THE
RADIO CONSTRUCTOR

Vol. 22 No. 12 JULY 1969 THREE SHILLINGS

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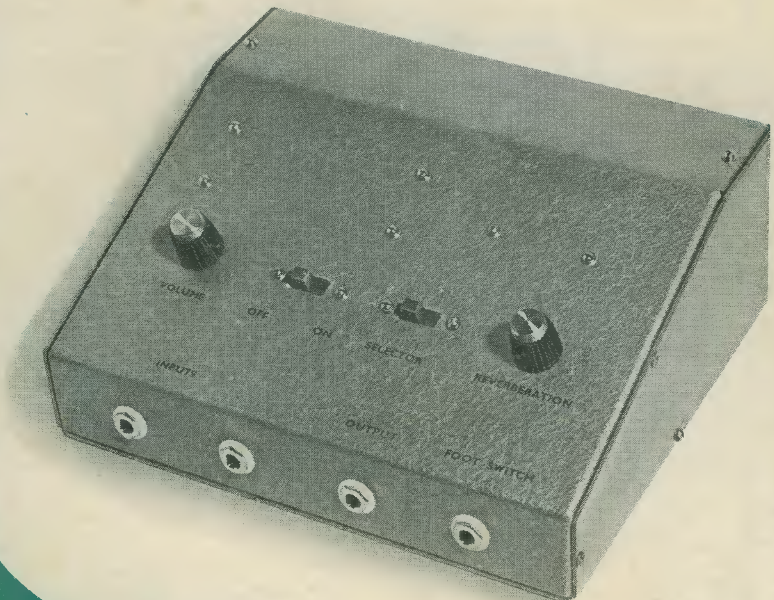

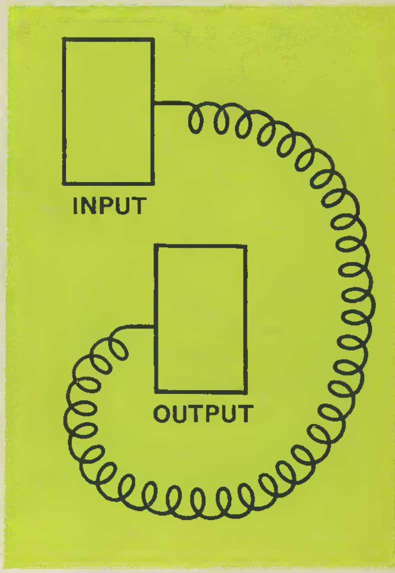

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300	—	2/3	3/9	4/6	6/6	22/–
400	2/–	2/6	4/–	5/6	7/6	25/–
500	—	3/–	—	6/–	8/6	30/–
600	2/9	3/3	4/3	6/9	9/–	37/–
800	—	3/6	4/9	7/6	11/–	40/–
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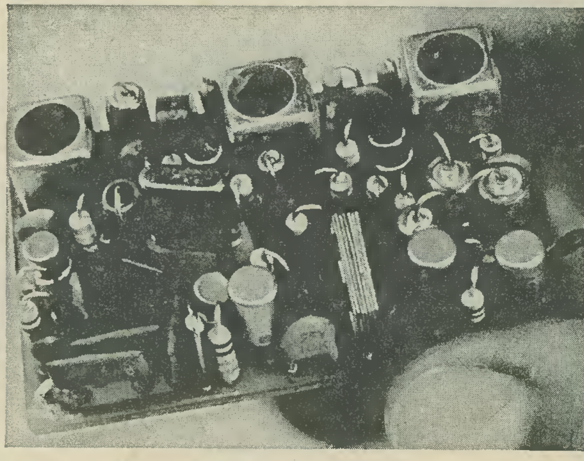

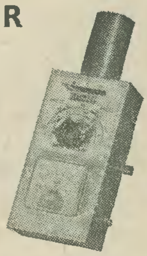

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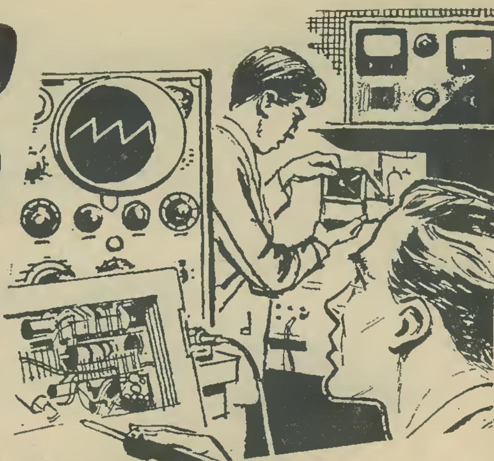

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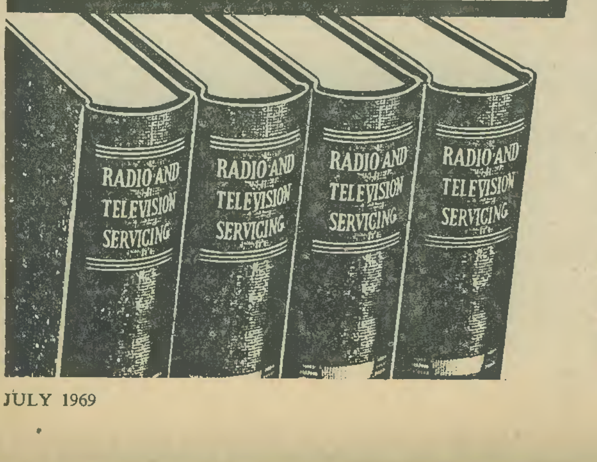

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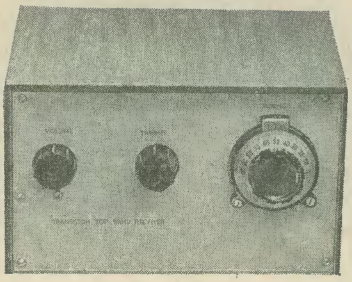
AUGUST ISSUE WILL BE PUBLISHED ON AUGUST 1st



TRANSISTOR SUPERHET FOR TOP BAND

by

A. S. CARPENTER, G3TYJ

Designed specifically for reception on the amateur 'Top Band' of 1.8 to 2.0 MHz, this receiver incorporates seven transistors and one diode. It may be used on its own or in conjunction with the transmitter described last month, and it can be operated from a 9V dry battery or a 12V car battery

Miniature or semi-miniature solid-state radio receivers are always of interest and may be particularly so to the Amateur transmitting and listening fraternity, many of whom require items which are inexpensive to construct and which are useful for either portable or mobile working.

The receiver to be described is in the semi-miniature class but could with ingenuity be made much smaller. 'Top Band' has always been popular for /P and /M working and a low-consumption receiver that can work either from a 9V dry battery or from a 12V car battery can be handy. Considerable amateur activity of the 'ragchew' type takes place on '160' at week-ends and this frequently provides interesting and informative listening material!

The transistors used in the receiver are available very cheaply and work well at the comparatively low frequencies involved. Quiescent current drain is 15mA.

Briefly, the receiver to be described is a 'Top Band only' affair completely transistorised and with an audio output of about 1 watt. Increased audio output could be secured by using a different type of amplifier and various inexpensive and ready-built items are available, should an alternative amplifier be desired.

Other amateur bands could doubtless also be catered for by revamping the front-end circuitry a little. The term 'amateur bands' should be noted; since the design permits of limited frequency coverage only, the circuitry shown cannot be made 'general coverage'. 'Top Band' extends from 1,800 to 2,000 kHz but since amateur QSO's rarely take place near the band edges partial band tuning is adequate. The receiver is intended for listening to 'Phone' QSO's mainly but if it is desired to tune additionally to either c.w. or s.s.b. transmissions a b.f.o. must be added. Single-sideband transmissions are not over-plentiful on the band but a fair amount of c.w. is to be heard; for completeness the circuit of a practical transistorised b.f.o. is included.

Physically the receiver is built as two units—an r.f. section and complementary a.f. section—and each of these is assembled on a small Paxolin panel or board.

THE R.F. BOARD

As may be seen from the r.f. board circuit diagram shown in Fig. 1, a total of five semiconductors constitute the r.f., mixer/oscillator, both i.f. amplifiers and demodulator stages. Signal frequency coils are provided by L1 and L2. The oscillator coil is L3 and is tuned higher than the signal frequency by the value of the intermediate frequency—in this case approximately 470kc/s—the converted signals being amplified by TR3 and TR4 in the i.f. strip. Since the bandwidth of the r.f. and mixer signal frequency circuits is sufficient to accept signals throughout the 'Top Band' range these may be preset, with a simple 'peaking' variable capacitor for the interstage signal frequency coil. In consequence, it is merely necessary to vary the oscillator tuning to produce the desired intermediate frequency and thereby tune the receiver. Main tuning via a reduction drive mechanism is thus associated with L3 only and permits the use of a small single-gang panel-controlled tuning capacitor.

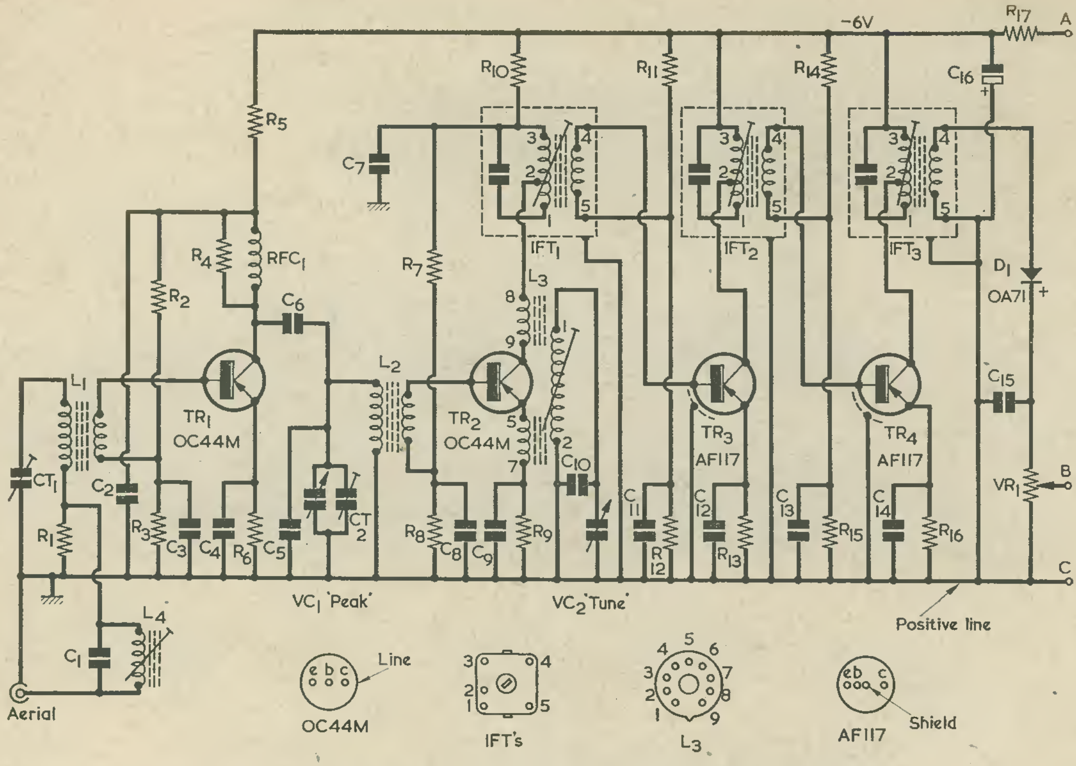


Fig. 1. The r.f., mixer/oscillator, i.f. and detector stages of the receiver

Simple calculation shows that a signal received at a frequency of 1,810kHz can be converted to 470kHz by tuning the oscillator to 2,280kHz whilst a 1,990kHz aerial signal can be selected by retuning the oscillator to 2,460kHz. Such a variable oscillator frequency range can be secured using a variable capacitor of about 50pF, and a suitable commercially made coil for the inductance is readily available. Aerial and inter-stage coils are home-made.

As already stated, a panel-controlled 'peaking' capacitor is associated with the interstage signal frequency coil and this is provided in the form of VC1.

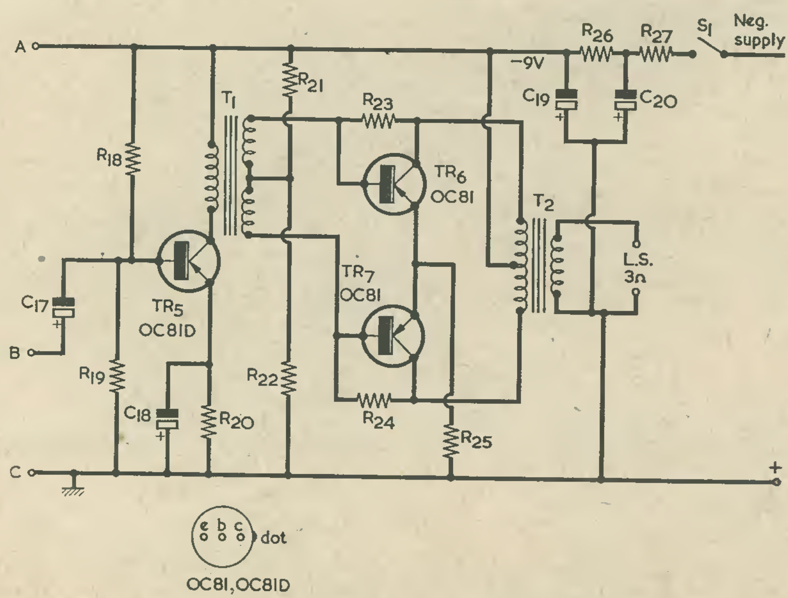


Fig. 2. The circuit of the a.f. amplifier stages

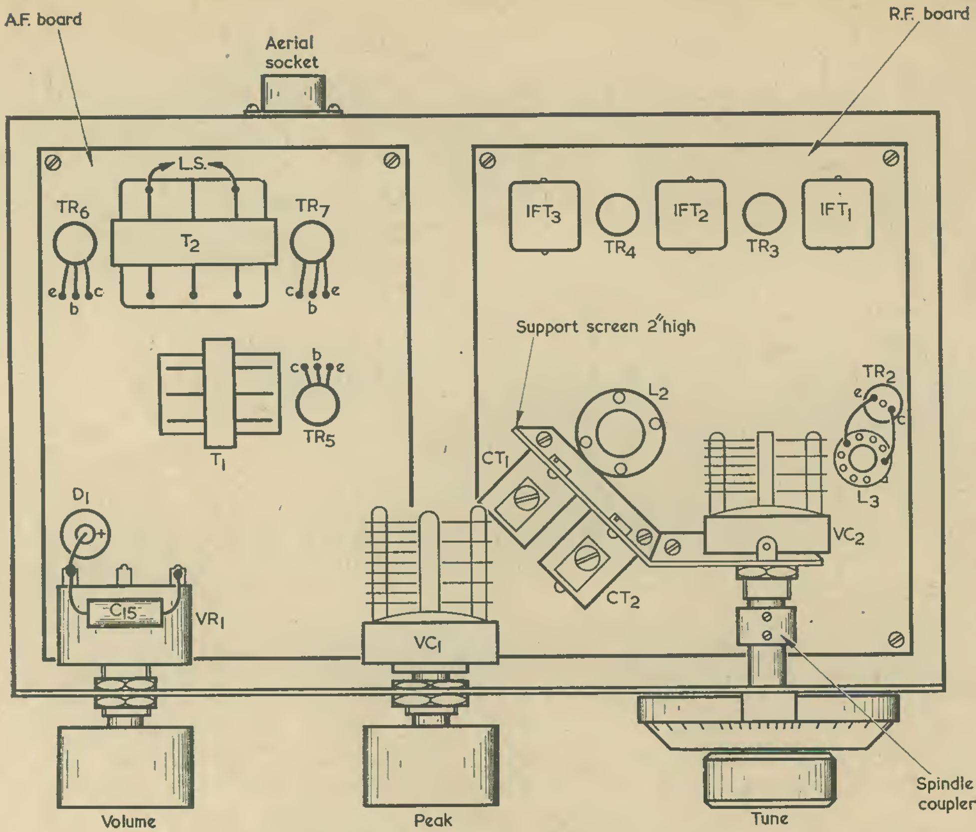


Fig. 3. View above the chassis assembly, showing the layout of principal components

In practice, coils L1 and L2 are pre-tuned to the mid-band position and VC1 permits of optional frequency variation within narrow limits. Trap coil L4 is tuned to approximately 2,840kHz since strong second channel signals around this frequency could otherwise break through to the mixer/oscillator. Any small inductor of around 75μH with an adjustable iron dust core may be used here, a suitable choice being the tuned winding of a medium wave oscillator coil such as the Osmor Q05. This can be easily resonated using either a grid-dip oscillator or a signal generator.

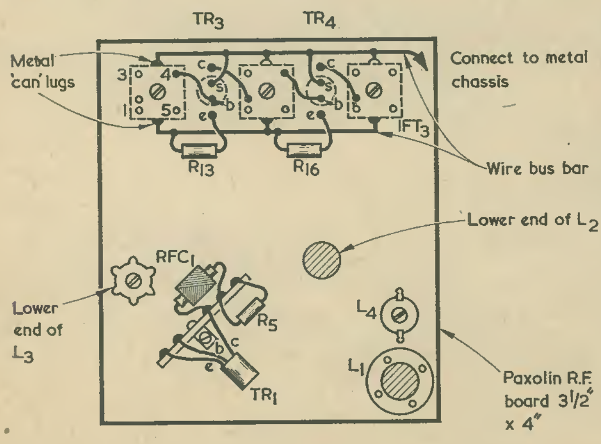


Fig. 4. Layout underneath the r.f. and i.f. board

Although the possibility is doubtful, it might be necessary to slightly alter the value of C1 to obtain resonance at the correct frequency with some coils in the category just mentioned.

The i.f. stages are conventional, with a.g.c. omitted to secure maximum gain. The On/Off switch can be external (as in the writer's receiver) or, if desired, may be made integral with a.f. gain control VR1.

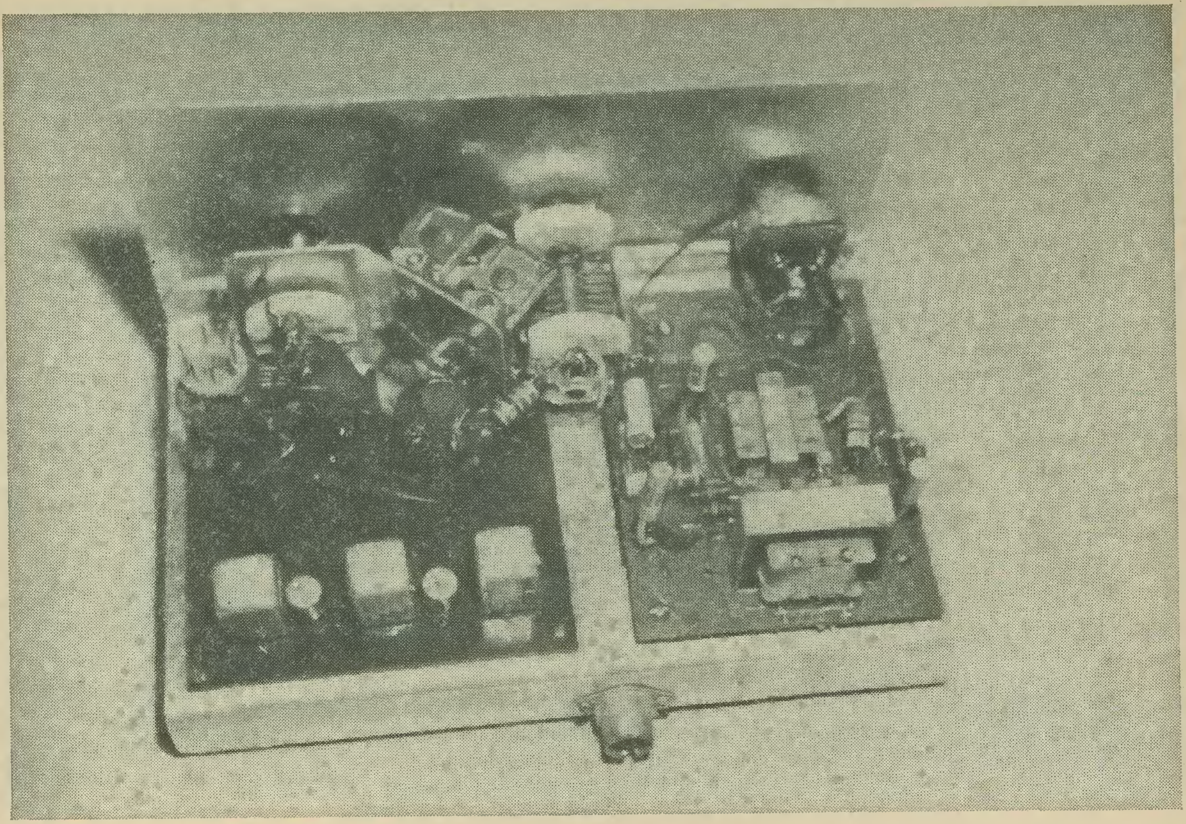
THE A.F. BOARD

The circuit for the a.f. board is given in Fig. 2, and it consists of a straightforward push-pull type of audio amplifier. This requires little comment, and it uses ready made and easily available components throughout. To prevent overheating, TR6 and TR7 should each be provided with a cooling fin having a surface area of approximately ¾ by ⅝in. The output transformer, T2, is available from Alpha Radio Supply Co. Ltd., 103 Leeds Terrace, Wintoun Street, Leeds. Again, in the interests of gain no degenerative feedback is introduced.

