 – £. Stg. 1750) plus an Inducement Allowance of £. Stg. 684 a year which is payable direct to the officer's bank in the U.K. Gratuity 25% of total salary drawn. Both gratuity and Inducement Allowance are normally TAX FREE. Liberal leave on full salary or terminal payment in lieu. Free passages. Accommodation at moderate rental. Education Allowances. Outfit and plain clothes allowances. Contributory pension scheme available in certain circumstances.

Candidates, who will serve in the rank of Inspector of Police, must have completed a five year apprenticeship or hold a Service Trade Certificate or equivalent qualification and have had at least six years post-qualification experience in the installation and maintenance of modern low and medium power H.F. equipment, S.S.B. and I.S.B. equipment, and of V.H.F. equipment including multiplex links. Knowledge of maintenance of teleprinters, diesel and petrol generators preferred.

The officer will be required to maintain and install police radio equipment throughout Zambia, travelling by road and air, and to train Zambian officers for City and Guilds examinations.

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/61274/WF

2811



ELECTRONICS TECHNICIANS

Overseas Careers

Posts To meet our expansion requirements further posts are now available for Electronic Technicians to join International Aeradio Limited for world-wide employment.

Men joining the company may be posted to any one of our overseas stations on a 1 to 2 year tour basis and will be involved in a variety of interesting work covering the maintenance of a wide range of communications equipment.

Requirements You should have a practical knowledge of HF, VHF and UHF equipment. A knowledge of navigational aids would be an advantage. A technical qualification is also desirable.

Company is well-established and fast expanding in its activities in the fields of aviation services and communications with over 3,000 employees around the world. Excellent career prospects are open to men of ability.

Benefits include excellent tax free starting salaries, free accommodation for single men and married men with families and in addition tax free marriage, children's and education allowances and leave passages.

Opportunities are also available for cheap holiday air travel.

To apply please write stating details of age and qualifications to:

Personnel Officer (Recruitment).

IAL *INTERNATIONAL AERADIO LIMITED*
AERADIO HOUSE · HAYES ROAD · SOUTHALL · MIDDLESEX

THE UNIVERSITY OF LEEDS

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.

The appointment is for 3 years in the first instance in the range £1,460-£1,940, the point of entry depending on qualifications and experience. Superannuation under F.S.S.U.

Applications (three copies) stating age, qualifications and experience and naming three referees should reach Dr. H. E. Nursten, Procter Department of Food and Leather Science, The University, Leeds, LS2 9JT, as soon as possible.

2799

BATH UNIVERSITY OF TECHNOLOGY

ELECTRONICS TECHNICIAN

A vacancy has arisen for an Electronics Technician in the School of Engineering to assist with the development and servicing of electronic equipment and instruments.

Applicants must have practical experience of wiring and electronic 'trouble-shooting'. The work is varied and interesting and offers the opportunity to become familiar with a wide range of modern electronic instruments and applications.

Starting salary in the range £773-£1,077 per annum. The post is superannuable. Application forms from Registrar (S), **The University, Claverton Down, Bath, BA2 7AY, quoting reference 69/86.**

2787

CRANFIELD

DEPARTMENT OF ELECTRICAL AND CONTROL ENGINEERING

Applications are invited from men with experience in waveguide techniques for appointment as

TECHNICAL OFFICER

in the high frequency and radar laboratories which are concerned with postgraduate teaching and research in radar, radio and microwaves. Experience in the aviation field is not essential.

Duties include supervision of the day-to-day activities in the laboratories and responsibility for the construction of specialised experimental equipment. Candidates should have passed the graduateship examination of the I.E.E., I.E.R.E., or possess a H.N.C. or equivalent qualification. Salary within scale rising to £1,623 p.a. (under review). 37 hour week of five days, generous holidays, staff superannuation and sick pay schemes, subsidised transport over a wide area.

Application form from Staff Records Officer, The College of Aeronautics, Cranfield, Bedford.