As mentioned earlier a ready-built transistorised amplifier can be employed here instead if preferred.

CONSTRUCTION

To provide rigid support, the two Paxolin board assemblies are located side by side on a metal chassis. Large cut-outs in the chassis main plate permit of access to the underside of each board; and the



Above-chassis view of the receiver

boards are prevented from fouling the metal by using small spacers. The above-chassis layout is given in Fig. 3.

The r.f. board requires greatest care in construction and some of its wiring is shown in the underside layout of Fig. 4. A total of eight holes are required for each i.f. transformer and a suitable drilling 'pattern' is given by pressing the pins of one against a piece of paper. The resulting impressions, if pricked with a pin, form an excellent template. Modern miniature capacitors and resistors must be used throughout. Note, too, that a bracket has to be made; this should be some 2in. high to carry the tuning capacitor VC2 and trimmers CT1 and CT2. The best way of coupling the tuning capacitor to the vernier drive is via a flexible insulated coupler. A normal coupler *can* be used, as in the prototype, but this necessitates more careful mechanical alignment of the tuning capacitor spindle.

COIL WINDING

Coils L1 and L2 are wound directly on to 1in. lengths of $\frac{3}{8}$in. diameter ferrite rod. These lengths may be obtained from a longer rod—say 8in.—the surface being scored with a hacksaw at the appropriate place and the required section broken off, being tidied up afterwards with a file. See Fig. 5. Paxolin cheeks, each with four tags, are force-fitted over the ends of the rods. These cheeks may be home-made or obtained from Alpha Radio Supply Co. Ltd. The tuned windings of L1 and L2 each consist of 43 turns closewound of 30 s.w.g. enamelled copper wire, these being laid on centrally over a layer of plastic insulating tape. The base coupling windings are next wound on, these being centrally positioned over the tuned windings and separated from them by a double layer of Sellotape. Each base winding consists of three turns of the same gauge of wire closewound, connections being made after winding to the tags on the end cheek. The two completed coils are located by pushing them through $\frac{3}{8}$in. holes in the r.f. board and additional rigidity is effected by using

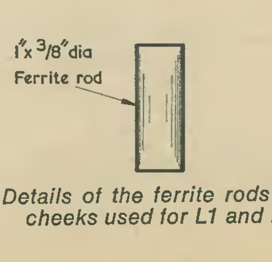


Fig. 5. Details of the ferrite rods and paxolin cheeks used for L1 and L2

stiff copper wire for connections. The coil locations can be seen in the diagrams.

If the audio amplifier is to be constructed, as in Fig. 2, the main layout given in Fig. 3 can be used as a guide. The correct windings of transformers T1 and T2 can be found by using an ohmmeter to locate the primary in each case and remembering that the secondaries show very low resistance readings. The transformers may be affixed by bending their spills close to the board on the underside. With regard to this section, consideration must be given to the way in which the receiver is to be powered and capacitor C20 and resistors R26 and R27 are required only when a 12V car battery is to be used; R26 is then selected experimentally to provide a potential of 9V measured across C19 under no-signal conditions. (When finding the value of R26, remember that the terminal voltage of a 12V car battery in use is usually of the order of 13.5V. For a quiescent current of 15mA, R26 would be 300Ω.—Editor.) The method of picking up the supplies is really one for individual consideration.

The dimensions of the metal panel and associated chassis plate employed in the prototype are given in Figs. 6 and 7 respectively. These are self-explanatory.

ADDITIONAL B.F.O. STAGE

Although not provided in the prototype receiver, the inclusion of a b.f.o. to facilitate c.w. or s.s.b. reception may be considered worthwhile by some readers, and adequate constructional space for a b.f.o. stage is available. The b.f.o. pitch control and its In/Out switch may be placed symmetrically on the panel below the other controls. A practical b.f.o. circuit with component values is given in Fig. 8, the i.f. transformer used being the same as that specified for IFT3 in the Components List. Sufficient stray coupling of the b.f.o. signal into the receiver circuits should result, with no additional coupling components being required.

CHECKING AND ALIGNMENT

Usually, the best time to get the receiver working well is on a Sunday morning, for not only are QRM and QRN then less troublesome than at other times, but also amateur activity is normally plentiful.

When aligning the receiver the precise value of intermediate frequency is not too important and although the transformers used are designed for a frequency of 470kHz, erring on the high side will do nothing but good. The main requirement is to get the i.f. strip in line throughout and if the core ends are towards the open ends of their formers as seen from below little difficulty should be experienced.

Initial adjustments consist of seeking a signal of some sort by adjusting VC2 and/or the core of L3. On receipt of a signal the cores of IFT3, IFT2 and IFT1 are adjusted, in that order, to peak the signal to maximum. Thereafter attention is given to L3 to obtain adequate band coverage. If a reasonably accurately calibrated grid-dip oscillator is available, all coils can be easily pre-tuned before the receiver is switched on, whereupon considerable time is saved. At mid-band position the vanes of VC1 should be about 50% enmeshed; trimmers CT1 and CT2 are adjusted accordingly. If bandspread is inadequate insert a capacitor of, say, 100pF in series with the

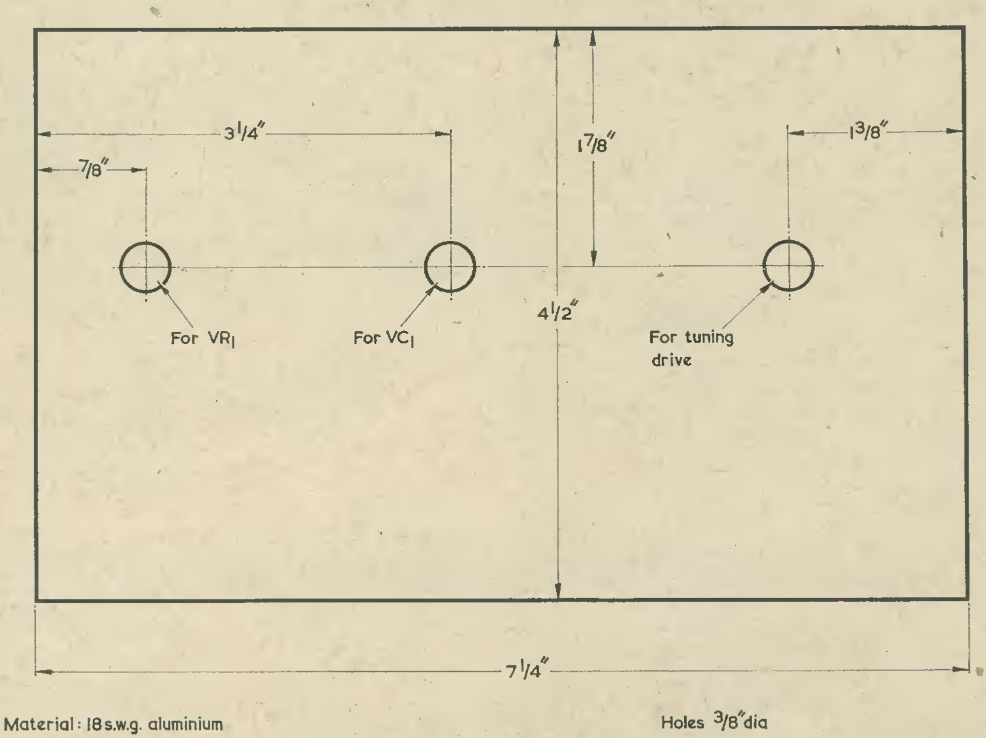


Fig. 6. Main drilling dimensions for the front panel

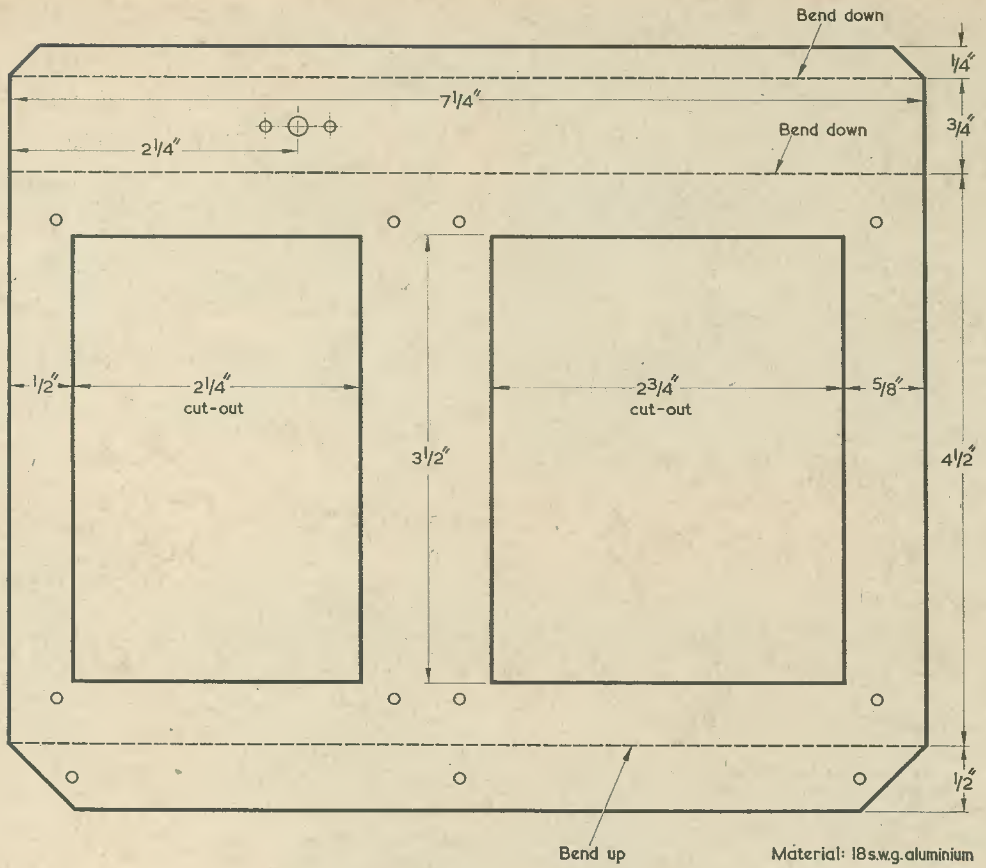


Fig. 7. Dimensions of the chassis plate

non-earthy terminal of VC2 and readjust the core of coil L3.

DEBUGGING!

Receiver circuits using transistors do occasionally tend to be more temperamental than their valve contemporaries and it is easy to become discouraged when a newly built item fails to perform! Also, transistor and component tolerances can make it difficult to specify firm component values and in a 'One-Off' design it is but possible to state values as used in the test model; some debugging may or may not thus be required.

A complete lack of signals may be due to non-oscillation of the circuitry around TR2 and L3 but if all connections are correct and adequate voltage is applied, oscillations should be present. Squegging may occur if capacitor C9 is overlarge in value whereupon its value should be reduced. If fierce oscillation results, suspect i.f. instability, the stage responsible for the trouble can sometimes be found by temporarily by-passing the lower member of a base bias potentiometer network—R15 for example—with a 3.3kΩ resistor. Spurious oscillation can also be caused in the TR1 circuit if a minor proportion of the r.f. present at choke RFC1 is fed back inductively to L1. To prove this stage disable TR1 by disconnecting R5 and connect the aerial to the fixed vanes of VC1 via a 100pF capacitor.

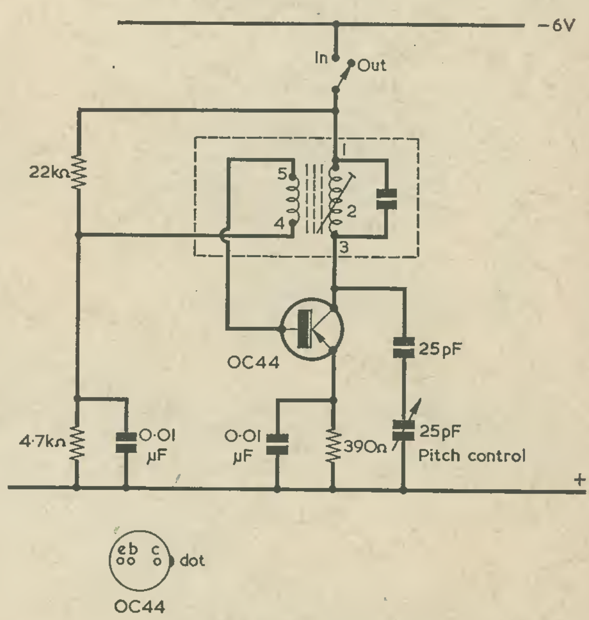


Fig. 8. Circuit of an optional b.f.o. stage

COMPONENTS

Resistors

(All fixed values $\frac{1}{8}$ watt 10% unless otherwise stated)

R1	10kΩ
R2	10kΩ
R3	2.2kΩ
R4	5.6kΩ
R5	1kΩ
R6	1kΩ
R7	10kΩ
R8	2.2kΩ
R9	1kΩ
R10	1kΩ
R11	56kΩ
R12	8.2kΩ
R13	470Ω
R14	27kΩ
R15	3.9kΩ
R16	1kΩ
R17	470Ω
R18	100kΩ
R19	10kΩ
R20	390Ω
R21	4.7kΩ 5%
R22	33Ω 5%
R23	8.2kΩ 5%
R24	8.2kΩ 5%
R25	4.7Ω 5%
R26	see text
R27	10Ω (see text)
VR1	10kΩ pot., log track (with optional on-off switch, see text)

Capacitors

(N.B. Undesignated capacitors in Fig. 1 are part of i.f. transformer assemblies.)

C1	47pF silver mica or ceramic (see text)
C2	0.04μF ceramic or paper
C3	0.01μF ceramic
C4	0.04μF ceramic or paper
C5	47pF silver mica or ceramic
C6	25pF silver mica or ceramic
C7	0.04μF ceramic or paper
C8	0.04μF ceramic or paper
C9	0.01μF ceramic
C10	47pF silver mica
C11	0.01μF ceramic
C12	0.04μF ceramic or paper
C13	0.01μF ceramic
C14	0.04μF ceramic or paper
C15	0.01μF ceramic
C16	100μF electrolytic 15V wkg.
C17	2μF electrolytic 6V wkg.
C18	100μF electrolytic 6V wkg.
C19	100μF electrolytic 15V wkg.
C20	100μF electrolytic 25V wkg. (see text)
VC1	50pF variable, type C804 (Jackson Bros.)
VC2	50pF variable, type C804 (Jackson Bros.)
CT1	40pF trimmer, mica
CT2	40pF trimmer, mica

Inductors

L1	See text
L2	See text
L3	Oscillator coil, Transistor Dual Purpose Coil Range 2T White (Denco)
L4	75μH (see text)
RFCI	Miniature r.f. choke, 2.5mH, type CH1 (Repanco)
T1	Driver transformer type LFDT4 (Weyrad)
T2	Output transformer type OPT2 (Weyrad)

Semiconductors

D1	OA71
TR1	OC44M
TR2	OC44M
TR3	AF117
TR4	AF117
TR5	OC81D
TR6	OC81 } matched pair
TR7	OC81 } matched pair

Switch

S1 s.p.s.t. on-off (may be part of VR1—see text)

Miscellaneous

1 vernier dial drive type T502 (Eagle)
1 small flexible spindle coupler
2 knobs
1 coaxial aerial socket
$\frac{3}{8}$in. ferrite rod and end cheeks (for L1, L2)
Paxolin, 18s.w.g. aluminium sheet, etc.

CONCLUSION

If the receiver is to be used close to a transmitter a means of 'killing' it during 'Transmit' must be considered otherwise transistors TR1 and TR2 may be destroyed. Normally the station 'Operate' switch —or a relay—interchanges the aerial between receiver and transmitter as appropriate and it is usually not difficult to arrange for a spare set of contacts on the switching device to break supplies to the receiver completely on 'Transmit'. (It will be recalled that it was suggested that an extra pole be provided in the function switch for the transmitter described last month. This extra pole may be used to break the supply to the receiver when transmitting.—Editor.)

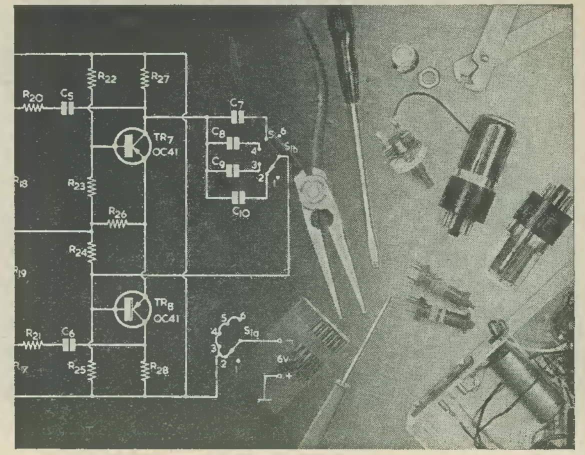
Final tidying-up activities consist of housing the receiver, lacquering the panel and affixing suitable legends alongside the controls. Suitable lettering is given with Panel-Signs transfers, Set No. 3 white or 4 black, available from Data Publications Ltd.

■

SUGGESTED CIRCUIT No. 224

COIL COVERAGE TEST UNIT

by G. A. FRENCH



THE TEST UNIT DESCRIBED IN this month's article in the "Suggested Circuit" series is a simple device which, in conjunction with a signal generator, allows the frequency coverage of r.f. coils to be directly assessed in terms of parallel tuning capacitance. It thereby enables the frequency range of home-wound coils or ferrite frames to be evaluated before they are fitted into a receiver. Thus, with the help of this unit, a coil can be made to give the precise range required whilst it has maximum accessibility. Adjustment of turns, etc., can of course be a difficult process after a coil has been mounted in a receiver.

The signal generator used with the unit should have a reliable frequency calibration and it must have a rated low impedance output voltage of 100mV or more. Most commercially manufactured service signal generators are capable of offering this output, and they can be used with the unit. On the other hand, it must be pointed out that some of the more inexpensive classes of signal generator do not always offer their nominal output over all their ranges and the results they would give with the coil coverage unit may not, in consequence, be entirely satisfactory. The signal generator employed by the author was an Advance Type P Model 1 which has been in use for quite some years, and this gave perfectly acceptable results when operated at full output. Signal generators having a rated output of less than 100mV cannot be reliably expected to provide a sufficiently high signal level to enable the tester to function satisfactorily, although they could be tried out on a purely experimental basis, if desired.

The maximum frequency at which the coil coverage test unit is intended to function is 30 MHz.

An additional facility provided by the test unit is that it allows the values of fixed capacitors between about 20 and 600pF to be measured.

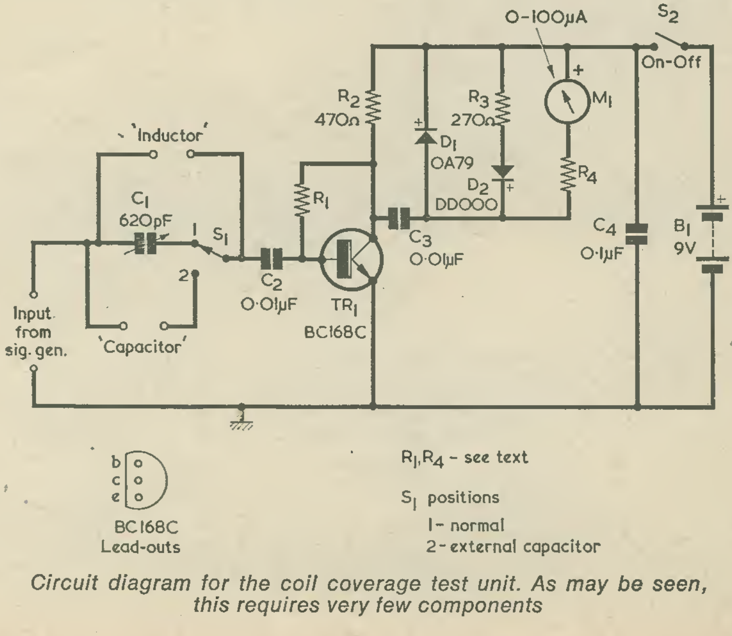
THE CIRCUIT

The circuit of the coil coverage test unit appears in the accompanying diagram.

The output of the signal generator is applied to the input terminals at the left, the earthy signal generator output lead connecting to the input terminal which is common to the test unit chassis. The 620pF variable capacitor, C1, is calibrated in terms of its capacitance. Switch S1 is normally in position 1, and the coil under test is connected to the "Inductor" terminals. Thus, C1 and the coil under test form a parallel rejector tuned circuit, offering greatest impedance at its resonant frequency. As a result, the signal fed to capacitor C2 is at a minimum when the resonant frequency of this tuned circuit is the same as the frequency of the signal generator output.

Capacitor C2 couples to the base of TR1, this being a silicon planar n.p.n. transistor type BC168C which offers the very high gain of 450 to 900. An amplified signal appears at the collector of TR1, this being applied via C3 to the shunt detector, germanium diode D1. The rectified voltage across D1 is limited to around 0.6 volts by silicon diode D2 and is passed to the 0–100μA meter, M1, via R4.

Both the values of R1 and R4 are chosen experimentally. R1 has a value which causes the particular



Circuit diagram for the coil coverage test unit. As may be seen, this requires very few components transistor employed to pass a collector current of 4 to 5mA. R4 is selected so that meter current is limited to 100μA, and its value depends on the specific diode employed in the D2 position and the internal resistance of the meter.

A little further explanation is required concerning the detector circuit. Since D1 is a germanium diode it commences to rectify at a very low forward voltage and thereby enables the meter to respond to low amplitude signals at the collector of TR1. D2 commences to pass current at a forward voltage of about 0.6, and thereby limits the rectified voltage provided by D1 to this figure. A secondary effect, however, is that when D2 *does* conduct it exhibits a much lower forward resistance than does D1. In consequence, and unless appropriate precautions are taken, diode D2 can "take over" as detector on high amplitude signals from TR1, causing the meter to give a negative reading. R3 is inserted into circuit to prevent this happening and it reduces the flow of forward current in D2 without excessively inhibiting its operation as a voltage limiter. The value for R3 was found empirically, and it offers a compromise between effective voltage limiting and elimination of the unwanted detection effect in D2. This latter is still present to some extent, and it causes the meter to read less than f.s.d. with some high amplitude signals. With the prototype, high amplitude signals at the collector of TR1 caused the meter to give readings ranging between 70 and 100μA according to their level and frequency, and this was considered satisfactory. As will shortly be made clear, the variance in actual meter reading for maximum r.f. signal in no way detracts from the usefulness of the test unit in determining resonant frequency.

To check the frequency coverage of a coil, it is connected to the "Inductor" terminals and S1 is set to position 1. C1 is adjusted to the minimum tuning capacitance which will be applied across the coil when it is eventually fitted in the receiver for which it is intended. The signal generator frequency control is then adjusted. As it approaches the resonant frequency of the tuned circuit given by the test coil and C1 a pronounced "dip" will be observed in the meter reading. The signal generator is then adjusted for maximum "dip" (i.e. minimum reading in the meter) whereupon the resonant frequency of C1 and the test coil may be read from the signal generator scale. As may now be seen the most important reading required in the meter is that corresponding to maximum "dip" and, at the low r.f. signal voltages which appear at TR1 collector under resonance conditions, it is D1 only which functions as detector. D2 is non-conductive under these conditions. The "dip" is very obvious in character and can in no way be confused with the variance in reading with high amplitude signals resulting from the detection effect in D2. The fact that a pronounced "dip" is obtained is, incidentally, due to the compression of the higher current readings on the meter scale due to D2. With the prototype it was found that minimum "dip" readings ranged from zero to 10μA according to the Q of the coil being checked and the amplitude of the signal generator output. A "dip" is, of course, given because C1 and the test coil offer maximum impedance at their resonant frequency.

After checking the coil with C1 at a minimum value, C1 may be adjusted to the maximum capacitance which will eventually be placed across the coil, whereupon the process is repeated. The two signal generator frequency readings then define the coverage to be expected from the coil.

There are alternative methods of using the unit other than that just described. For instance, a coil may be connected to the "Inductor" terminals, the signal generator set to a predetermined frequency and C1 adjusted for resonance. The capacitance needed across the coil for resonance at the predetermined frequency may then be read from the scale of C1. Again, both the signal generator and C1 may be set up to predetermined readings, after which the inductance of the test coil is varied until resonance is obtained by either adjusting its dust core or its position along a ferrite rod.

To measure values of capacitance between about 20 and 600pF the unknown capacitor is connected across the "Capacitor" terminals and S1 is set to position 2. Any coil is connected across the "Inductor" terminals and the signal generator frequency adjusted for resonance. S1 is then set to position 1 and C1 adjusted, in its turn, for resonance. The value of the unknown capacitor may then be read from the scale of C1.

An interesting point arising from the circuit configuration is that C1 and the test coil form a band-stop filter similar to a wave-trap in series with the aerial input to a receiver. The resonant frequency of such a filter is virtually unaffected by impedances on either side to a common earth point, although the presence of such impedances may alter the response curve on either side of resonance. To satisfy himself that this point was, in practice, true the author checked operation with 100pF fixed capacitors added between chassis and both sides of the tuned circuit given by C1 and the test coil, and found that the frequency corresponding to maximum "dip" in the meter remained unaltered. The same applied even when a 0.01μF capacitor was connected, in addition, across the input terminals. (Such a capacitor could not be connected between the right hand side of the filter and chassis, as it would have prevented the unit from functioning). These checks were carried out at two frequencies, one around 30 MHz and the other around 1 MHz, with C1 very near minimum capacitance.

COMPONENTS AND CONSTRUCTION

All the components are standard types and require only a few words of additional comment.

C1 consists of a 2-gang 310+310pF capacitor, both sections being connected in parallel. If desired, constructors may use alternative variable capacitors here, these offering maximum capacitances of, say, 500pF to 730pF (two 365pF in parallel). Alternative values in C1 will, of course, correspondingly alter the range of fixed capacitors whose values can be measured. It is preferable to avoid having an unnecessarily high maximum capacitance in C1 because, in general, variable capacitors which give a high maximum capacitance tend to offer a correspondingly high minimum capacitance when their vanes are fully open. It is essential that C1 be a good quality air-spaced component. Its metal frame must be insulated from chassis, and the circuit is wired up such that this frame connects to the non-earthy input terminal. The fixed vanes of C1 then connect to S1. This method of connection is recommended because the input terminal will have a much lower impedance to chassis that the base circuit of TR1. With the prototype, C1 was fitted with a standard insulated knob and no hand-capacitance effects were noted as this knob was adjusted.

To keep stray capacitances to a minimum, S1 should be a rotary switch. The 'Inductor" and "Capacitor" terminals may be mounted on a panel of good-quality Paxolin, being positioned such that all wiring between them and C1 and S1 is kept short.

Transistor TR1 should be a BC168C as specified. This type is available from Amatronix Ltd. Diode D1, an OA79, should also be as specified. Silicon diode D2 should be a Lucas DD000. All the resistors may be $\frac{1}{4}$ watt types, R2 and R3 being 10%. R1 is omitted during construction, and a 10kΩ variable resistor is temporarily wired up in the R4 position.

The unit may be built up in any small metal or insulated case of suitable size. The components in the collector circuit of TR1 should be kept apart from those in its base circuit. However, the two circuits need not be screened from each other.

After construction has been completed, set the temporary 10kΩ variable resistor in the R4 position so that it inserts maximum resistance into circuit. No input signal is applied at this stage and no external components are connected to the "Inductor" or "Capacitor" terminals. Insert a current-reading meter in series with the positive battery terminal and switch on. Then, starting from about 3MΩ and working down in value, find the resistance needed in the R1 position which causes the current-indicating meter to give a reading between 4 and 5mA. With the prototype it was found that R1 needed to be 1MΩ for a current reading of 4mA, which indicated a gain under present circuit conditions for the particular transistor employed of approximately 450. It should not be necessary for R1 to have a value much lower than 1MΩ. It must be emphasised that the value required in R1 should be found by reducing the experimental resistance *carefully*. The transistor has an exceptionally high gain and too low a resistance for R1 can cause a relatively heavy collector current to flow. After the required value has been found the unit may be switched off, and a fixed resistor of the requisite value connected permanently in the R1 position. The unit may then be switched on again to check that battery current is still correct, after which the current-reading meter is taken out of circuit.

Apply the signal generator output to the input terminals, with C1 set to maximum capacitance and S1 in position 1. Inject a signal at a frequency in or near the medium wave band and adjust the signal generator attenuators for maximum reading in M1. Remember that, due to the presence of D2, an amplitude increase in a high-level input signal may cause a small *decrease* in meter reading. Then set up the variable resistor in the R4 position so that the meter reads full-scale deflection. The variable resistor is not taken out of circuit at this stage, and it should be retained until a little experience has been gained with the unit. This is because the detector and limiter circuit is slightly frequency dependent and it may be found that, at some input frequencies, the meter will still read a little higher than f.s.d. It is just feasible that exceptionally high input levels may, because of D2, cause the meter reading to drop below the 70μA level experienced with the prototype. Should this effect be present to any serious extent either avoid using very high input levels by attenuating the signal generator output or slightly increase the value of R3. No trouble was experienced on this score with the prototype, even when the transistor was driven sufficiently hard by the generator for its collector current to drop (due to detection in its base-emitter junction) to 3mA.

Next, connect a series of coils across the "Inductor" terminals in order to become familiar with the operation of the unit. It should be found that very pronounced "dips" in meter reading are given at resonance. If, for any combination of input level and input frequency, the meter reads slightly higher than f.s.d., adjust the temporary 10kΩ variable resistor in the R4 position accordingly. When these checks have been completed, disconnect the temporary variable resistor, measure the value it provides, and replace it with a fixed resistor of the same value.

The final task consists of calibrating C1, and this is carried out with the aid of fixed capacitors whose values are known. Fit C1 with a temporary scale, connect any coil across the "Inductor" terminals and a known capacitor across the "Capacitor" terminals. Put S1 to position 2 and adjust the signal generator frequency for resonance. Then set S1 to position 1 and similarly adjust C1 for resonance. C1 then offers the same capacitance as did the known capacitor and its scale may be marked accordingly. Repeat the operation with other known capacitors until there are sufficient markings on the temporary scale fitted to C1 to enable a permanent scale to be drawn up.

RESULTS WITH THE PROTOTYPE

The prototype unit was checked from 150 KHz to 30 MHz using the tuned windings (between pins 2 and 5) of coils in Ranges 1 to 5 inclusive of the Denco Miniature Dual Purpose Green series. At all frequencies a satisfactory "dip" was observed and the frequency ranges actually measured indicated very low stray capacitances across the coils at the high frequency end of each range. (The ranges quoted by Denco for these coils assume a minimum tuning capacitance, including capacitance due to trimmer and wiring strays, of 39pF). The signal generator was set to give its full output at all frequencies and, in most cases, the dip obtained brought the microammeter needle to zero or to very nearly a zero reading. All frequencies could be satisfactorily determined by observing the meter reading. ■

'WHITE ROSE' MOBILE RALLY

The 'White Rose' Mobile Rally, organised by the Pudsey and District Radio Club, will be held on Sunday, 27th July, 1969, at Allerton Girls' High School, Leeds. Talk-in stations will be operating on 2 and 160 metre bands. The Rally will feature a large number of trade stands, refreshment facilities, a raffle with attractive prizes and items of interest to XYL's and harmonics. Ample car parking space will be available.

DERBY & DISTRICT 1969 MOBILE RADIO EVENT

Derby & District Amateur Radio Society will hold their 12th Mobile Radio Event on Sunday, 17th August, 1969, at Rykneld School, Bedford Street, Derby. Talk-in stations operating on 2, 4 and 160 metre bands. Admission and car parking is free, together with all the entertainment provided. Trade stands, numerous field events in addition to the regular events. Refreshment facilities available.

Simple Voltage to Frequency Converter

by

J. B. DANCE, M.Sc.

A neat circuit which provides linear change of frequency with change of input voltage

A VOLTAGE TO FREQUENCY CONVERTER IS A CIRCUIT which produces an output frequency which varies with the voltage applied at its input.

Voltage to frequency conversion is widely used in electronic instruments, such as digital voltmeters, and also in electronic control and measurement systems in industry.

The circuit to be described is a very simple one which has been designed by the S.G.S. Fairchild Company. Although it is ideal for the amateur experimenter, it is also likely to be of interest to the professional engineer.

MULTIVIBRATOR

The type of circuit used to generate the output waveform is a normal multivibrator using p.n.p. transistors, as shown in Fig. 1.

This well known type of circuit will, of course, produce an output of a rectangular waveform and of a frequency determined by the time constants R1C1 and R2C2. The larger the value of the sum of these time constants, the lower the output frequency.

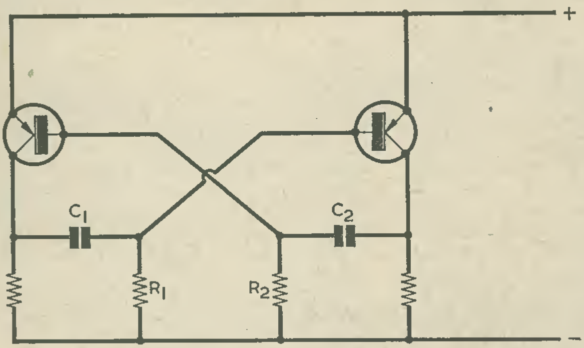


Fig. 1. A multivibrator using p.n.p. transistors

In order to alter the frequency of the output waveform, it is necessary to alter the effective time constants used in the multivibrator. This is achieved in the circuit to be discussed by employing the input voltage to control a pair of transistors which in turn control the current available for charging the feedback capacitors of the multivibrator.

PRACTICAL CIRCUIT

The practical circuit of the voltage to frequency converter is shown in Fig. 2.

The transistors TR1 and TR4 form the multivibrator itself; this part of the circuit can be compared with the simple multivibrator circuit of Fig. 1. The input voltage is fed to the bases of the n.p.n. transistors TR2 and TR3, and affects their collector current. This collector current is taken from the capacitors which determine the frequency of the multivibrator.

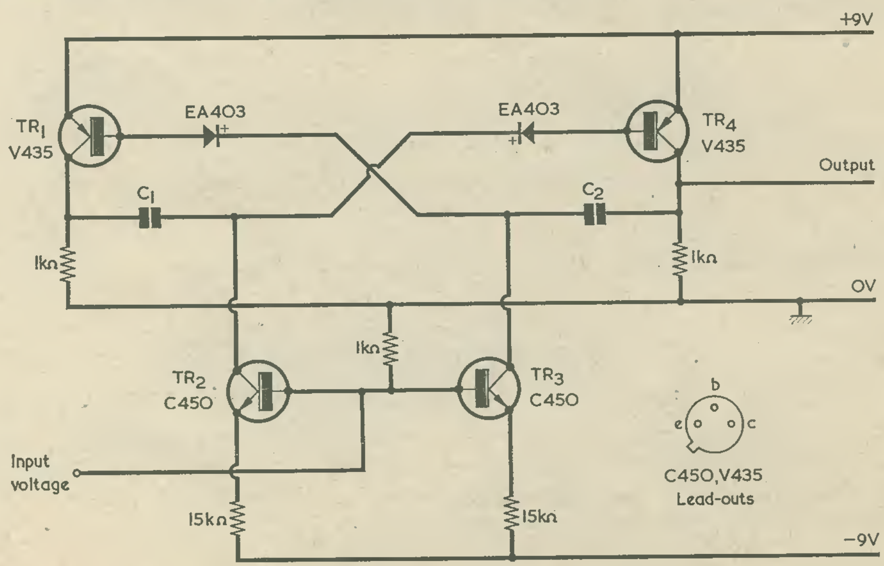


Fig. 2. A practical voltage to frequency converter

As the input voltage applied to TR2 and TR3 becomes more positive, these transistors tend to pass a higher current. Therefore the frequency determining capacitors C1 and C2 are discharged more quickly and the frequency of the multivibrator increases. The input voltage should be in the range −5V to +5V.

The frequency of the multivibrator with zero input voltage can, of course, be set to a suitable value for the application concerned by an appropriate choice of capacitors (see Table).

The duty cycle of the output voltage waveform is approximately 50%. The output frequency is linearly related to the input voltage.

If good frequency stability is required as the temperature varies and as the components age, the frequency determining capacitors marked C1 and C2, the 15kΩ resistors and the 1kΩ resistors in the emitter circuits of TR1 and TR4 should be high stability components.

The writer is indebted to S.G.S. Fairchild Ltd. for permission to reproduce their circuit.

TABLE

Relationship between capacitor values, output frequency and frequency coefficient.

Capacitors C1 and C2 (μF)	Frequency (V_{in} =0) (kHz)	Frequency coefficient (kHz per volt)
0.001	35	3.5
0.01	3.5	0.35
0.1	0.35	0.035
1.0	0.035	0.0035
10.0	0.0035	0.00035

Editor's Note

Transistors type V435 and C450, and diodes type EA403, may be obtained from L.S.T. Electronic Components Ltd.

LOCAL RADIO DEMONSTRATION

by

H. G. MIDDLETON

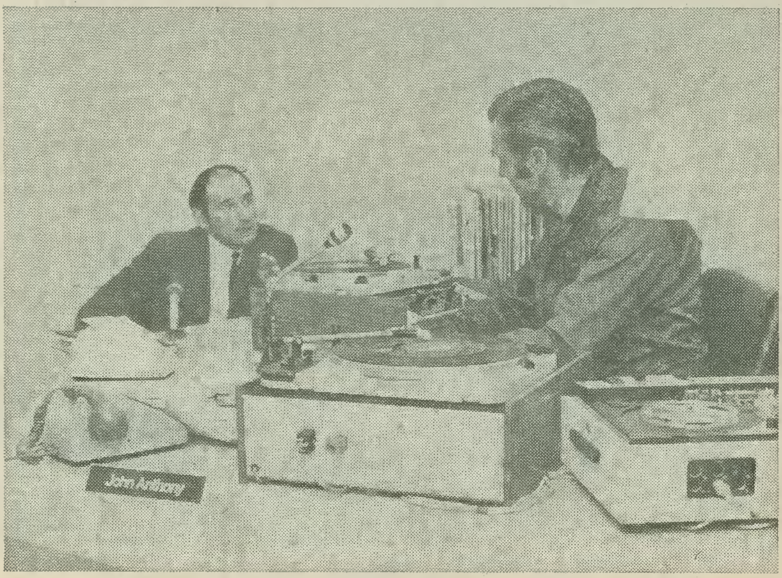
Local radio is still in its infancy in this country. Members of the public without previous experience of the services it can offer were able to evaluate its usefulness during the recent 'Daily Mail' Ideal Home Exhibition, at which the London 'Evening News' and Pye of Cambridge joined forces to stage a complete working studio and control room installation

At the Ideal Home Exhibition this year, visitors were able to see and hear how a local radio station operates when they visited "Radio Ideal Home", a complete demonstration local broadcasting station set up by Pye of Cambridge.

With less than ten local radio stations in Great Britain few people know what local broadcasting is like, and so the exhibition provided an ideal opportunity to acquaint the general public, especially Londoners with the advantages offered by a station which can take an interest in local affairs. There are of course four B.B.C. radio services but, even though one of these is transmitted on a regional basis, they cannot really be classified as anything but national, and are thus unable to cater for local and more personal needs.