2780

Science Research Council

RADIO AND SPACE RESEARCH STATION

THE RADIO AND SPACE RESEARCH STATION require a TECHNICIAN FOR MAINTENANCE, TESTING AND CALIBRATION OF ELECTRONIC EQUIPMENT intended for use in the RSRS research laboratories. Should be capable of interpreting manufacturers' specifications, and preferably be familiar with modern test equipment and circuit techniques currently analysed, i.e. oscilloscopes, counters, signal generators, etc.

QUALIFICATIONS. Applicants should have a general experience of electronics engineering; hold an Ordinary National Certificate in a relevant subject or a City and Guilds Final Technicians' Certificate, and preferably have served a recognised engineering apprenticeship (or have had comparable training) with at least three years post apprenticeship experience.

SALARY. Salary according to age and experience in the scale of £1,030-£1,550. Age 26 years £1,280.

Apply: The Secretary, Radio and Space Research Station, Ditton Park, SLOUGH, Bucks. Telephone SLOUGH 24411

Closing date 20.2.70. 2825

RADIO OPERATORS

There will be a number of vacancies in the Composite Signals Organisation for experienced Radio Operators in 1970 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 September 1970.

During training a salary will be paid on the following scale:

Age 21	£800 per annum
„ 22	£855 „
„ 23	£890 „
„ 24	£925 „
„ 25 and over	£965 „

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	£965 per annum
„ 22	£1025 „
„ 23	£1085 „
„ 24	£1145 „
„ 25 (highest age point)	£1215 „

then by six annual increases to a maximum of £1,650 per annum.

Excellent conditions and good prospects of promotion. Opportunities for service abroad.

Applicants must normally be under 30 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:

Recruitmont Officer, Government Communications Headquarters, Oakley, Priors Road, CHELTENHAM, Glos., GL52 5AJ.

Telephone No. Cheltenham 21491 Ext. 2270.

92

Test Engineers

Due to expansion there are excellent opportunities for Test Engineers in our laboratories and production departments, testing Radio, Navigator and Survey equipment.
Applicants with first-class background of T.V. and Radio Servicing or Telecommunications, Electronic and Control Circuiting should apply giving details of experience. Conditions are excellent and salaries will be commensurate with ability and experience.

DECCA

Apply quoting Ref. NAV/29/D to
The Personnel Officer, The Decca Navigator Company Ltd., 88 Bushey Road, Raynes Park, London, S.W.20. Tel: Wimbledon 8011.

281

SCIENCE RESEARCH COUNCIL

RADIO AND SPACE RESEARCH STATION

EXPERIMENTAL AND ASSISTANT EXPERIMENTAL OFFICERS

are required for investigations of the propagation of radio waves through the troposphere and ionosphere.
Duties will include the development of electronic and other apparatus, performance of experiments and the processing and analysis of results.
Much of the current work is directed towards the improvement of communications, particularly by studying the propagation of centimetre and millimetre waves. Experiments are carried out using rockets and satellites to study the upper atmosphere.
Suitably qualified staff may spend a tour of duty of up to 3 years' duration in the Falkland Islands to operate and maintain radio telemetry equipment for the reception of data from satellites.
QUALIFICATIONS: University or CNAA degree, HNC or equivalent qualification. If under 22 years, five G.C.E. passes including two science or mathematical subjects at "A" level or equivalent.
SALARIES: Assistant Experiment Officer between £683 and £1,454 p.a. Experimental Officer between £1,590 and £2,006 p.a. Non-contributory superannuation scheme.
Apply: **The Secretary, Radio and Space Research Station, Ditton Park, Slough, Bucks. Telephone: Slough 24411.**
Closing date 20.2.70. 2827

UNIVERSITY OF DUNDEE

Applications are invited for the following posts in the Electronics Workshop of the Department of Electrical Engineering:

SENIOR TECHNICIAN (Electronics)

TECHNICIAN (Electronics)

Salary Scales:
Senior Technician £1,056-£1,311
Technician £773-£1,077

The Senior Technician will be required to look after the day-to-day running of the Workshop, which serves the Department by making a wide range of electrical equipment for teaching and research, and by servicing the electronic instruments of many kinds which are used in the laboratories.