STATION DETAILS

The station which Pye and the London *Evening News* put on exhibition was complete in most details, except for the absence of a transmitter. Three rooms were provided for the staff: an office, a studio and a control room, visitors being allowed to see into the latter two through thick soundproof windows. The studio was occupied by the announcer or DJ, who was equipped with a microphone, two turntables and a mixer unit. From here, provided the



John Anthony, in the DJ's chair, interviews a visitor to the Exhibition

Smiles all round in the "Radio Ideal Home" studio as Diana Dors and her husband share a gag with DJ John Anthony

programme material was reasonably straightforward, he could virtually run the whole station single-handed. If, however, he wanted to bring in background music, pre-recorded spots or interviews, the producer would take control from his room, issuing all the necessary cueing instructions and operating his own mixer. This was only a six-way unit, but it could be set up to accept many more sources by programming with a patch-panel. In this way two additional turntables, four tape recorders, the DJ's microphone plus the output of his mixer, and any interviewers' microphones could be routed through to what would, in the normal installation, be the transmitter. In the case of the demonstration station the final programme was relayed to loudspeakers outside the stand and in the exhibition lounge.

The whole station could be run on a skeleton staff of a DJ, a producer and one technical/operating assistant, but normally there would be an interviewer, another technical assistant, plus several clerical staff and copywriters.

Radio Ideal Home gave out the national news and local news on the hour every hour, between which were record programmes, live telephone interviews with local journalists about the news, local traffic and weather reports, interviews with celebrities invited to the station and special announcements about what to do and see at the exhibition. There were also live programmes on local government affairs, local industries and schools, together with programmes presented by students from London University. Special coverage of local sport on Saturday afternoons was given, and throughout each day members of the general public were interviewed, each one aspiring to be the "Radio Ideal Home Personality of the Day" to whom a special award was presented.

THE CASE FOR LOCAL RADIO

Local radio may be new to Great Britain, but it is well established in other countries. For instance, New York has no less than 60 stations, whilst Toronto, Canada, has 14, and Sydney, Australia, has eight. The latter two cities are only a quarter the size of London, but our capital has never previously heard what a local radio station sounds like.

Local radio is based on the assumption that most people live within a radius of ten to 15 miles of their home town. Their places of work, their children's schools and the shops they use are all within this area, and so a transmitter sited within the boundary represents a considerable personal boon. Generally, people have little or no interest in weather or traffic conditions several hundred miles away, and all these facts show why local radio can give a township a sense of more individual identity. A typical local radio station is small and friendly. It is closely in touch with its listeners and is able to provide a completely new focus for community and home life.

The station demonstrated at the Ideal Home Exhibition was of great value, because it showed those who have had no previous encounter with local radio just exactly what community services such a station can provide. Thus, when the subject comes up for serious discussion at Parliamentary level, more of the people whom the decisions will affect are able to voice knowledgeable opinions and to ensure that there is a greater certainty of an informed majority being satisfied. ■

George Gilbert of Pye controls sound output level from the studio. The six-way mixer beneath the microphone combines with a separate patch-panel to take a wide variety of programme inputs

QSX

by

L. SAXHAM

(All times GMT)

A report on the stations – both amateur and broadcast – that may be logged by the s.w.l. on the various short wave bands; compiled by a Dx'er whose QTH is located near the S. Suffolk coast.

● TOPIC

One of the continuing fascinations of short wave listening is the sudden and unexpected appearance of a station on what is often an unlikely channel. Short wave listening, as a hobby, may sometimes be full of the unexpected. Out of the ether sometimes comes signals which are mysterious, puzzling and often incapable of identification.

Two such instances have occurred, to the writer, in recent times. The first (Mystery 1) was that of the appearance of a Broadcast station on a measured frequency of 5077.5kHz at 1920GMT with a SINPO rating of 22432. This transmitter was logged, and taped, on several occasions during last October and, on the 21st of that month, African type drums, chants and trilling cries were heard through the heavy teletype QRM. Several attempts were made to *positively* identify this station. Returning some days later to the same channel produced, apart from the teletype transmissions, an absolute blank. The sudden appearance and subsequent disappearance of this suspected African transmitter is unexplained and remains a complete mystery. Needless to say, the channel has been monitored many times since with no results.

Mystery 2, concerns a station transmitting on a frequency of 4695kHz at 2000GMT with a SINPO rating of 33333. The station was several times heard opening at 2000 with announcements in a Chinese dialect, followed by a western type band and choir presumably rendering a national song or anthem. This was usually followed by a harangue in a Chinese dialect with both male and female speakers. These transmissions were taped and the station was consistently logged over a period of two weeks. The writer has been unable to *positively* identify the taped broadcasts, but suspects that the transmitter is located in Mongolia with the transmission beamed to China. The station was logged during May of this year but, needless to say, nothing has been heard of the transmitter from that time to the instant of writing.

The unexpected? The unexplained? The mysterious? Yes, they sometimes occur on the Broadcast bands, and the *positive* identification of such transmitters often involves long periods of reception and not a little detective work. Would you make a good detective?

● AMATEUR BANDS

These frequencies have provided a whole host of Dx during the past weeks, both on CW and SSB.

21MHz

CW: CO2BB, CO2KG, HLØTU/MM, HZ4KO, JA1JLL, JA3CNQ, KR8EA, ZF1KV, ZL3JO, ZS5UT/MM and 4Z4NC.

14MHz

CW: CE9AT, CR6BX, CX4CO, HK7GM, HK7YB, JA4DMB, JA5BXJ, KG6AQ, KP4DDO, LU3EJ, LU4ECO, OA4ZG, PJ2CB, PZ1AV, VK2HW, VK3SR, VK7LJ, XE1AAG, XE1OE, ZE1DG, ZF1CW, ZL1ATH, ZL4IB, ZS1A, ZS6AJS and ZS6HR.

SSB: CP6GY, CR7DS, EP3AM, FP8CS, HC2RZ, HK1XDP, HK3BR, HK3UA, HK3WO, HK4AZX, HP1JK, KG4AA, KG4AOD, OA1J, OA3TT, OA4AS, OA4TJ, OA5AO, PJ3AV, TG9EP, TG9GF, TG9RN, VK2SG, VK3AKP, VK4HA, VK4KN, VK4KS, YS1MAX, ZL1AJU, ZL3TD, 5N2AAU, 8R1G and 9K2BV.

7MHz

CW: CO2BB, CO2RP, CR6AI, HI7JMP, KZ5JQ, LU6FA, PY1KJ, PY2BQL, PY2EWL, PY2NE, PY6GS, PY7AWE, VE1AWB, VE3BLU, VE3DQX, VE7PQ, VK2VN, WAØVYI, WA4JHH, WA4PFE, W2JAU, W6GP, W6NLZ, W7COB, W7JII and ZS3AW.

1.8MHz

CW: EI9GB, GM3WDF, GW3MOP, GW3SVY, GW3YGH, GW3XSQ, GW5TW, OK1AKG, OK1ARH, OK1DAK, OK1FAB, OK1FVV, OK1IAR, OK1IPF, OK1IPF, OK1KZE, OK1LD, OK1NC, OK2BJJ, OK2BOL, OK2CIM, OK2DW, OK2PCS, OK2ZU, OK3CHX, OK3KWK, OL1AKG, OL1ALM, OL2AIO, OL2AKS, OK1IAR, OK1IPF, OK1KZE, OL6AKP, OL6AMB, OL9AJK, OL9AKP, OL9AKT and PAØAHO.

● BROADCAST BANDS

Plenty of Broadcast DX was there to be heard by those who cared to search and 'dig' for it, as usual the lower frequency bands producing the thrills and spills.

3225kHz 2010 Radio St. Elwa, Liberia, with African choir. CW QRM on the channel marred reception.

3336kHz 1810 Ziguinchor, Senegal, with a programme of African chants. Station announcements in French at 1815. CW QRM.

3339kHz 1920 Zanzibar, Tanzania, newscast in dialect. Teletype QRM.

3350kHz 1945 Franceville, Gabon, with talk in French. Teletype QRM.

3365kHz 0310 YVPM Tovar, Venezuala, with Latin-American songs and music.

3380kHz 0305 TGCH Jocatan, Guatemala, with Latin-American music.

3385kHz 0302 YVQI Barcelona, Venezuala, with programme of rhumbas, etc.

3395kHz 0300 YVOK Merida, Venezuala, with Latin-American songs and station identification.

4740kHz 0332 HCBK2 Guayaquil, Ecuador, Latin-American dance music. Tentative logging. Frequency measured, unable to resolve taped station identification at 0330. Power 0.25kW. SINPO 23432.

4770kHz 0348 YVQE R. Bolivar Venezuala. Station identification and 'pop' records.

4775kHz 1650 AIR Gauhata, India, with Eastern type music. Teletype QRM on channel.

4777kHz 2047 Libreville, Gabon, with African rhythmic songs, drums and music.

4792kHz 0430 HIAS Santa Domingo, Dominican Republic. Station identification and closing with National Anthem.

4807kHz 2100 R. Clube de Sao Tomé, with identification in Portuguese and English.

4815kHz 2002 Ouagadougou, Upper Volta, with programme of recorded light music.

4839kHz 1955 9RBU Bukavu, Congo, with native music and sign-off. Heterodyne from CR6RY.

4840kHz 1958 CR6RY Novo Redondo, Angola, with commentary in Portuguese audible after 9RBU closes down.

4960kHz 1725 AIR Delhi, India, with Indian type music.

4990kHz 1720 AIR Delhi, India, with Indian songs and sitar music.

5035kHz 2024 Bangui, Central African Republic, African drums and chants – complete with awe-inspiring female shrieks!

7225kHz 1825 Sebaa-Aioun, Morocco, with talk in French.

11920kHz 1745 R. Kuwait, Kuwait, radiating their English programme.

11950kHz 1825 Riyadh, S. Arabia, with Arabic songs and music.

15020kHz 0940 Hanoi, Vietnam, with talk in vernacular.

15060kHz 1315 Peking, China, with talk in dialect.

17795kHz 0540 RSA, South Africa, with news in English and identification.

17870kHz 0515 R. Australia, with news in English and identification.

17905kHz 1640 Cairo, Egypt, with Arabic music. ■

NEWS . . . AND .

HOME RADIO EXPANDS

The hosts and all the guests gathered together in the grounds of the Grange Restaurant for an after-luncheon photographic record of the occasion

Twenty-three years ago, using their Service gratuities, two brothers, Mr. Alan Sproxton and Mr. Colin Sproxton, opened a radio and television shop – 'Home Radio' – the name being chosen by their father. The firm, still flourishing, has in the last ten years made a significant change. Although outwardly still a conventional radio and television shop, there has grown up an organisation for the sale of electronic components by mail order which has made the name Home Radio, and the town of Mitcham, known all over the world. The vast increase in the volume of mail order business brought many problems, the greatest being the need for more space in which to stock the many thousands of items offered in their well-known and excellently produced catalogue.

For three and a half years, a search for suitable premises was carried out with many consequent disappointments. Finally, the solution to the problem was found only 400 yards away from the original shop in London Road – the top floor of a new office block at 240 London Road, having 2,400 square feet of space.

To celebrate the opening of the new premises and to afford the opportunity to exhibit Messrs. Bulgin's new mobile display van, Mr. Sproxton and Mr. Layton (Mr. Colin Sproxton retired five years ago, the business now being carried on by Mr. Alan Sproxton and Mr. Ernest Layton) invited many of their friends from the industry, the trade and the radio press to a luncheon at the Grange Restaurant and a conducted tour of the new premises. Also present was a very old friend of the Sproxton family – Mr. B. Mund Hopen from Bergen, Norway, who was in charge of the Norwegian Shipping Mission during World War II.

In a short after-lunch speech, Mr. Sproxton welcomed the guests, thanked them for their attendance and added that he hoped they would forgive the digression, but as it was St. George's Day, he felt he might be forgiven for referring to the last War. In his opinion, three things saved our country from defeat – radar, the tenacity and courage of the R.A.F., and the Norwegian tanker fleet (the third largest in the world) which came over to Britain. He ended by proposing a toast to Her Majesty the Queen and to the Norwegian Royal Family.

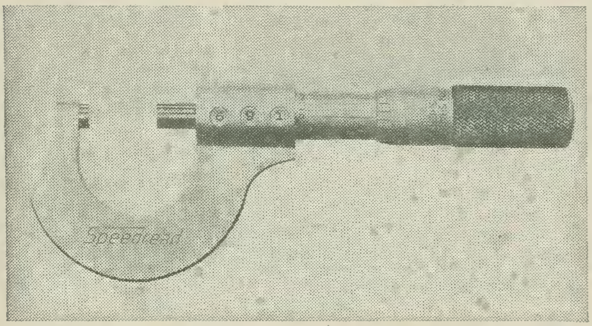
Mr. Sebystin of Radiospares said how delighted he was to be present, and wished Home Radio every success. Mr. Hopen thanked Mr. Sproxton for his kind remarks and added that he had been living in this country for forty years and remarked how happy Norwegians are when in London.

Mr. F. Bennet, Editor of *Practical Electronics*, said how well Home Radio had looked after the needs of the Amateur Radio hobbyists as a whole.

Finally, Mr. A. J. Crowe, representing the National Publicity Company, said he would like to speak as one of the non-V.I.P.'s present, remarking that he had been associated with Home Radio for many years and had found them such friendly people. This, he added, was exemplified by the gathering that day, and he felt in view of this they should change their business name to 'Homely Radio'!

. . . COMMENT

SPEEDREAD DIRECT READ-OUT MICROMETER



Error is eliminated, and measurement made faster by the use of the new direct read-out micrometer made by GKN Shardlow Metrology Limited, of Heath Street, Smethwick, Warley, Worcs., called Speedread.

The precise measurement is shown numerically in the windows on the barrel of the micrometer; no interpretation is required. A conventional vernier scale is also incorporated to give measurement to finer limits. Use of Speedread in the Metric reading version will overcome the problems and errors likely in the change to Metric measurement.

Initially GKN Shardlow Speedread micrometers will be available in size 0–1in. (reading to 0.0001in.) and 0–25 mm. (reading to 0.01 mm., equivalent to 0.0004in). The direct read-out feature will become progressively available throughout the GKN Shardlow range of precision measuring instruments.

Our General Editor, Frank A. Baldwin (holding glass and cigarette), our Advertising Manager, O. W. J. Rundle and Mrs. Crowe (wife of Mr. A. J. Crowe, National Publicity Company) engaged in an interesting discussion about historic churches, buildings and the work of local historical societies, at the Home Radio luncheon reported opposite

THE TELEVISION RECEIVING AERIAL

"The viewer who was content with a 'soot and magenta' picture will not accept a magenta face!" is a claim made by Mr. R. S. Roberts, C.Eng., FIERE, Sen. MIEE Consultant, in an article on the TV receiving aerial in Bulletin No. 6 published this week by the British Bureau of Television Advertising.

Explaining how even the most expensive system of transmission and receiver design can result in poor quality pictures with an incorrect type of aerial or one which is badly designed, Mr. Roberts describes how the advent of colour had resulted in the receiving aerial manufacturers agreeing a specification for the performance of a reasonably priced, easily erected receiving aerial.

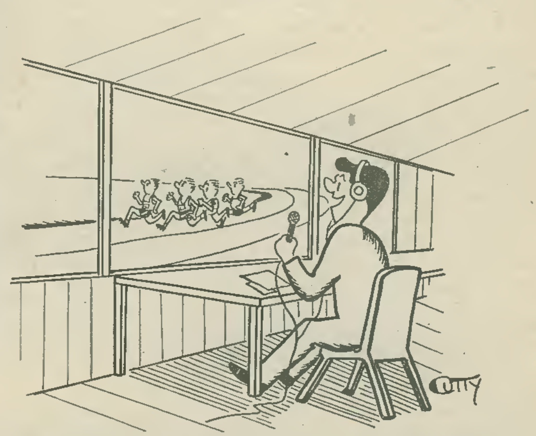
Although the UHF aerial looks like a smaller version of the familiar Band 3 aerial the design includes important differences. Three main requirements have to be met. (i) operation must be over a much wider band width, (ii) directivity must be unusually good, (iii) there must be a large signal voltage to the receiver.

Although deceptively simple in appearance such an aerial incorporates considerable technical sophistication and should be obtained from a reputable manufacturer, such as a member of the Radio and Electronic Component Manufacturers Federation.

A suitable aerial is about three feet long, weighs approximately 16 ounces and is neat and unobtrusive in appearance.

The article describes a special form of wide-band aerial for Band 3 which, installed now, will not require changing in the future.

Bulletin No. 6 is available free of charge from the British Bureau of Television Advertising, Knighton House, 52/66 Mortimer Street, London W1N 7DG, telephone 01-636 6866.



"This commentary is coming to you on 100 metres, 440 metres, 1500 metres and the Marathon"!

PRINCIPLES OF METAL DETECTION

PART 2

by F. L. THURSTON

In this concluding article our contributor describes the basic operating principles of inductance bridge locators, induction balance locators, u.h.f. balance locators and transmitter receiver locators

INDUCTANCE BRIDGE LOCATORS

As with the beat frequency metal detector described in Part 1 of this series, the inductance bridge locator also relies on the change in inductance brought about by a metal target in the vicinity of the search coil, but in this case the inductance change is detected directly in a bridge circuit, as shown in Fig. 5(a). Here, the search coil forms one arm of an inductance bridge energised by an r.f. oscillator; any out-of-balance voltage from the bridge (due to a change in search coil inductance) is fed to an r.f. amplifier and thence on to a detector circuit, to give a final visual indication on a moving coil meter.

The instrument can be made to give an audible indication of balance in a speaker or earphones by replacing the meter with a voltage-sensitive audio generator, if required. Alternatively, the circuit can be modified as in Fig. 5(b), the output of the r.f. amplifier being mixed with that of a reference oscillator to produce an audio beat note, the amplitude of which will vary in proportion to the magnitude of the out-of-balance signal from the bridge. Both oscillators are crystal controlled, but the frequency of the reference oscillator can be varied over a small range (by means of a trimmer capacitor) to enable the audio beat note to be varied to suit individual requirements.

The balance of the inductance bridge is not greatly affected by changes in operating frequency, so that the inductance bridge type of instrument has the advantage that high search frequencies can be used without restriction due to drift problems. The design criteria of search coil shape and search frequency are the same as those of the beat-frequency type of locator so that, in the general case, the inductance bridge type of locator will give better sensitivity than the conventional beat-frequency locator, but will not be appreciably better than the frequency-corrected locator shown in Fig. 3 of Part 1 in this series.

The actual bridge circuitry used in the detector can take any one of a number of forms, so a few words on the general principles of the induction bridge will not be out of place at this stage. Fig. 6 (a) illustrates the basic circuit on which all inductance bridges are based. The bridge can be regarded as two voltage divider networks (Z1 with Z2, and Z3 with Z4) energised from a common source of a.c., the output of the circuit being taken from the junctions of the upper and lower arms of the two dividers.

Now, the attenuation provided by a voltage divider network is dictated by the value of the upper arm relative to the value of the lower arm, and not by the absolute value of any one component, so it follows that, in Fig. 6(a) if the ratio $\frac{Z1}{Z2}$ is equal to $\frac{Z3}{Z4}$, both voltage dividers will give equal attenuation and zero difference signal will appear at the output. The bridge is then said to be balanced.

Thus, at balance,

$$\frac{Z1}{Z2} = \frac{Z3}{Z4}$$

or, put another way,

$$Z1.Z4 = Z2.Z3$$

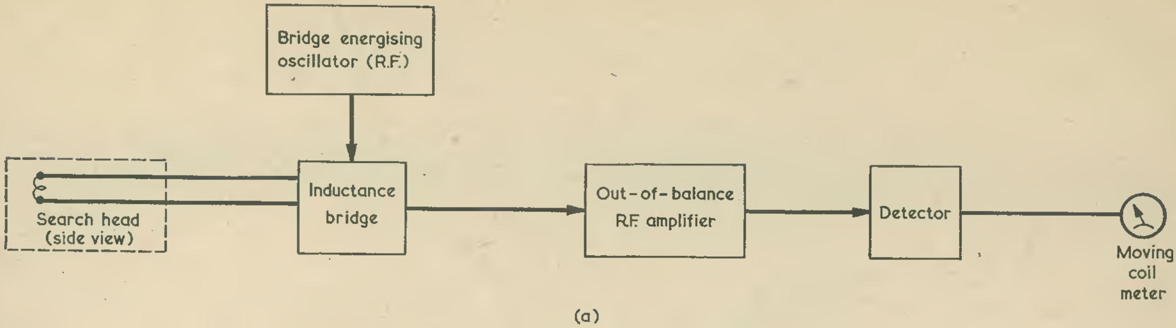
The value of any one component can, at balance, be expressed in terms of the values of the remaining components; thus,

$$Z3 = \frac{Z1.Z4}{Z2}$$

From the above it should be noted that *any* arm of the bridge can be used to adjust the balance state of the circuit, and that any change caused in balance due to Z3 can be counteracted by making Z4 adjustable and using a fixed ratio voltage divider in the Z1-Z2 positions.