Applications containing the name and address of two referees should be sent as soon as possible to The Secretary, The University, Dundee, DD1 4HN, from whom further particulars may be obtained.
Please quote reference Est/140/69

2781

BATH UNIVERSITY OF TECHNOLOGY

A TECHNICIAN

is required in the School of Mathematics to assist mainly in developing and servicing

ANALOGUE AND DIGITAL COMPUTING

devices. Candidates should have experience in electronics, should possess a basic qualification and be competent in elementary workshop skills.

Salary in the range £773-£1,077 per annum, according to age, experience and qualifications.

Further details and application form from Registrar (S), The University, Bath BA2 7AY, quoting reference 69/82A. 2821

NEVE GROUP

specialise in the design and manufacture of sound control equipment and the supply of complete installations for professional sound studios in the fields of recording, broadcasting, television and films.

RUPERT NEVE & COMPANY LIMITED

require the following staff:

SENIOR SALES APPOINTMENTS

We require mature and experienced men with drive and initiative to open up new fields and markets at home and overseas. These posts will carry considerable responsibility and will be offered to those who can prove a successful experience in a similar capacity. Some technical knowledge of these fields will be necessary together with the ability to negotiate the sale of capital equipment at Board level. Since the posts involve world wide travel, the ability to speak fluent German, French or one other language in addition to English at the time of applying will be a positive advantage.

Age should be 28-40. Salary will be commensurate with age and experience. Benefits will include the provision of a car and assistance with housing or moving may be arranged.

The posts will normally be based in England but consideration would be given to applicants resident in Holland or Switzerland. A qualifying period at headquarters in England would be required.

Direction is by committed Christians and the business is dedicated to the support of Christian outreach by radio. The successful candidates must be able to associate themselves with these objectives.

ASSISTANT TO CHIEF ENGINEER

experienced in audio systems specification and application, to work on major projects in the professional recording, broadcasting and television field. Applicants should be capable of accepting a high degree of responsibility, including the direction of the necessary technical staff. Applicants should be equipped with an extrovert personality and will be expected to have direct contact with the customer at a high level in close co-operation with the Sales Department. The post will include a certain amount of overseas travel.

Qualifications—H.N.C. Minimum. Age—25-35. Salary—commensurate with age and experience.

NEVE ELECTRONIC LABORATORIES LIMITED

require the following staff:

PROJECT ENGINEERS

experienced in circuit and mechanical layout and able to work on their own initiative to plan and progress projects from initial block and 2 wire diagram stage through production, test and installation. Age over 25.

TEST ENGINEERS

to take responsibility for final test. A knowledge of the audio field is desirable, but greater importance is attached to experience of semiconductor circuits and a sound understanding of the techniques of electrical measurements. Applicants will be expected to be capable of direct dealing with customers and of making on-the-spot decisions and will work in close collaboration with the Sales Department. Applicants must be of good personality and presentation, combined with the necessary technical expertise to carry out their assignments competently.

Generous salaries are offered in accordance with age, qualifications and experience. Assistance with housing or moving may be arranged for suitable applicants.

Apply to: Personnel Manager
RUPERT NEVE & COMPANY LIMITED
Cambridge House, High Street, Melbourn, Nr. ROYSTON, Herts.
Telephone: Melbourn 776

2838

OPPORTUNITIES IN TELECOMMUNICATIONS

Men with good telecommunications knowledge are required to be responsible for telephone switching and transmission equipment 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*) Multi-channel carrier equipment.

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 £27 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.I. (Ref. A.T.L.)

2786

SITUATIONS VACANT

A FULL-TIME technical experienced salesman required for retail sales; write giving details of age, previous experience, salary required to—The Manager, Henry's Radio, Ltd., 303 Edgware Rd., London, W.2. [67

ARE YOU INTERESTED IN HI FI? If so, and you have some experience of selling in the Retail Radio Trade, an excellent opportunity awaits you at Telesonic Ltd., 243 Euston Road, London, N.W.1. Tel. 01-387 7467. [21

ATV NETWORK LIMITED, ELSTREE. Salaries in excess of £2,000 in Commercial Television. ATV has vacancies for Vision Control Engineers based at their Elstree Production Centre to maintain and operate a wide range of modern colour television camera equipment. Applicants should have had considerable relevant experience in colour television. APPLICATIONS giving full details of age, knowledge and experience should be sent to the Head of Staff Relations, 150 Edmund Street, Birmingham 3—please mark on the envelope VACANCY 107(E). [2789

CENTRAL AMERICA: Radio Engineer required to install and manage broadcasting equipment at new Radio School to be established at Choluteca, Republic of Honduras. Challenging post for the adventurous, trying to get out of the rut! Volunteer terms: fares, board, lodging, pocket-money, allowances. — Write: CIIR/OV, 38 King Street, London, W.C.2. [2737

CIVILIAN INSTRUCTOR GRADE III (Telecommunications). Up to 3 posts for men fully experienced in the maintenance of radio and/or terminal channelling equipment (including ancillary equipment such as DC telegraph machines and telephone exchanges) to teach Royal Signals technicians and trainees. Possession of appropriate ONC, C. & G. certificates or equivalent qualifications are desirable but not essential as selection will be by written examination and interview. Starting salary £1,061 (at age 21)—£1,491 (at age 30 or over) rising to £1,643. Prospects of pensionable appointment and promotion. Opportunities exist for further technical study and Day Release will be granted where possible. Accommodation may be provided for single and for unaccompanied married men on a temporary basis. Write for application form to CEPO, HQ Northumbrian District, Peronne Lines, Catterick Camp, Yorkshire. Closing date: 30 January, 1970. [2829

ELECTRONICS and Instrumentation for Medical Research. Electronics Technical Officer required to work on data processing equipment related to diagnostic apparatus using radio-active isotopes, also data transmission, and other interesting electronics work connected with medical research. Graduate electronics engineer with experience of digital circuits preferred. Salary £1,285—£2,120 per annum. Applications to the Secretary, Royal Postgraduate Medical School, Hammersmith Hospital, London, W.12, quoting ref.: 8/104. [2833

ELECTRONICS TECHNICIAN required by Guy's Hospital Physics Department, for a responsible position in a team concerned with the design, construction and maintenance of electronic equipment throughout the Hospital and the Medical School. Minimum qualifications O.N.C. Salary scale: £1,120-£1,455 p.a. Apply, naming two referees, to Hospital Secretary, Guy's Hospital, London, S.E.1. [2839

EXPERIMENTAL OFFICER—Digital Electronics. An Experimental Officer is required to advise and assist in research into the application of on-line real-time computers to Mechanical Engineering research. He should be able to design, construct and test the special interfaces needed and to ensure their compatibility with a PDP 9 computer. HNC preferred. Salary in the range £1,042-£1,996 per annum according to age, qualifications and experience. Superannuation scheme. Four weeks annual leave. Apply in writing to Dr. C. E. Turner, Department of Mechanical Engineering, Imperial College, London, S.W.7. [2804

PERSONAL ASSISTANT with servicing experience required by owner of TV retail business of the highest standing established over 40 years in N.W. London. Good position and prospects for capable man. State age and details of career.—Box WW2822, Wireless World.

PROTOTYPE electronics wiremen required for a small but rapidly expanding company manufacturing "one off" systems to customers specifications. The work covers the fields of Analogue, Digital and Industrial electronics. Five years experience on prototype wiring, including making the ancillary hardware, to sketches is required. Ability to teach trainees would be useful.