A variable inductance bridge can be made by using inductors in all four arms of the circuit, but this is only rarely done in practice. A more frequent practice is to use a transformer to give the voltage divider action previously offered by Z1 and Z2, as shown in Fig. 6(b). This circuit is known as the *transformer ratio-arm* bridge, and has the advantage that it only requires the use of two inductors.

The most widely used type of inductance bridge, however, has only one inductor, as shown in Fig. 6(c). The principle used here is that, so far as voltage phase shifts are concerned, a capacitor can be regarded as a negative inductance, so that the phase shifts caused in the inductive arms of a bridge can be balanced out



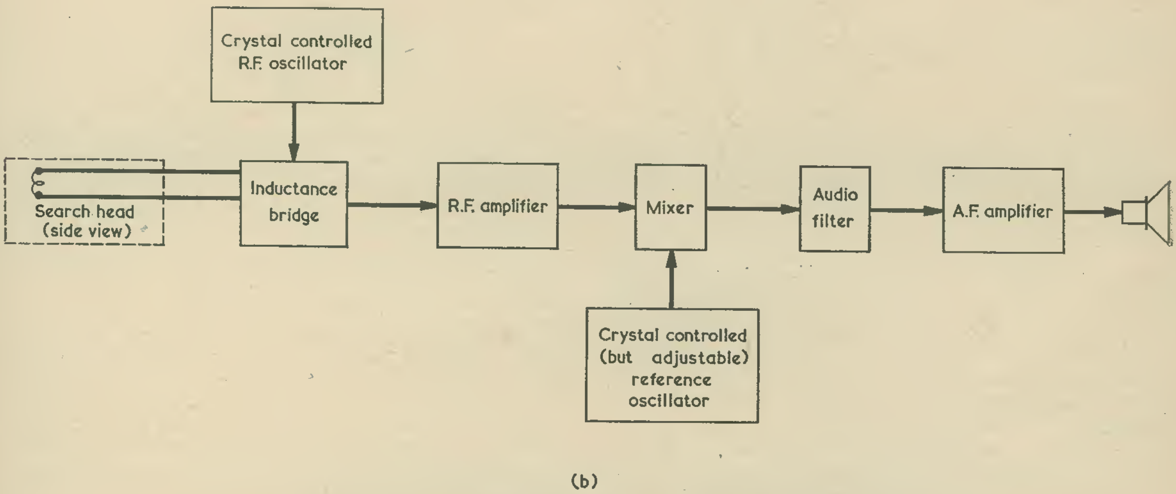


Fig. 5(a). Block diagram showing the basic inductance bridge locator
(b). An inductance bridge locator offering an audio output

by the opposing arms phase shifts of a capacitor placed in the opposite arm. The bridge shown in Fig. 6(c) is the Maxwell type, and, at balance,

$$L = R1.R2.C1$$

The component shown as r in Fig. 6(c) is not a physical resistor. Instead it represents the inevitable resistive component which will be present in the inductor, and it is balanced out by R3. At balance

$$r = \frac{R1.R2}{R3}$$

A simple method of finding R3 is to initially adjust the

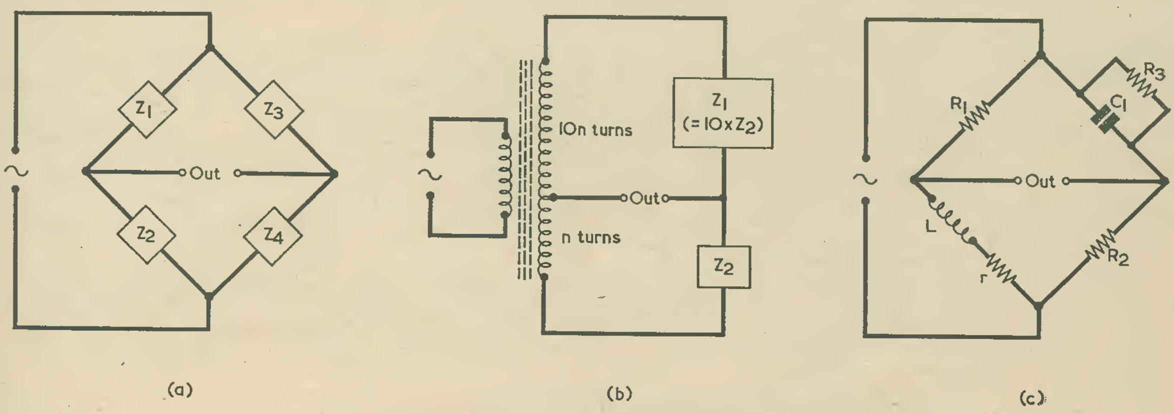


Fig. 6(a). The basic impedance bridge
(b). The transformer ratio-arm bridge. A 10:1 ratio is assumed
(c). The Maxwell bridge

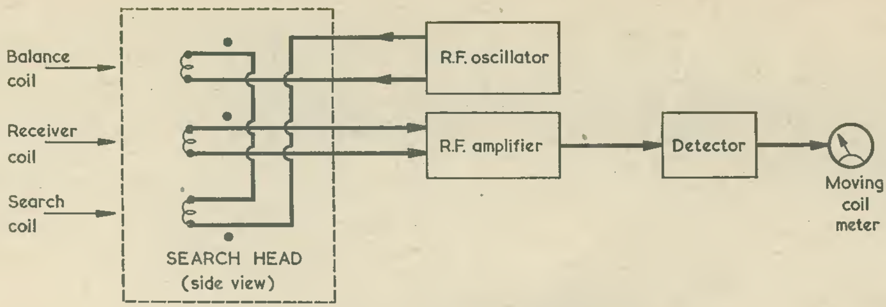


Fig. 7. Block diagram for the induction balance locator

bridge for balance (by varying R1, R2 or C1) with R3 inserting a high value of resistance. R3 is then adjusted, together with small adjustments in the variable arm, until the lowest possible null output is obtained.

All of these bridge circuits can be used in practical metal locator circuits. One interesting variation, that is believed to be used in the British army, uses a small (approximately 5in diameter) coil in each arm of the bridge, and these are mounted adjacent to each other, in the form of a square, in the search head. When the search head is placed centrally over a target, all coils change inductance by equal amounts, so the bridge stays in balance; when the search head is placed over the edge of a target, the coils change inductance by differing amounts, and an output is obtained. This instrument is of particular value in tracing the outlines of buried targets like mines, and may even respond to non-metallic objects, like wood, plastic, bone, etc., due to the small changes that these objects can produce in the earth's conductivity when buried at shallow depths.

INDUCTION-BALANCE LOCATORS

Induction-balance locators rely on the "field pattern change" principle as the means of target location. The block diagram of the basic system is shown in Fig. 7. Here, the search head contains three coils, positioned vertically one above the other and spaced equal distance apart. The two outer coils are energised from a common r.f. oscillator, but are connected in anti-phase, so that, in the absence of a target, the field of the lower (search) coil is nullified by that of the upper (balance) coil at a point midway between the two coils, and at which the third (received) coil is situated. In the presence of a target below the search head, the field pattern of the search coil is distorted and the balance condition just described is upset, so that an r.f. signal is induced in the receiver coil. This signal is fed to an a.f. amplifier and detector, to finally give a visual indication on a moving coil meter.

The instrument can, if required, be made to give an audible indication of the presence of a target by replacing the meter with a voltage sensitive oscillator or by incorporating a b.f.o., as in Fig. 5(b).

The design criteria of search coil shape and search frequency are similar to those of the beat-frequency locator, but the operating frequency is not restricted by the same drift problems. Consequently, target sensitivity is usually slightly better than in the case of the conventional beat-frequency locator, but not appreciably better than the frequency corrected type shown in Fig. 3 of Part 1.

In the presence of a metal target, the signal picked up by the receiver coil in Fig. 7 comes predominantly from the balance coil (in phase with the r.f. oscillator signal), but in the presence of a mineral target it comes predominantly from the search coil (in anti-phase to the oscillator signal). Thus, the receiver signal contains phase information relating to the nature of the

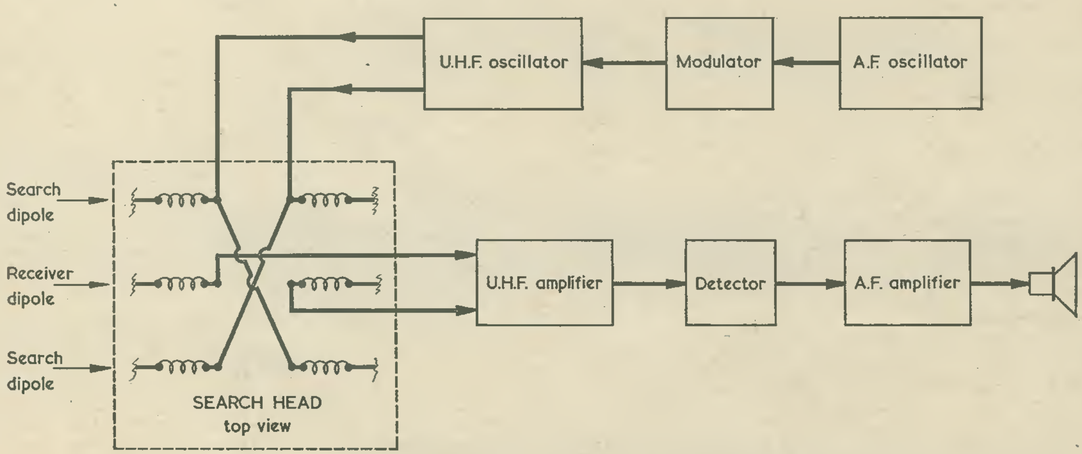


Fig. 8. A locator which uses a balanced field pattern around u.h.f. dipoles in the search head

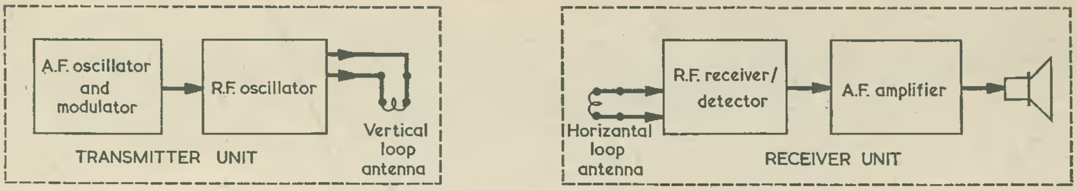


Fig. 9. The transmitter-receiver locator

target. This information can, if required, be extracted with the aid of synchronous demodulators.

U.H.F. BALANCE LOCATORS

U.H.F. balance locators also rely on the "field pattern change" principle of target location, but operate at ultra-high frequencies, The block diagram of the system is shown in Fig. 8. Here, the search head contains three inductively loaded dipole antennas, mounted side by side and spaced equal distances apart. The two outer (search) dipoles are energised from a common u.h.f. source that is audio modulated, but these dipoles are connected in anti-phase so that, in the absence of a target, their field patterns cancel out in the central receiver dipole. In the presence of a target, the balance of the field patterns are upset and a signal is induced into the receiver dipole. This signal is first fed to a u.h.f. amplifier and then on to a demodulator, and the resulting audio signal is passed on to the speaker (or to earphones) to give an audible indication of the presence of the target.

When the search head is placed centrally over the target, both field patterns are distorted by equal amounts, so no signal is injected into the receiver dipole. It is only when the two field patterns are altered by different amounts that a signal can be injected into the receiver and an audio indication given in the speaker. Thus, this type of locator is particularly suited to finding and tracing the outlines of targets.

Because of the very high operating frequencies used and the inductive loading of the dipoles, the search patterns can be affected in a number of different ways, including inductive loading by a metal target, signal reflection by the target, and signal absorbtion by non-metallic targets. This last factor enables local changes in the qualities of the ground to be detected, so the u.h.f. balance locator has the advantage that it can detect the presence of buried rocks, bones, rabbit burrows, wood, etc., as well as metal targets. This type of detector has been used by the U.S. Army for locating metallic and non-metallic (wood or plastic cased) mines.

TRANSMITTER-RECEIVER LOCATORS

All of the metal locator types that we have considered so far have made use of a flat search head mounted on the end of a long handle, and are intended to be used rather like a broom to "sweep" a search area. They can all offer good sensitivity to small targets, but they suffer from rather poor depth of penetration.

The "transmitter-receiver" locator differs from these other instruments in all respects. In appearance it resembles a pole with a "black box" mounted on each end. In use, the pole is held centrally in one hand, and horizontal to the ground, with each of the "black boxes" a foot or two above ground level; the operator then simply moves around until a response signal is heard, indicating the presence of a metal target somewhere below the locator. In performance, small-target sensitivity is rather poor, but depth of penetration is very good; large targets can be located at depths of several feet.

The unit relies on the "reflected energy" principle of target location. The block diagram of the locator is shown in Fig. 9. Here, two physically separate units are used, one of them being a modulated r.f. transmitter feeding into a *vertical* loop antenna, and the other being a simple r.f. receiver (tuned to the transmitter frequency) fed from a *horizontal* loop antenna. Thus, the two loop antennas are at right angles to one another.

Now, a loop antenna features a figure-of-eight field pattern, with a complete null (zero signal) along the axis of the loop and maximum signal strength at right angles to the axis, as shown in Fig. 10. In the transmitter-receiver instrument the receiver antenna is set at right angles to, and exactly along the axis of, the transmitter antenna, so that zero signal is coupled into the receiver antenna directly from the transmitter antenna, even though the two antennas may be only a few feet apart.

When a metal target is moved into the field of the transmitter antenna, however, the target reflects the transmitter signals in all directions from its own position, and these signals are picked up by the receiver, to give an audible indication in the speaker or earphones.

Maximum signal return is given when the target is directly below the transmitter antenna, but the target must be reasonably large (at least 2in diameter) if it is to give any appreciable indication, and, due to the shape of the field, must be at least 12in. away from the actual antenna. This type of instrument is widely used by local authorities for locating underground

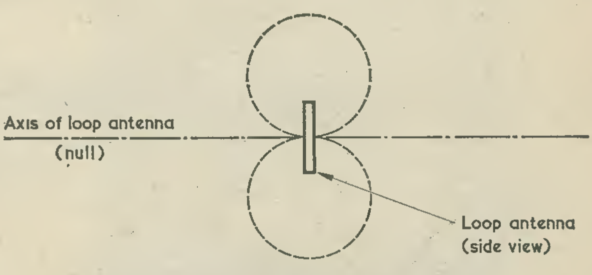


Fig. 10. The characteristic figure-of-eight field pattern given by a loop antenna. Note the null on the loop axis

pipes and cables, and by geologists for tracing mineral veins.

CONCLUSION

In this and the preceding article we have looked briefly at the operating principles and performance characteristics of the five most widely used types of metal detecting instruments, and have seen that a high degree of sophistication has been attained in this particular branch of electronics. It should not be thought, however, that these instruments are the only types that have been developed, or that the principles described are the only ones that can be used for locating buried targets. A number of establishments are, for example, at the moment experimenting with portable sonic and ultra-sonic locator systems that rely on the "echo" method of target indication, rather like radar, and these show great potential. Much progress can be expected in this field within the next few years. ■

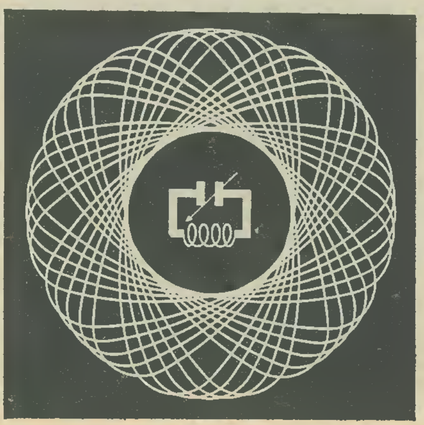
EXHIBITION OF ELECTRONIC COMPONENTS PARIS 1969

by

MAURICE WALTERS

Highlights of an important international exhibition

IT IS MORE THAN 30 YEARS SINCE THE FIRST FRENCH Exhibition of Electronic Components was held. From 1958 the exhibition took on an international character and at that time the exhibitors—totalling 320—including 40 from overseas. Also, at that time, the duration of the exhibition was extended from four to six days. This year's Electronic Components exhibition featured 1,000 exhibitors, nearly half of whom were foreign companies. The event is held at the Parc des Expositions, Porte de Versailles, Paris, where it covers an area of 540,000 square feet. The attendance has grown steadily over the years and now stands at 160,000.



LECTURE MEETINGS

Supporting the 1969 exhibition were a number of conferences and technical meetings. The topics included television components, electroacoustics, discrete semiconductors, integrated circuits, measurements, passive r.l.c. components, switch and connection techniques, and the equipment used in the manufacture of components and component materials.

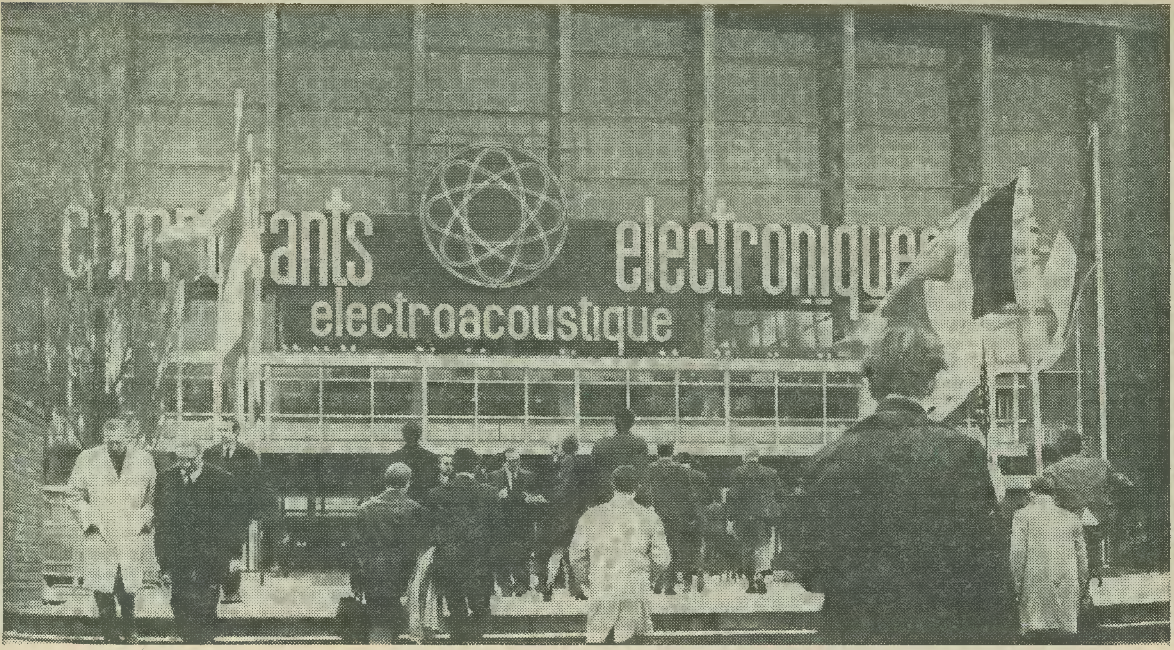
TRENDS

Microelectronics have once again this year been the star attraction, and the spheres in which they are used have broadened considerably, these including TV receivers. Receiver tuning circuits incorporating variable capacitance diodes are also available. Extremely compact and highly reliable rigid or flexible multi-layer printed circuits were prevalent.

Optoelectronics were also well to the fore with photomultipliers combining a light-sensitive element and transistors on one and the same silicon module. Colour television also gave rise to a wealth of special components and interesting items of equipment.