Salary up to £1,500 depending on experience. Applications in writing to—Parametric Ltd., Highfield Works, Canal Street, RUNCORN, Ches. [2803

RADIO SCHOOL IN PANAMA: Radio Technician required to operate radio school in Santiago de Veraguas. The school provides an elementary adult education programme and is now unable to function for lack of a technician to take charge. Challenging opportunity to fill a vital need in the development of rural areas. Volunteer terms: board, lodging, pocket-money, fares, allowances. Write CIIR/OV 38 King Street, London, W.C.2. [2770

REDIFON LTD. require fully experienced TELECOMMUNICATIONS TEST ENGINEERS and ELECTRONICS INSPECTORS. Good commencing salaries. We would particularly welcome enquiries from ex-Service personnel or personnel about to leave the Services. Please write giving full details to—The Personnel Manager, Redifon Ltd., Broomhill Road, Wandsworth, S.W.18. [26

UNIVERSITY OF EAST AFRICA UNIVERSITY COLLEGE—DAR ES SALAAM. Applications are invited for post of CHIEF TECHNICIAN (ELECTRONICS) in the Department of Physics. Applicants must possess a Higher National Certificate or equivalent. They should have a wide experience of the design and construction of electronic circuits, especially using transistors. The appointee will have to organise and supervise the work of up to four electronics technicians, which consists of the repair, development and construction of electronic equipment for the Faculties of Science and Medicine; also to seek out and solve special instrumentation problems in these Faculties. Salary scale: £EA 1,350-£EA 2,230 p.a. (£EA1 = £1. 3s. 4d. sterling). Salary supplemented in range £612-£744 p.a. (Sterling) and education allowances and children's holiday visit passages payable in appropriate cases under British Expatriates Supplementation Scheme. Superannuation scheme; family passages;

communications technicians

Home and Overseas

The Diplomatic Wireless Service requires men capable of working without supervision for the installation, modification, maintenance and operation of (*a*) radio transmitters and receivers, remotely tuned aerial systems, teleprinters and voice-frequency telegraph equipment over a worldwide network, or (*b*) very high power transmitters, receiving equipment, tape-recorders, generating plant, etc. at several high power broadcasting stations, or (*c*) a wide variety of telephone subscribers' apparatus, machine telegraph and other specialised equipment, or (*d*) microwave receivers, associated test equipment, recorders and audio amplifiers.

Initial appointment will normally be at either Hanslope Park, Bucks., or Crowborough, Sussex, but successful candidates must be prepared to serve anywhere in the United Kingdom or overseas.

QUALIFICATIONS: City & Guilds Intermediate Telecommunications Certificate plus Mathematics B, Telecommunications B, and Radio and Line Transmission B, or equivalent standard of technical education; and at least 5 years' appropriate training and experience.

SALARY (national): £1,155 (at 21) to £1,275 (at 23) to £1,550 (at 28 or over on entry), rising to £1,735, with prospects of increases to £2,575 on promotion. Non-contributory pension.

WRITE to Civil Service Commission, Savile Row London W1X 2AA or telephone 01-734 6010 extn. 229 (after 5.30 p.m. 01-734 6464 "Ansafone" service), for application form, quoting *S/7102/69*. Closing date 5 February 1970.

2824

Technicians

The United Kingdom Atomic Energy Authority offer opportunities at Aldermaston for Technicians to work on the inspection, test to specification, fault diagnosis and calibration of electronic equipment. A wide variety of equipment is involved including general test purpose equipment and data handling and control systems.

Applicants must have served a recognised apprenticeship or have had equivalent experience in the field of electronics. Diagnostic experience in digital circuitry or semi conductor techniques would be an advantage.

Candidates must possess an ONC, a City and Guilds Technicians Certificate or equivalent qualification.

Salary: £1105-£1660 a year.

Housing or Hostel Accommodation will be available.

For application forms write to Chief Personnel Officer,

UKAEA, Aldermaston, Reading RG7 4PR
quoting reference 3707/45

2794

VISUAL SYSTEMS ENGINEERS

THE JOBS

Project & Systems Engineering on Advanced Training Aids for Aircraft.