AUDIO

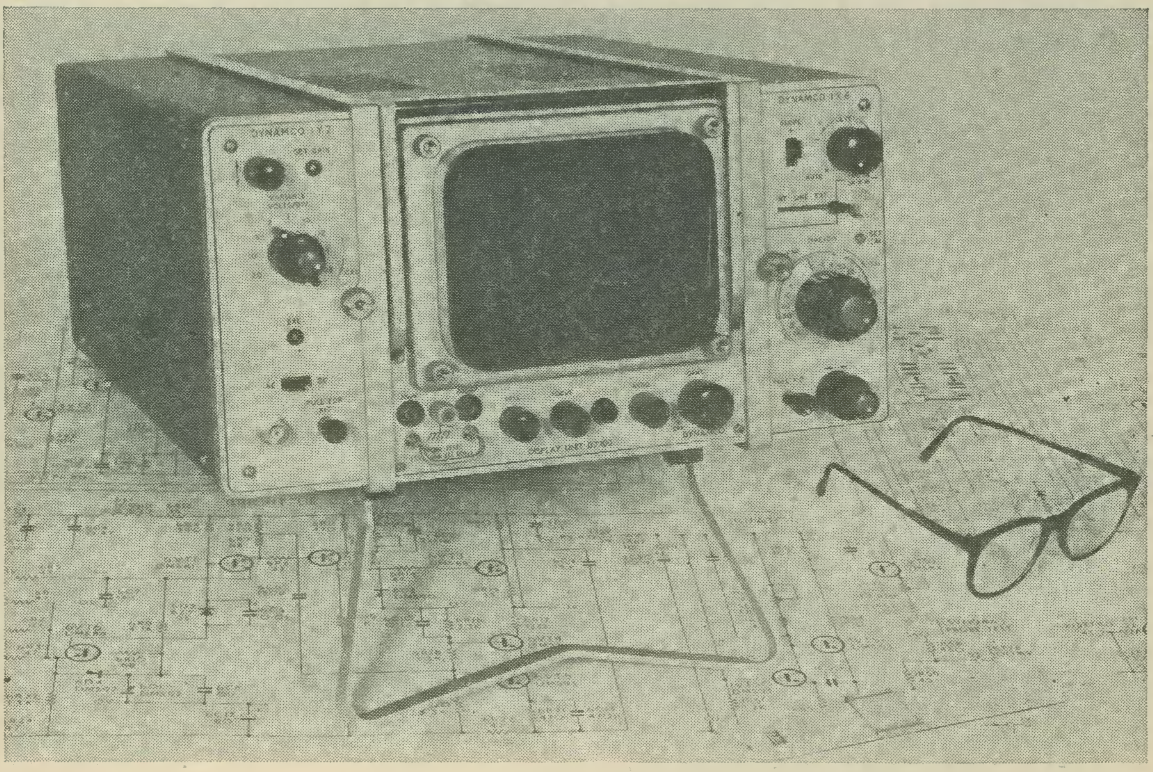
The International Exhibition of Audio Equipment was tied in with the actual components show and was confined strictly to the products of firms manufactur-



ing equipment such as accessories for magnetic recording, dictating machines, record players, decks, f.m. adapters, a.f. preamplifiers, microphones, speakers, phones, and speaker enclosures, etc.

The interest aroused by the Paris Components Show is very evident in this view of the exhibition building entrance

(continued on page 780)



Claimed to be the smallest solid-state oscilloscope of its kind, this Dynamco instrument – exhibited at the Paris Component Show – offers a bandwidth of 15MHz

COMPONENTS

Plessey Ltd., featured new developments in microelectrics, wound components, switches, memories and

Cover Feature

TRANSISTORISED REVERBERATION UNIT

by

R. J. CABORN

Add a "third dimension" to reproduced music with the aid of this simple-to-build reverberation unit, which can take its input from electric guitars, medium or high impedance microphones, or any other normal sound source. The output of the unit can feed into a standard amplifier or tape recorder, and results are particularly impressive when it is employed with an electronic organ. Construction time is considerably reduced by taking advantage of a ready-assembled transistor amplifier

The reverberation unit to be described in this article is completely self-contained with its own battery, and it may be inserted between any normal sound source, such as an electric guitar or a microphone of medium or high impedance, and a following a.f. amplifier or tape recorder. It offers especially impressive results when used with an electronic organ. A selector switch enables two reverberation modes to be provided, one consisting of a high reverberation signal with a treble effect whilst the other consists of a lower, more rounded, tone. Reverberation amplitude can be varied by a panel control, and a jack socket enables a foot-switch to be plugged in which can switch the reverberation in or out as desired.

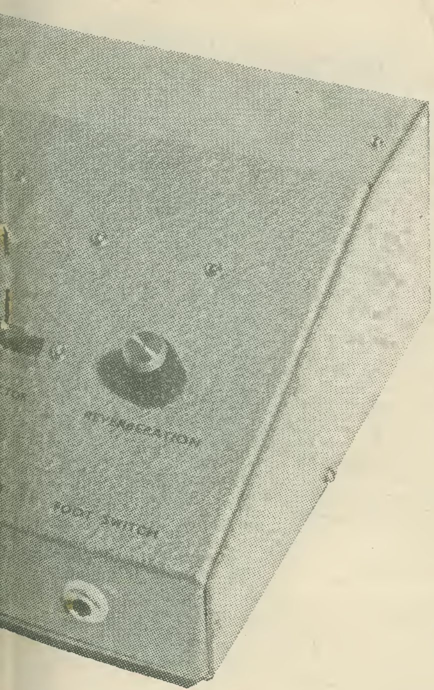
The unit is built into a metal case which may be purchased either plain or with all the major holes cut out. Power is provided by a 9-volt PP3 battery. Current consumption for low level inputs is approximately 5mA, this rising to some 20 to 30mA on sound peaks. To simplify construction, a ready-assembled 4-transistor amplifier with an output of 250mW is incorporated. Two single-transistor pre-amplifiers need to be made up by the constructor. These are assembled on printed circuit boards which are already etched, cut to size and pierced. Also required of the constructor is the general assembly of the unit, together with the wiring-in of a small quantity of resistors and capacitors.

The heart of the equipment is a reverberation spring unit, in which two specially tempered springs are coupled to electromagnetic transducers at either end. Audio frequency signals induced into the springs by the input transducer continue after the activating sound has ceased, thereby giving the well-known reverberation effect. The reverberation vibrations are taken off by the output transducer.

THE CIRCUIT

The complete circuit of the reverberation unit appears in Fig. 1. Here, the input signal is applied to either jack socket J1 or J2, it then passing via volume control VR1 and capacitor C1 to the base of the 2N4061 transistor, TR1. TR1 and its immediate base, emitter and collector components are fitted to a printed circuit board, as indicated by the dashed line which encloses them. This is identified as the "input pre-amplifier board". (Dashed line borders are used in Fig. 1 merely to show that the components enclosed appear in single units; the dashed lines are not intended to indicate the presence of a screen.)

TR1 is the input pre-amplifier transistor and its output passes via C3 and R6 to two separate sections of the "Eagle" EG2004 amplifier. The latter is a standard ready-built amplifier assembled on its own printed circuit board. In normal usage, the EG2004 amplifier would have the output of the first 2SB54



transistor coupled to the second 2SB54 transistor by way of an external volume control, this connecting to the amplifier board at its positive supply rail and at the points indicated "A" and "B" in the diagram. In the present application there is no external coupling between points "A" and "B", whereupon the EG2004 board provides a single-transistor amplifier (the first 2SB54) and a separate power amplifier (the second 2SB54 and the two output 2SB56's). Note that this alternative use of the EG2004 amplifier involves no modification to its printed a.f. circuitry whatsoever. All that is done is to make different connections to the flying leads which are already fitted for connection to an external volume control.

The EG2004 also has an auxiliary input point which couples to the collector of the first 2SB54 via a $5\mu F$ capacitor. This input circuit is not employed for the present application and is not shown in Fig. 1.

Returning to the output from TR1 it may now be seen that it passes, by way of the potentiometer given by R7 and R10, to the base circuit of the first 2SB54.

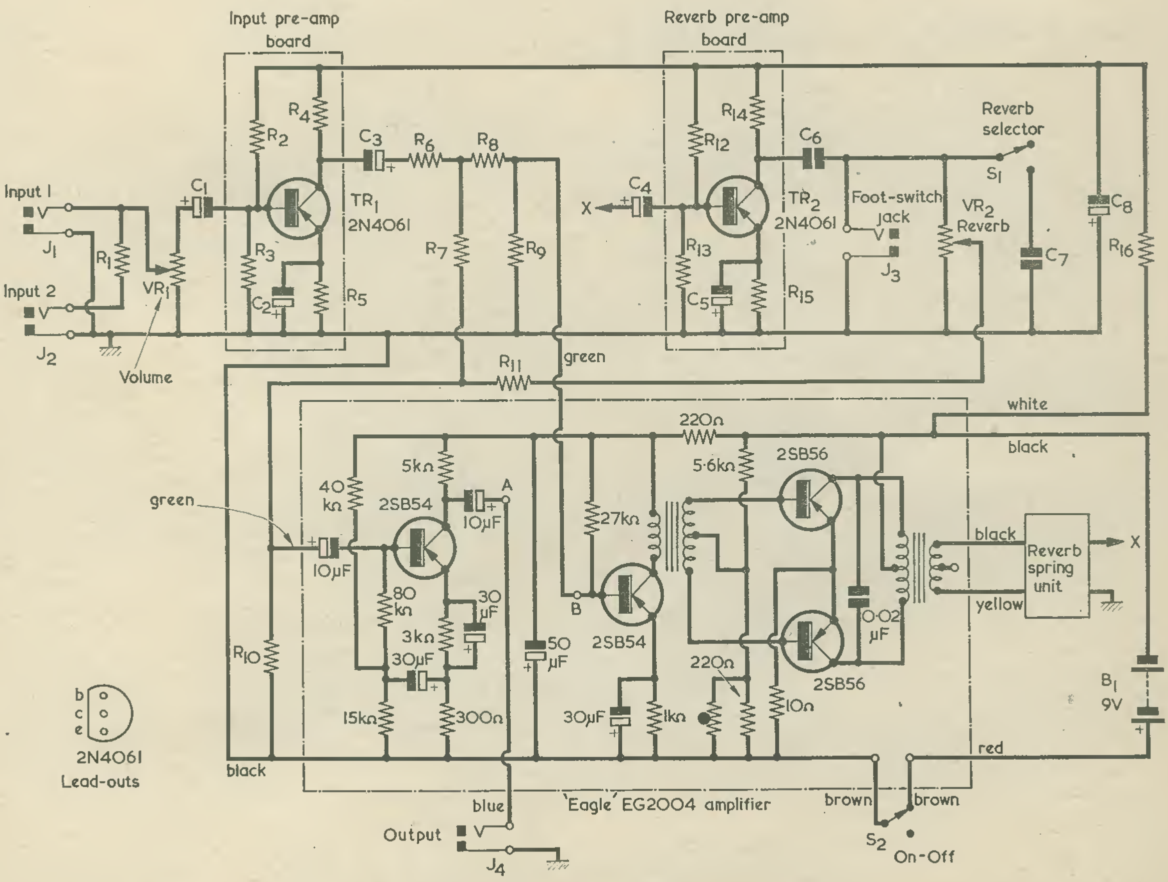


Fig. 1. The complete diagram of the reverberation unit

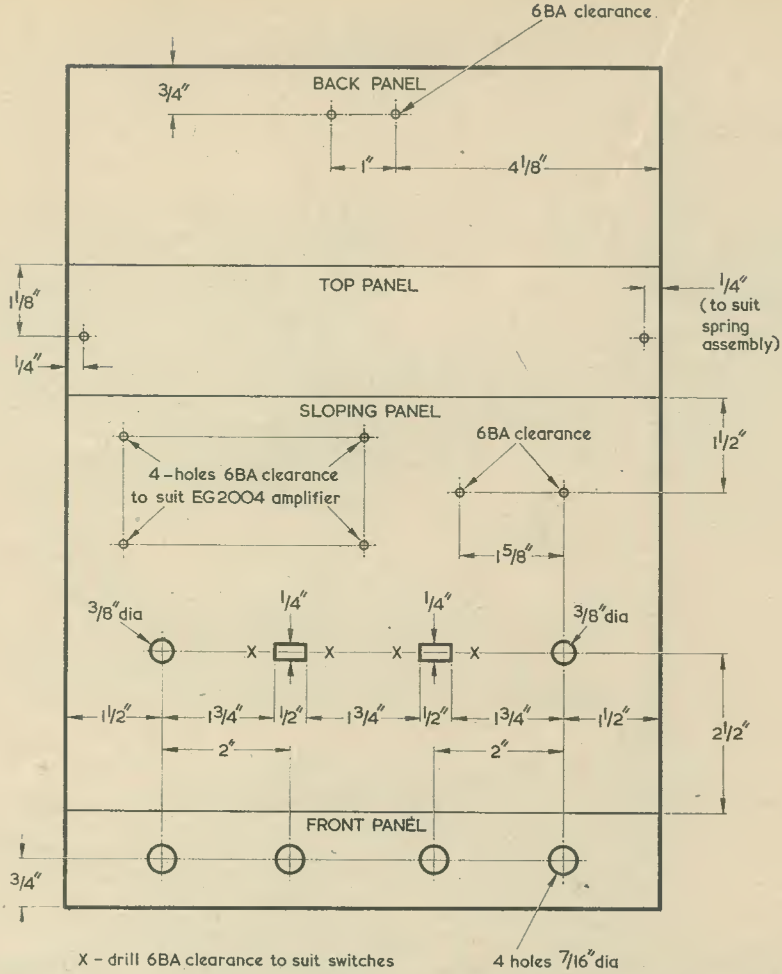


Fig. 2. The metal case is available in plain or finished versions. If the plain case is obtained it should be drilled and cut out as shown here

The amplified signal at the collector of this transistor is then passed to jack socket J4, which provides the composite output for the whole reverberation unit. At the same time the output from TR1 also passes, by way of the potentiometer formed by R8 and R9, to the base of the second 2SB54 transistor. This drives the two output 2SB56's, allowing a finally amplified signal, at 8Ω impedance, to be provided at the secondary of the EG2004 output transformer for application to the input terminals of the reverberation spring unit.

The output terminals of the reverberation spring unit connect to chassis and to C4 (the two points designated "X" are connected together). The reverberation signal is then applied to transistor TR2 which is also fitted, together with its base, emitter and collector components, to a printed circuit board. The latter is the "reverberation pre-amplifier board". The amplified signal at the collector of TR2 next passes, via C6, to the reverberation control VR2, the slider of which couples back, by way of R11, to the input circuit of the first 2SB54 transistor in the EG2004 amplifier.

The functioning of the overall circuit may now be summarised in the following manner. The input signal is amplified by TR1 and then passes through the second section of the EG2004 amplifier, the reverberation spring unit and TR2. In company with the amplified input signal at TR1 collector, the reverberation signal is then applied to the first 2SB54 of the EG2004 amplifier and thence to the output jack socket. Thus, the output consists of the input signal plus reverberation. The signal level fed into the whole system, including the reverberation spring unit, is controlled by volume control VR1. The level of the reverberation signal is controlled by VR2.

Two additional controls have yet to be dealt with. The function of selector switch S1 is to vary the reverberation effect, and it provides a lower, more rounded, tone when it switches C7 into circuit. An optional foot-switch may, if desired, be plugged into jack socket J3. When the foot-switch is closed the reverberation channel is short-circuited and the input signal appears at the output jack socket without reverberation.

As a final point, it may be noted that the input signal from jack sockets J1 and J2 passes to the slider of volume control VR1 rather than, as in the more

COMPONENTS

Resistors
(All fixed values ¼ watt 5%)

R1	33kΩ
R2	62kΩ
R3	10kΩ
R4	3.9kΩ
R5	1kΩ
R6	22kΩ
R7	22kΩ
R8	4.7kΩ
R9	1kΩ
R10	56kΩ
R11	22kΩ
R12	62kΩ
R13	10kΩ
R14	3.9kΩ
R15	1kΩ
R16	4.7kΩ
VR1	100kΩ potentiometer, linear (see text)
VR2	100kΩ potentiometer, linear (see text)

Capacitors
(Electrolytic capacitor voltage ratings are minimum figures—higher ratings may be used, if desired)

C1	10μF electrolytic, 4V wkg.
C2	125μF electrolytic, 4V wkg.
C3	10μF electrolytic, 10V wkg.
C4	10μF electrolytic, 4V wkg.
C5	125μF electrolytic, 4V wkg.
C6	0.001μF, paper or plastic foil
C7	0.022μF, paper or plastic foil
C8	125μF electrolytic, 12V wkg.

Transistors

TR1	2N4061
TR2	2N4061

Sockets
J1-J4 Jack sockets

Switches
S1 2-pole 2-way slide switch (see text)
S2 2-pole 2-way slide switch (see text)

Battery
B1 9-volt battery type PP3 (Ever Ready)

Reverberation Unit
1 Spring reverberation unit (Wilsic Electronics, Ltd.)

Printed Circuit Boards
2 Printed circuit boards (Wilsic Electronics, Ltd.)

Amplifier
1 Amplifier type EG2004 (Eagle)

Miscellaneous
1 Metal case and base plate (see text)
1 plastic insulating sheet, 8 x 1¾in. (Wilsic Electronics, Ltd.)
2 knobs
1 Battery mounting clip (Wilsic Electronics, Ltd.)
1 3-way tagstrip, centre tag earthed
1 5-way tagstrip, centre tag earthed
4 rubber feet
Wire, screws, nuts, washers, etc.

usual type of volume control circuit, to the upper end of its track (whereupon C1 would connect to the slider). This method of connecting the volume control is adopted because it has been found to accept a wider variety of signal sources and offers a smoother control of gain. It should be pointed out, however, that input signals coupled to jack socket J1 are short-circuited when VR1 is set to minimum volume, whereupon it is recommended that the outputs of amplifiers or tape recorders, etc., be plugged into jack socket J2 rather than into J1. Electric guitars may be plugged into whichever socket gives better results. Low level signals, such as those offered by microphones, should be applied to J1.

COMPONENTS

All the specialised components and assemblies may be obtained from Wilsic Electronics, Ltd., 6 Copley Road, Doncaster, these including the reverberation spring unit, the pre-amplifier printed circuit boards and the EG2004 amplifier.

The metal case is available in one of two versions. It can be purchased in undrilled form from H. L. Smith & Co., Ltd., 287 Edgware Road, London W.2, as a standard "U" type instrument case with sloping front measuring 9¼ by 7½ by 3½in. This is then drilled and cut out as shown in Fig. 2. Alternatively, it may be obtained completely punched and drilled (with the exception of eight 6BA clearance holes) and with all legends printed on the panel, from Wilsic Electronics. This is the case which appears in the cover photograph. Wilsic Electronics, it may be added, will also supply a complete kit of parts for the unit.

The eight holes just mentioned may be identified in Fig. 2, and comprise four for the EG2004 amplifier and four for the two switches. These should be marked out from the amplifier and switches themselves. There are two reasons for this course. Firstly, the hole positioning on some amplifier boards tends to vary slightly, and it is necessary to ensure that the mounting holes in the panel coincide exactly with those in the amplifier board to be used or the latter may be strained when the mounting screws are tightened. Secondly, if the switch holes are drilled by the constructor it is possible for a wider range of switch types to be incorporated. (Wilsic Electronics will drill the eight holes for readers purchasing the complete kit, if requested.)

Two tagstrips are needed in the assembly of the unit. These are 3-way and 5-way respectively, with the centre tag on both providing a mounting earth lug. The two potentiometers, VR1 and VR2, have metal cases. This is necessary because the two tagstrips are mounted by soldering their earth lugs to the backs of these potentiometers.

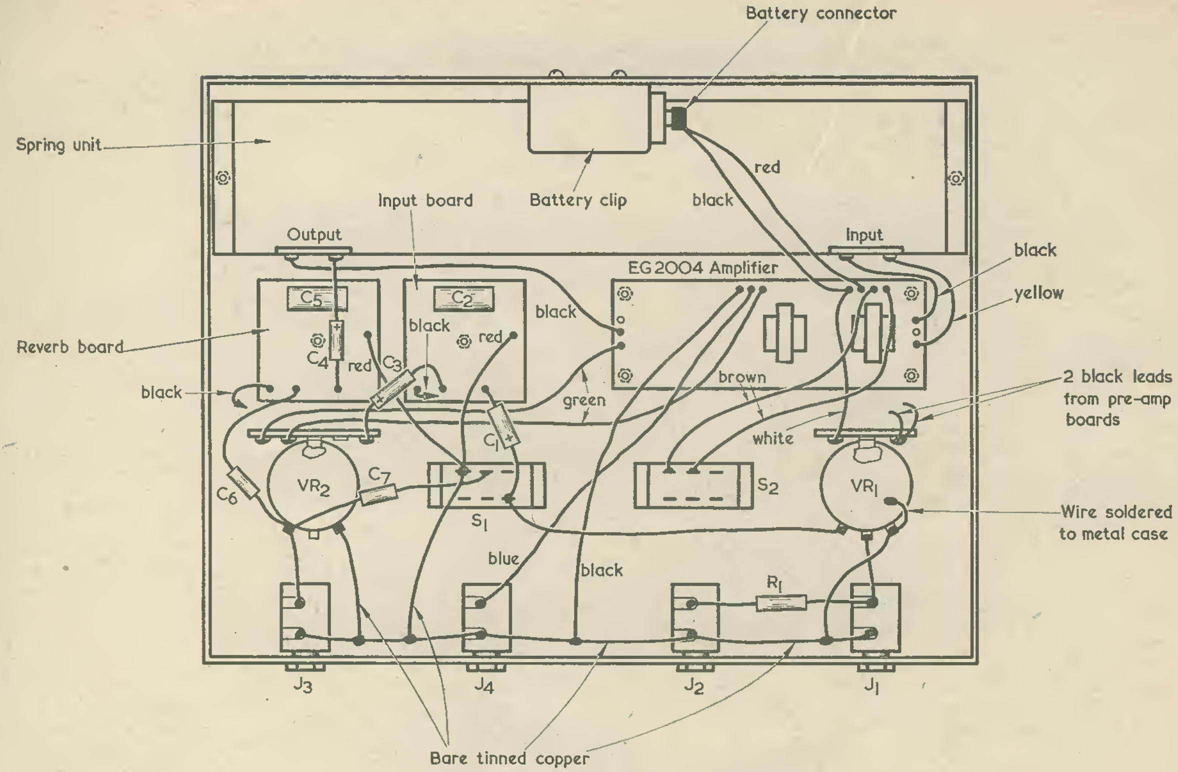


Fig. 3. Main assembly and wiring diagram

No battery connection clips are required, as these are an integral part of the EG2004 amplifier. It will be noted from Fig. 1 that the on-off switch, S2, is coupled into the EG2004 amplifier, and that the connections to this amplifier enable S2 to control the supply to the circuits external to the amplifier as well.

Although Fig. 1 shows both S1 and S2 as single-pole switches, double-pole switches are listed in the Components List. This is because no economic saving is given in practice by employing single-pole switches. Also, the use of a double-pole switch for S1 enables a spare tag on its unused pole to be employed as an anchor tag in the wiring. If the ready-drilled case is employed, the switches should preferably be obtained from Wilsic Electronics, in order to ensure that the slide slot dimensions agree.

CONSTRUCTION

The construction of the unit will next be described. For ease of reference the individual steps are numbered.

1. Commence by trimming $\frac{1}{8}$in. off each end of the reverberation spring unit base so that it will fit into the instrument case under the top panel surface in the position shown in Fig. 3. Only a very small amount of metal needs to be removed.
2. If the undrilled "U" case from H. L. Smith & Co. has been obtained, drill and cut it out to the dimensions given in Fig. 2. Should the case from Wilsic Electronics have been obtained, this is ready for use without any further metalwork apart from drilling, if necessary, the eight 6BA clearance holes mentioned earlier.
3. Using 6BA screws and nuts, fit the reverberation spring unit in the case, with its input and output terminals taking up the positions shown in Fig. 3. It will be helpful to use long screws (around $\frac{3}{4}$in.) for this operation. It should be mentioned at this stage that it is preferable that plain washers be fitted under all screw heads in this and later steps, together with shakeproof washers under the nuts.
4. Mount the two slide switches, S1 and S2, using 6BA screws and nuts.
5. Mount the four jack sockets to the front panel, with tags facing outwards away from the sloping panel underside. This is for ease of soldering later. Bush spacing washers may be fitted, as desired, on the inside of the panel.
6. After having first cut off their locating lugs, fit the two potentiometers, VR1 and VR2, so that their tags point towards the jack socket panel. See Fig. 3.
7. Thread a length of 22 s.w.g. bare tinned copper wire through the jack socket earth tags (i.e. the tags which connect to the jack plug sleeve), press down the tags to prevent them touching the baseplate when it is later fitted, and solder at all four tags. This wire forms the main earth bus bar.
8. Using bare tinned copper wire, connect together the earthy end of VR2 track (See Fig. 3) and the bus bar.
9. Using bare tinned copper wire, connect together the metal case of VR1, the earthy end of its track (see Fig. 3) and the bus bar.
10. Fit and solder R2, R3, R4, R5, C2 and TR1 to the input pre-amplifier board, as illustrated in Fig. 4(a), which shows the component side of the board. Similarly fit and solder R12, R13, R14, R15, C5 and

TR2 to the reverberation pre-amplifier board. Both boards are identical, with R2 having the same value as R12 and so on. The boards are not mounted into position yet, and further connections will later be made at the unused holes.

11. Take the Eagle EG2004 amplifier board and modify it in the following manner. First, transfer the yellow output lead to the 8Ω connection so that both yellow and black output leads are at the outside holes at the output end of the amplifier board, and are soldered to the adjacent sections of the copper print. Remove the white auxiliary input lead and reconnect it at the same circuit point as the black battery lead. The EG2004 amplifier leads should now be as shown in Fig. 5.

12. Place the white plastic sheet over the rear surface of the sloping panel where the printed circuit boards will later be mounted (see Fig. 6). This sheet provides insulation from the panel surface. Make holes in the sheet with any sharp instrument to enable mounting screws to pass through. Note, at this stage, that "spikey" solder joints or projecting wire ends on the undersides of the printed circuit boards need to be rounded over to obviate the risk of their piercing the plastic sheet.

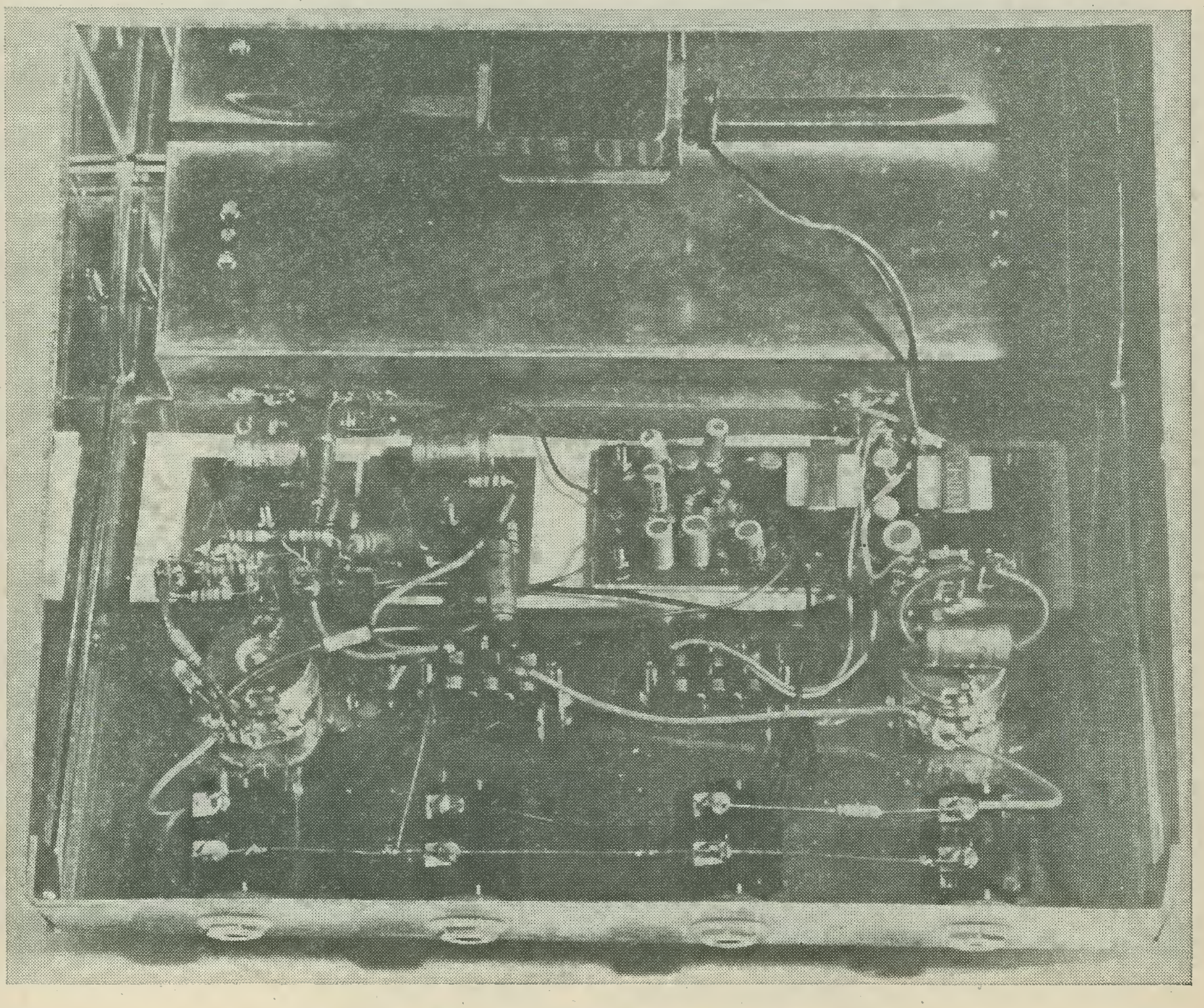
13. Using four 6BA screws and nuts, mount the EG2004 amplifier with the orientation shown in Fig. 3. Support it at each corner with a rubber washer made by cutting a grommet in half. Each of these washers passes over the 6BA screw between the plastic sheet and the copper side of the board. The washers prevent distortion of the board when the screws are tightened. Do not over-tighten the screws.

14. Following Fig. 3, connect the following leads from the EG2004 amplifier, shortening as necessary. Blue lead to the rear tag of jack socket J4, two brown leads to switch S1, and output leads (black and yellow) to the input terminals of the spring unit.

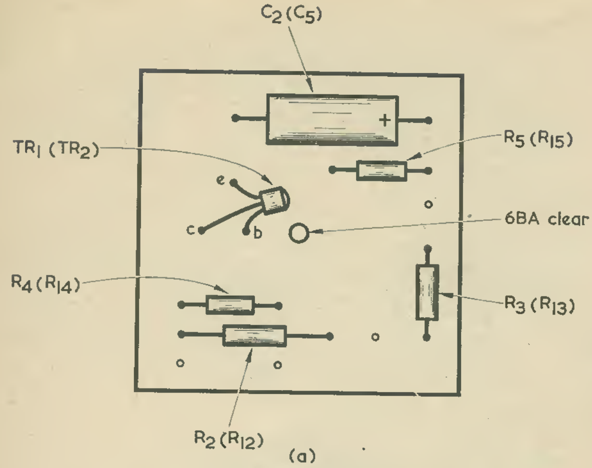
15. Solder R16 and C8 to the 3-way tagstrip, then solder the centre lug of the tagstrip to the top rear of VR1 metal case. The resultant assembly appears as shown in Fig. 7(a).

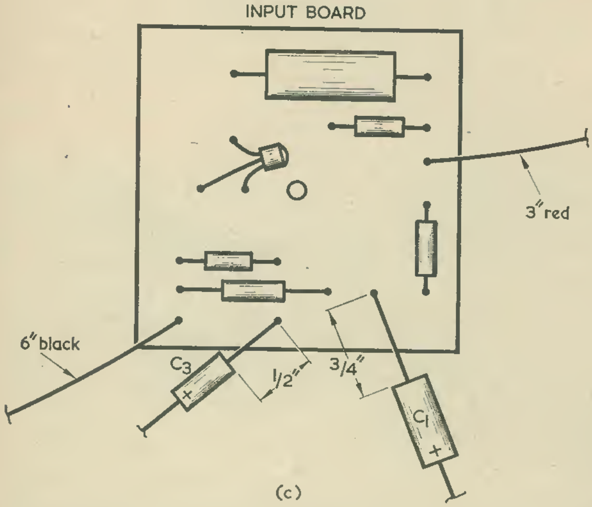
16. Returning to Fig. 3, fit R1 between J1 and J2 rear tags. Then, using flexible p.v.c. wire, connect J1 rear tag to the slider of volume control VR1. Press down the jack socket tags before soldering, to prevent them touching the baseplate when it is fitted later.

17. Also as in Fig. 3, and shortening as necessary, connect one black lead from the EG2004 amplifier to the earth bus bar. Connect the other black lead from



The internal layout of the components inside the unit





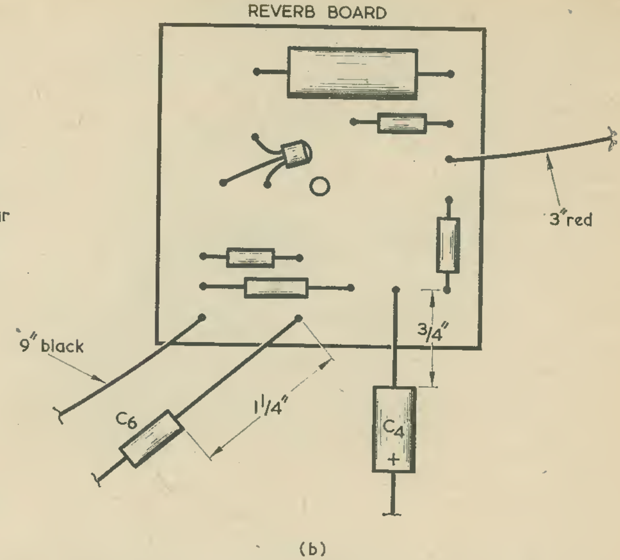


Fig. 4(a). Component side of the input pre-amplifier and reverberation pre-amplifier boards. Both boards are identical. The component references in brackets apply to the reverberation pre-amplifier board

(b). Adding external components and wiring to the reverberation pre-amplifier board

(c). The external components and wiring fitted to the input pre-amplifier board

the amplifier to the earthy output terminal of the spring unit. This is the terminal which is already connected to the spring unit case.

18. Solder the centre lug of the 5-way tagstrip to the top rear of VR2 metal case, as in Fig. 7(b). It takes up a similar position on the potentiometer case as does the 3-way tagstrip illustrated in Fig. 7(a). The components shown in Fig 7(b) are *not* fitted yet.

19. Following Fig. 3, and shortening as necessary, connect the white lead (repositioned in Step 11) from the EG2004 amplifier to the 3-way tagstrip.

20. Take up the reverberation pre-amplifier board (already partly assembled in Step 10) and, fitting sleeving over the capacitor lead-outs, connect to it one end of C6, the negative end of C4, a 3in. red p.v.c. flexible wire, and a 9in. black p.v.c. flexible wire. These connections are illustrated in Fig. 4(b). The capacitor lead-out dimensions shown in this diagram are intended merely as a guide, and need only be followed approximately.

21. Mount the reverberation pre-amplifier board, with C5 nearest the spring unit as in Fig. 3, using a single 6BA screw and nut. Fit a half-grommet for spacing, as with the EG2004 amplifier.

22. Fitting sleeving over the lead-outs, connect the positive end of C4 to the non-earthy output terminal of the spring unit, and connect the free end of C6 to the non-earthy end of VR2 track. See Fig. 3. At the same time and again fitting sleeving, connect C7 between the same tag of VR2 and the rear centre tag of S1. Also, and using flexible p.v.c. wire, connect the same tag of VR2 to the rear tag of J3.

23. Take up the input pre-amplifier board (already partly assembled in Step 10) and, fitting sleeving over the capacitor lead-outs, connect to it the negative end

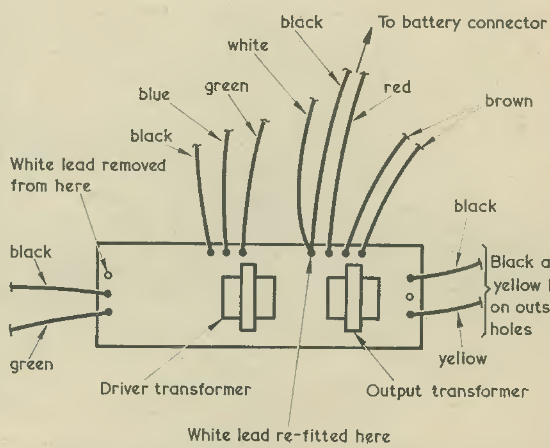


Fig. 5. The connections to the Eagle EG2004 amplifier after it has been prepared for installation in the reverberation unit

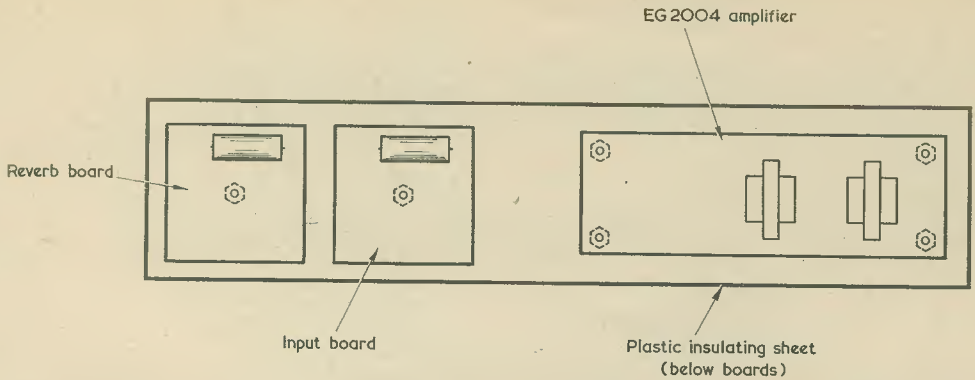


Fig. 6. The plastic insulating sheet is positioned under the boards in the manner shown here

of C1, the negative end of C3, a 3in. red p.v.c. flexible wire and a 6in. black p.v.c. flexible wire. These connections are illustrated in Fig. 4(c). The capacitor lead-out dimensions shown are merely intended as a guide and need only be followed approximately.

24. Mount the input pre-amplifier board, with C2 nearest the spring unit as shown in Fig. 3, using a single 6BA screw and nut. Fit a half-grommet for spacing, as with the previous boards.

25. Fitting sleeving over its lead-out, connect the positive end of C1 to an unused front tag of S1 as shown in Fig. 3, and run a flexible p.v.c. wire from this tag to the non-earthy end of VR1 track. The tag on S1 is used merely as an anchor point and does not enter the circuit.

26. Connect the black leads from the two pre-amplifier boards to the 3-way tagstrip, as in Fig. 3.

27. Connect the red leads from the two pre-amplifier boards to the left-hand rear tag of S1, as in Fig. 3, and connect this tag to the earth bus bar with bare tinned copper wire.

28. Fit R6, R7, R8, R9, R10 and R11 to the 5-way tagstrip and VR2, as shown in Fig. 7(b). Solder only at the three tags indicated in this diagram.

29. Shortening as necessary, and following Fig. 3 *carefully*, connect the two green leads from the EG2004 amplifier to the 5-way tagstrip. Also, connect the positive end of C3 to this tagstrip. All the unsoldered connections on the 5-way tagstrip may now be soldered.

30. Using two short 6BA screws, mount the battery clip to the back of the case.

31. Fit knobs to VR1 and VR2.

32. Check that all jack socket tags are pressed down and will clear the baseplate when this is fitted.

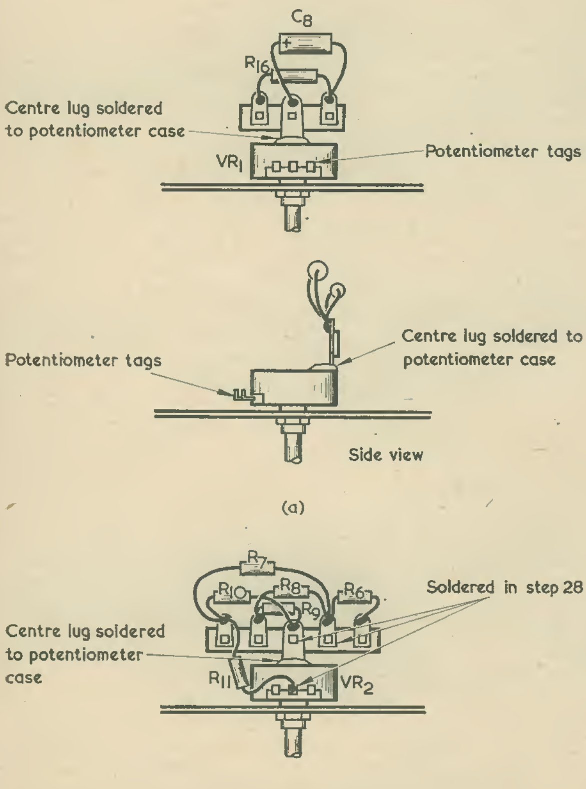


Fig. 7. Wiring and mounting details for (a) the 3-way tagstrip and (b) the 5-way tagstrip

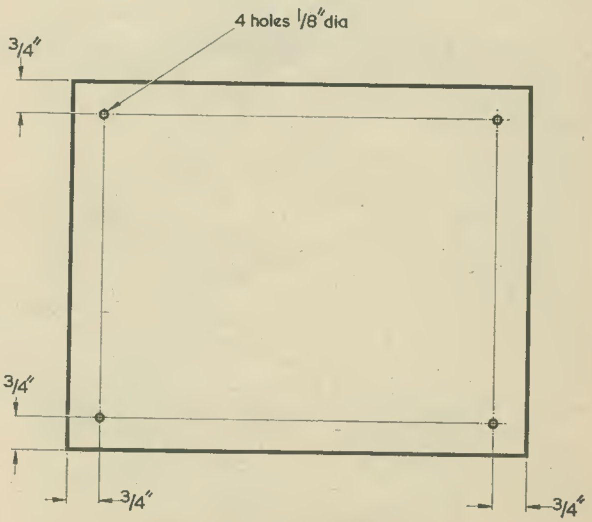


Fig. 8. Four holes are drilled in the base plate for the rubber feet

33. Drill a $\frac{1}{8}$in. hole in each corner of the base plate, as in Fig. 8. Mount four rubber feet with self-tapping screws to these holes.