THE MEN

Electronic Engineers preferably H.N.C. or B.Sc. having had practical experience in one or more of the following fields. Flight test, Auto Pilot, Weapons Control, General Process Control, Instrumentation, Systems Design, Colour Video, Systems Maintenance and Design, with a keen desire to learn new techniques and applications.

THE REWARDS

A salary up to £2,000 per annum. High job interest. Opportunity to work on complex systems incorporating digital and analogue computers, associated peripherals, colour television systems and servo systems as a member of a team. Opportunity to fly and operate simulated aircraft and other equipments. High quality training will be given.

OTHER BENEFITS

Our terms and conditions of employment are good and include contributory pension scheme, free life assurance, etc. We are not merely offering posts which will afford candidates opportunities of attaining a good job. Selected candidates will be offered long-term careers. Opportunities for occasional overseas travel, etc.

Apply, quoting reference WW/70 to:
H. C. Hall, Personnel Manager.
REDIFON LIMITED
Flight Simulator Division
Gatwick Road, Crawley, Sussex
Tel: Crawley 28811

REDIFON

A Member Company of the Rediffusion Organisation

GEC-Marconi Electronics

Technicians and Engineers for St. Albans and Luton

qualified or not!

Vacancies in all grades

- **VACANCIES** exist for work on testing and calibrating valve and solid-state electronic measuring equipments embracing all frequencies up to u.h.f. in Production, Service and Calibration departments.
- **APPLICATIONS** are invited from people of all ages with experience or formal training in electronics and from ex-Armed Services technicians.
- **SALARIES** up to £1,600 negotiable and backed by valuable fringe benefits.
- **RE-LOCATION** EXPENSES available in many instances.
- **CONDITIONS** excellent; free life assurance, pension schemes, canteen, social club.
- **37½-hour,** 5-day, office-hours week.
- **WRITE** or 'phone Personnel Department stating age, details of previous employment, training, qualifications, approximate salary required.

mi **Marconi Instruments Limited**

Longacres, St. Albans, Herts. Tel: St. Albans 59292

Luton Airport, Luton, Beds. Tel: Luton 31441

A GEC-Marconi Electronics Company 2671

Communications Officer

Telephone Systems

BOAC have a vacancy at Heathrow Airport for a Communications Officer to be responsible to the Communications Superintendent—Telephones, for carrying out a wide range of traffic and engineering studies related to large PABXs and Automatic Call Distribution equipment. This is an important and highly responsible position offering excellent future career prospects and occasional visits overseas.

Essential qualifications are a minimum of five years' wide practical experience of telephone administration or manufacture coupled with a sound knowledge of traffic studies, equipment engineering and preferably some network planning.

Applicants, aged 25-35, should have HNC, City & Guilds Fixed Telecom Technicians Certificate or equivalent qualifications. Salary will be in the range £1751-£2086 per annum plus £85 London Weighting. Additional benefits include an excellent pension scheme and opportunities exist for holiday air travel.

Write with full personal and career details to:

Manager Selection Services (WW/220),
BOAC
P.O. Box 10,
Heathrow Airport–London,
Hounslow, Middlesex.

BOAC

biennial overseas leave. Detailed application (6 copies) naming 3 referees by 13 February 1970, to Inter-University Council, 90/91 Tottenham Court Road, London, WIP ODT from whom particulars are available. [2802

UNIVERSITY OF WALES Institute of Science and Technology, Cardiff, Department of Applied Physics, M.Sc./Diploma Course in Electronics. Applications are invited for places in the full-time one-year M.Sc./Diploma Course in Electronics, commencing 28th September, 1970. Further details can be obtained from the Registrar and Secretary, University of Wales Institute of Science and Technology, Cathays Park, Cardiff, CF1 3NU. Application forms should be completed and returned to the College as soon as possible. [2835

WE HAVE VACANCIES for Four Experienced Test Engineers in our Production Test Department. Applicants are preferred who have Experience of Fault Finding and Testing of Mobile VHF and UHF Mobile Equipment. Excellent Opportunities for promotion due to Expansion Programme. Please apply to Personnel Manager, Pye Telecommunications Ltd., Cambridge Works, Haig Road, Cambridge. Tel. Cambridge 51351. Extn. 327. [77

ELECTRONICS TEST ENGINEERS

are required for a newly formed section in an expanding company. Previous experience of testing and "fault finding" on electronics components and assemblies is essential. Applicants must be suitably qualified, preferably to H.N.C. standard. Familiarity with Ministry/ARB procedures would be advantageous.

Applications in writing to Personnel Officer, S. DAVALL and SONS LTD., Wadsworth Road, Perivale, Greenford, Middx. 2793

ARTICLES FOR SALE

BRAND NEW ELECTROLYTICS, 15/16 volt, 0·5, 1, 2, 5, 8, 10, 20, 30, 40, 50, 100, 200 mfds. 8d. Carbon Film Resistors ¼ watt 5% E12 Series 10 ohms to 1 Megohm 1/6 dozen, minimum order 7/6, postage 1/-. The C. R. Supply Co., 127 Chesterfield Rd., Sheffield S.8. [2796

BRAND NEW FULL SPECIFICATIONS DEVICES. Integrated circuits complete with data: GE PA230 Audio Preamplifier, 18/6 each; GE PA234 1W Audio Amplifier, 17/6 each; GE PA237 2W Audio Amplifier, 32/6 each; Plessey SL402A Preamp & 2W Amp, 42/- each; MEL 11 Photo Darlington Amp, 9/6 each; High quality low cost plastic transistors: GE 2N5172 NPN 200mW Transistor, 1/9 each; ME 0412 PNP 200mW Transistor, 3/9 each; TI 2N4059 PNP 250mW Transistor, 3/6 each. Plastic rectifiers for power supplies: 1N4820 1·5A 400V Si Rectifier, 2/6 each; WOO5 1A 50V Full Wave Bridge Si, 7/6 each. C.W.O. P. & P. 1/- per order. JEF ELECTRONICS, York House, 12 York Drive, Grappenhall, Warrington, Lancs. Mail Order Only. [2797

BUILD IT in a DEWBOX quality plastics cabinet. 2 in. × 2½ in. × any length. D.E.W. Ltd. (W), Ringwood Rd., FERNDOWN, Dorset. S.A.E. for leaflet. Write now—Right now. [76

COLOUR TV COMPONENTS, all specialist parts for W.W. Colour Receiver. S.A.E. for new catalogue. Forgestone Components, Ketteringham, Wymondham, Norfolk. [2785

DISC RECORDING UNIT complete with Leak stereo amplifier, mod. meters, console, motorised swarf suction unit, spare blank, sapphires, etc., etc. Sugden cutter unit. Good condition. Best offer over £50.—John King (Films) Limited, Film House, 71 East Street, Brighton, BN1 1NZ. [2749

E.H.T. Rectifiers, K8/30 5/-, K3/50 7/6, K3/100 12/6. Oluf 6KV 4/6. Power Rheostat L25W 5ohms 10/-. Vib. pack 6V-220VDC 30/-. 12V2A Projector Lamp Ses 3/-. ·5uf 750 VDC 1/6. P&P 1/6. S.A.E. for list. BOURDON CAMPS, 41 Higher Compton Road, Plymouth, Devon, PL3 5HZ. Tel. 0752 77974. [2826

HOW to Use Ex-Govt. Lenses and prisms. Booklets. Nos. 1 & 2, at 2/6 ea. List Free for S.A.E. H. W. ENGLISH, 469 RAYLEIGH RD., HUTTON, BRENTWOOD, ESSEX. [87

OSCILLOSCOPE TELEQUIPMENT, Type D43R, as new, £90. 182, Bevendean Crescent, Brighton. Tel.: 61444. [2791

PRECISION RESOLVER, Reeves Instrument Corp. Quantity, new, Type R601H Model 102 and R601 Model 101. AMPEX Video Tape Recording Head, Cat. No. 167700—10. ENGLISH ELECTRIC Vidicons Types P813 and P826. Branson, 111 Park Road, Peterborough. Tel. 67604. [2828

T.F. 144 Spare Thermocouple Units, new, boxed, 45/-. 20 ft. Telescopic Masts, new, packed two in a wooden case, £5/15/- the pair; bases to match, 30/- each. CT218 FM/AM Signal Generator, 85KCS to 30 MCS, excellent condition, £65. RA17 Communications Receiver, £200. EE8 Field Telephones, £5/10/- per pair. Valve Tester I 117B with adaptor MX949, new, £11. All carr. paid. Wanted, Manuals on Army and R.A.F. Equipment C13, C42, R210, RT2002, etc. Box No. W.W. 2790, Wireless World.

25 KVA Voltage Stabiliser, 240v, 3 phase, 49 HZ output. Please phone Dane End 334 (Herts). [2782

UHF, COLOUR and TV SERVICE SPARES. Leading British makers' surplus Colour Frame and Line time base units incl. EHT transformer, £5, carriage 10/-. Integrated UHF/VHF 6 position push button tuner, 4 transistors, knobs, circuit data. Easily adjusted for use as 6 position UHF tuner, £4/10/-, P/P 4/6. UHF 3 transistor tuner incl. circuit, £2/10/-, P/P 4/6. UHF/VHF transistorised IF panel, £3/10/-, P/P 4/6.

computer engineering

NCR requires additional ELECTRONIC, ELECTRO MECHANICAL ENGINEERS and TECHNICIANS to maintain medium to large scale digital computing systems in London and provincial towns.

Training courses will be arranged for successful applicants, 21 years of age and over, who have a good technical background to ONC/HNC level, City and Guilds or radio/radar experience in the Forces.

Starting salary will be in the range of £900/£1,250 per annum, plus bonus. Shift allowances are payable, after training, where applicable. Opportunities also exist for Trainees, not less than 19 years of age, with a good standard of education, an aptitude towards and an interest in, mechanics, electronics and computers.

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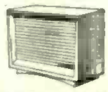

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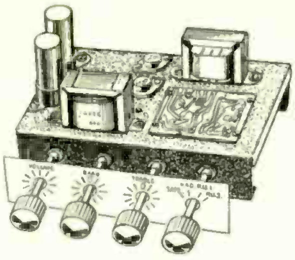

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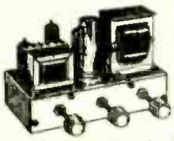

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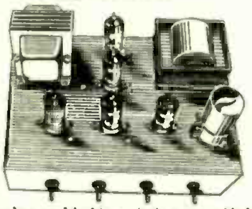

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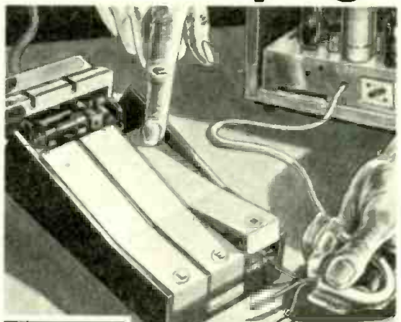

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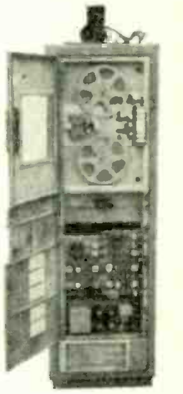

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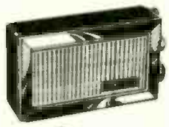

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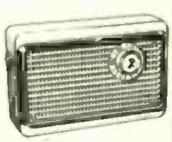

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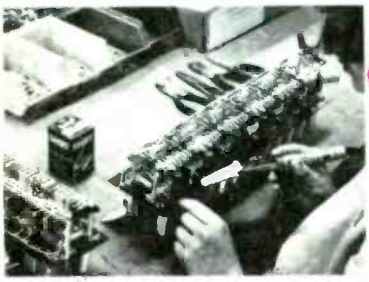

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