34. Check all wiring for obvious faults or short-circuits, then fit the battery into its clip and the battery connector to its terminals. Fit the base plate with the aid of two self-tapping screws passed through the sides of the case.

The reverberation unit is now complete.

OPERATION

The reverberation unit may next be tested. Feed in a suitable signal, such as a microphone to jack socket J1, and connect the output from J4 to an amplifier or tape recorder. With a low level signal the volume control may be set fairly high, the reverberation then being introduced by turning the reverberation control clockwise. Actuate S1 to obtain the different reverberation modes. A little experience with the unit soon enables the user to familiarise himself with the controls.

If desired, the unit may be powered by a battery eliminator, such as the Eagle LA9P. In this case, a mains hum may be apparent, whereupon it is necessary to add extra bypass capacitance across the supply rails. Two 250μF electrolytic capacitors are sufficient and they may be wired to the 3-way tagstrip. Their negative lead-outs connect to the ends of R16 and their positive lead-outs to the centre tag.

When mains powered, the EG2004 amplifier may tend to overload. This effect can easily be overcome by removing R8 and R9 from the 5-way tagstrip, and fitting a 10kΩ skeleton preset potentiometer between the centre earthed tag and the junction of R7 and R6. Connect the slider of the potentiometer to the green lead from the EG2004 amplifier which previously connected to the junction of R8 and R9. Adjust the potentiometer so that the input to the amplifier is sufficiently reduced for the distortion to clear.

If the unit, either mains or battery powered, is fed with high level signals such as those from radio tuners, etc., use input jack J2 and reduce the volume control setting if distortion of the reverberation signal occurs. ■

EXHIBITION OF ELECTRONIC COMPONENTS — PARIS 1969

(continued from page 771)

fluidics. Among their range integrated circuits was the ML 150 series of analogue switches including matched combinations of 6 p-channel enhancement mode MOS transistors. MOS driver circuits and MOS shift registers were also shown. The Plessey microswitch units featured three new products. Plessey also exhibited wound components for colour and monochrome TV sets, scanning assemblies for professional and industrial use and a range of centrifugal type switches and solenoids.

A display of the tubes exhibited by English Electric Valve Company

A. B. Electronic Components, Ltd., of Glamorgan, exhibited potentiometers, rotary switches, connectors and microcircuits, all of these being new. *Adcola* exhibited their "R" series of soldering irons, which have angled heads to allow good visibility of the work and precise control of the bit. *G. T. Schjeldahl Company*, of Bracknell, Berkshire, exhibited a range of laminates consisting of various weights of copper on substrates of polyester, glass epoxy and polyomide. Also on display was a do-it-yourself kit for producing flexible printed circuits.

Ferranti exhibits included their Micro-E microminiature diodes and n.p.n./p.n.p. plastic encapsulated transistors for use on both thin and thick film circuits. A new deflection coil on show had a 47 mm minimum bore that permits the magnetic axis to be aligned with the tube's electron beam axis and is for use with any high-resolution system. *Marconi-Elliott* exhibited their ranges of integrated circuits whilst *AEI Semiconductors* had three working displays and a range of their discrete semiconductor devices on display. The Valve Division of *EMI Electronics* was showing a wide range of special valves and tubes which included the recently introduced $\frac{1}{2}$in. and 1in. all-electrostatic vidicons, together with a selection of photo-multiplier and cathode ray tubes. New products on show for the first time included a 3-stage magnetically focussed image intensifier, a miniature 13 mm diameter all-electrostatic vidicon camera tube and the Prinlicon all-electrostatic monoscope tube for the generation of alphanumeric characters for data display units. Another feature consisted of two solid-state radiation detectors.

Multicore Solders were at Paris again this year and exhibited their range of products including Ersin Multicore solder and Extrusol—the latter being the first oxide-free high-purity extruded solder intended specifically for printed circuit soldering machines.

Electrolube displayed their electrical contact lubricants and freezer, and *Venner Electronics* displayed for the first time their new 12.5MHz frequency counter/timer TSA 6635. This piece of equipment makes extensive use of both printed circuit boards and microcircuits, and is basically a 5-digit counter that can measure from d.c. to 12.5MHz. *Marconi Instruments* exhibited two high-performance digital voltmeters and a low-cost double-pulse generator. *Dynamco* showed a new model in their range of digital voltmeters and an oscilloscope that is said to be the smallest solid-state oscilloscope of its kind with a 15MHz bandwidth. It is priced at £355 or, if you prefer it in dollars, $930. Eight *ITT* components and instrument organisations came together on a single stand and showed components, sub-assemblies and instruments from their 38 factories in Europe in addition to some specialised components from their American plants. Exhibits included rectifiers, electron tubes, thermistors, switches and piezoelectric elements.

BSR Limited exhibited their full range of record changers including the C109 with tubular arm, and the C110. The C109 replaces the UA25 and has a 4-speed changer. Type C110 is a 4-speed changer featuring a polished aluminium pickup arm with a cartridge shell accepting mono or stereo cartridges and incorporating a finger lift. Other models on display included the MA65, MA70 and MA75 record changers.

■

NEW U.H.F. TRANSMITTER FOR LONDON

Two very high powered u.h.f. television transmitting systems were recently installed in London by The Marconi Company, a member of GEC-Marconi Electronics Limited, to put BBC-1 on the air in colour, and also to improve the reception of BBC-2. The equipment will feed two separate 80 kilowatt television signals and associated sound signals to a single aerial at Crystal Palace. These transmitters will provide both BBC-1 and BBC-2 colour signals for the London area.

The Marconi equipment is worth nearly £¼ million, one of the largest orders ever placed for equipment at a single u.h.f. television transmitter station. Four 40 kilowatt transmitters with associated sound transmitters will be employed in groups of two, operating in parallel, to give two 80 kilowatt vision signal outputs. Marconi engineers are carrying out the installation. The existing pair of Marconi 25 kilowatt transmitters will be moved to Divis, to put BBC-1 on u.h.f. in Northern Ireland.

At Crystal Palace, existing buildings have been extended to accommodate the new 40 kW transmitters. For this power these are among the smallest ever designed, and can be accommodated in a working area of 730 square feet. Already Marconi have supplied, or hold orders for, 29 u.h.f. transmitters for the BBC, eight of which are duplicated equipments operated in parallel.

These very powerful transmitters are among the most advanced ever designed for television operation. All of the video, sound and radio frequency circuitry is solid-state, apart from the massive vapour-cooled output klystrons, made by the English Electric Valve Company, and an intermediate valve amplifier. In addition, a unique diode modulation system produces the highest quality linear modulation – an essential for colour operation.

FUNCTION-CODE FOR SGS INTEGRATED CIRCUITS

In order to make device designations more descriptive, SGS (United Kingdom) Ltd. revised the coding system for its professional range of integrated circuits. The change, which took effect from 1st April, 1969, applies to all devices except certain long-established circuits.

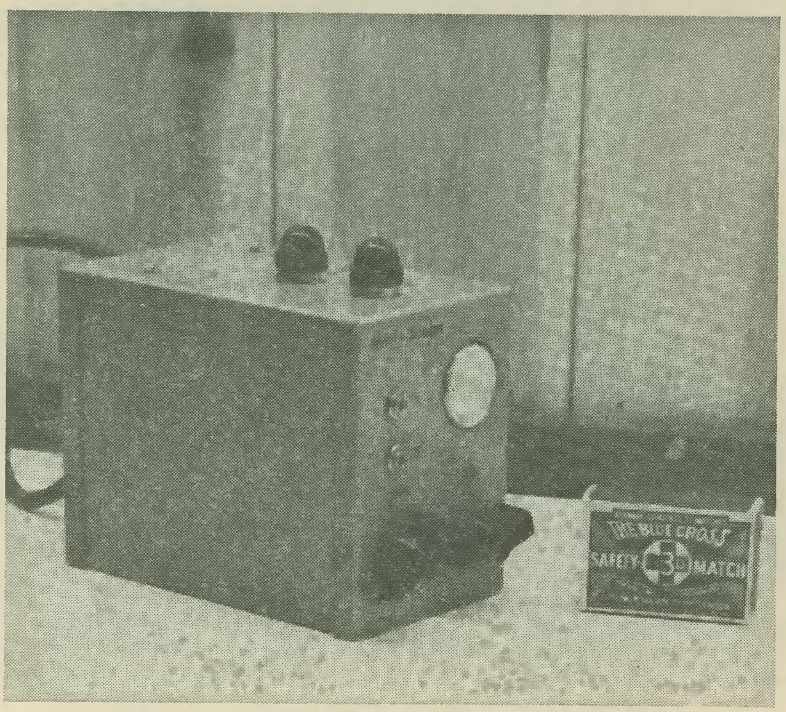
The new code is fundamentally a four-character system, consisting of a letter and three digits, which readily indicates the basic identifying information: device family and function. The letter indicates the family; the three digits the function.

Supplementary information, comprising type of package, temperature range and any possible performance variation, is shown by additional single-character suffixes: a letter for type of package; a figure for temperature range; and, where necessary, a final letter for performance variation.

Thus variants of a device keep the same type indication and their differences are indicated by a maximum of only three suffixes.

Exceptions to the new coding system are the 930 series DTL, 900 series RTL, and Counting Logic, plus the linear circuits μA702, 709, 710 and 711. All other devices have been re-coded and their associate data sheets are being revised and reprinted.

RADIO CONSTRUCTOR — Next Month



THE MINISCOPE

This small instrument, 3in. x 4in. x 5in., is fitted with a 1-inch c.r.t. and enables traces to be examined in the alignment and repair of radio receivers and amplifiers. The small size has been achieved by the omission of some of the circuits normally associated with oscilloscopes and by the inclusion of an extremely simple timebase. The Y amplifier has a response from 5Hz to 150kHz ± 3dB, the useful response including 465kHz. 2V peak-to-peak input at 0dB attenuation fills the screen from top to bottom. The timebase generator provides sweeps from 30Hz to 150Hz. There is also an X input for examination of Lissajous figures.

ALSO

★ TRANSISTOR AMPLIFIER FOR BATTERY OR MAINS

This high-efficiency low-distortion transformerless audio amplifier can be used either as a 2-watt battery-operated circuit with low standby current running from an 18-volt supply, or as a 4-watt mains amplifier operated from a 24-volt supply. For many purposes it is suitable for use without a pre-amplifier.

★ THE KANGAROO RADIOGRAM

This ingenious design consists of a record player and a medium and long wave receiver combined in a single cabinet. The receiver section may be removed, if desired, and operated on its own as a completely separate portable receiver.

ON SALE AUGUST 1st

UNDERSTANDING RADIO

CRYSTAL FILTERS

by W. G. Morley

QUARTZ CRYSTAL FUNDAMENTALS

In last month's issue we completed our discussion of the beat frequency oscillator. We then turned to the question of i.f. selectivity in communications receivers, and pointed out that a number of circuit devices are employed in such receivers to provide a level of selectivity which is greater than can be achieved with i.f. transformer tuned circuits on their own. In the small amount of space available, brief details were then given of a very simple a.f. filter. This consisted of a tuned circuit resonant at an audio frequency and was intended for connection between any two a.f. amplifying stages. It caused greatest amplification to be given to detected a.f. signals at its resonant frequency and could therefore be employed, during reception of a c.w. signal, to reduce the amplitude of interfering c.w. signals having frequencies close to that of the desired signal.

We next turn our attention to more sophisticated circuit devices, one of the most important of these being the crystal i.f. filter. However, we have not yet introduced crystals (of the type that are employed for filters) in this series of articles, and it is essential to understand how these work before we can appreciate the functioning of the crystal filter. In consequence, this month's article must be devoted to the fundamentals of crystal operation, after which we shall see, in next month's issue, how the crystal is employed for improving receiver selectivity.

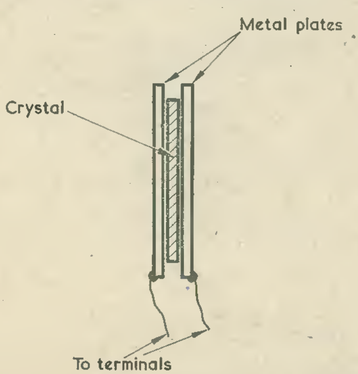


Fig. 1. A commonly employed type of crystal assembly

PIEZOELECTRICITY

Certain crystalline substances, such as Rochelle salt and natural quartz, exhibit what is described as the *piezoelectric effect*.[1] If pressure is applied in certain directions to a piece of piezoelectric material, opposite electric charges appear on opposite surfaces of the material. Should these surfaces be connected together by a high impedance external circuit, a current will then flow in that circuit.

A simple way of explaining this phenomenon is to initially look upon the basic crystal structure as consisting of ions which are formed up in the characteristic lattice pattern for the particular crystalline material. Each ion has either a positive or a negative charge and, when the crystal is in its normal unstressed state, the positive and negative ions cancel each other out, whereupon the total structure is electrically neutral. In a piezoelectric crystal, the ions can be displaced along some of the lattice axes more readily than along others. Thus, if external pressure is applied to a piece of piezoelectric crystalline material in the requisite direction, the resultant displacement of ions results in a condition of unbalance, with an excess of negative ions appearing at one

1. The first part of the term "piezoelectric" derives from the Greek **piezein**, "to press".

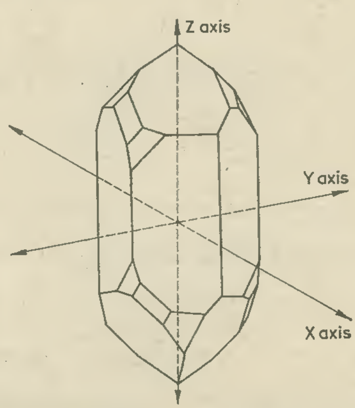


Fig. 2 A crystal of quartz, illustrating the X, Y and Z axes

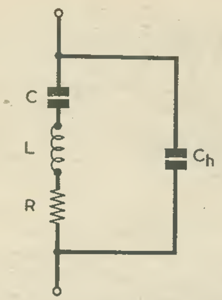


Fig. 3. The equivalent electrical circuit for a crystal

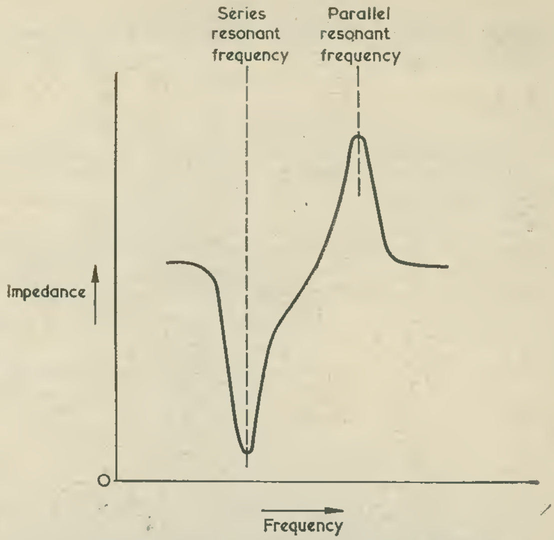


Fig. 4. This curve illustrates the changes in impedance presented by a crystal at the series resonant and parallel resonant frequencies

surface and an excess of positive ions at the opposite surface.

The reverse process also takes place. If an e.m.f. is applied to the two surfaces of the piece of material it changes shape. This change of shape is due to repositioning of ions in the crystalline structure in order to counteract the effect of the applied e.m.f.

Both of these effects are widely exploited in electronic devices. For instance, crystal microphones and crystal gramophone pick-ups take advantage of the first effect by changing mechanical energy (the physical movement of the microphone diaphragm or pick-up stylus) to corresponding electrical energy. Conversely, crystal earphones and crystal loudspeakers convert electrical energy to sound energy.

Like other hard substances, crystals exhibit mechanical resonances, and it is this property which is of interest to us in our present discussion. It is possible to cut slices from a crystal of piezoelectric material which are so dimensioned that they exhibit mechanical resonance at frequencies in the r.f. range. Since the frequency of mechanical resonance is dependent upon the physical dimensions of each slice so obtained, it follows that the stability of that frequency will be exceptionally high. This point is put to use in practice by employing crystal slices to control the frequency of transmitters and other equipment where it is important that a high degree of frequency stability is maintained.

The faces of the crystal slice are parallel and, in one form of assembly, the slice is positioned between two flat metal plates in the manner shown in Fig. 1. The plates connect to an external circuit which activates the slice. In some versions of this assembly, a very small air gap is allowed to exist between the plates and the slice. Alternatively the electrodes may consist of metal films (frequently gold) deposited on the faces of the slice. Here, connection is made to the metallising by thin wires at nodal points (i.e. at points where there is minimum mechanical vibration of the crystal slice). The crystal slice and its electrodes, either plates or metallising, are then mounted in an insulated housing having external terminals, the latter usually consisting of pins which enable the assembly to be plugged into a suitable socket. Housings encountered in practice range from simple bakelite containers to evacuated glass envelopes (the latter being used for crystal slices with metallised electrodes only). In electronic work the assembly of crystal slice, electrodes and container is referred to as a "crystal". The electrodes and the housing form the "crystal holder".

Crystals of the type which we have just discussed employ slices cut from natural mined quartz. They are then ground to the dimensions which correspond to the specific resonance frequencies required. The other piezoelectric materials, notably Rochelle salt, appear in the crystal microphones, pick-ups, earphones and loudspeakers mentioned earlier.

A quartz crystal, when properly formed, has a six-sided body with sundry facets at points where one surface changes to another. The piezoelectric effect of a slice taken from the crystal varies to some extent according to the plane in the crystal at which the slice is cut. The crystal is stated to have three axes; one, the Z axis, passing through its length, and the two remaining axes, the X and Y axes, passing through its body. See Fig. 2. The X and Y axes are at right angles to the Z axis. The presence of the three axes enables the plane of slices cut from the crystal to be precisely defined. Two fairly commonly encountered planes of cut are the X cut and the Y cut, these terms applying to slices whose surfaces are perpendicular to the X and Y axes respectively. More recently introduced crystal cuts include the AT cut, the BT cut and the GT cut. These are cuts whose planes have a specifically defined angular relationship with respect to the X, Y and Z axes, and they offer a better performance than do the X and Y cuts in terms of frequency stability with change in temperature.

The resonant frequency of a crystal slice increases as the thickness of the slice decreases. The maximum frequency of a crystal is, in consequence, limited by the thinness to which the slice can be ground before it becomes too fragile to be used. The frequency/thickness relationship varies with different cuts, with the result that some cuts can operate at higher frequencies than others.

Before concluding on this particular subject it should be mentioned that, for operation at frequencies below some 500kc/s, a crystal bar is frequently employed instead of a slice. The principle of operation is the same as for the slice and the bar is mounted between two metal plates, or has metallising applied to form the electrodes.

EQUIVALENT CIRCUIT

The equivalent electrical circuit for a crystal (i.e. a crystal slice mounted in a holder) is shown in Fig. 3. As may be seen, the circuit comprises an inductor L, in series with a resistor R and a capacitor C, together with a second capacitor, Ch, across the three. The inductor L and capacitor C represent the electrical analogy for the mechanical resonant behaviour of the crystal slice on its own, and resistor R represents the resistance of the slice to vibration. Capacitor Ch is the capacitance between the two plates of the holder between which the crystal slice is positioned.

A crystal has two resonant frequencies, and this point may be explained by referring to Fig. 3. The lower is the series resonant frequency and is given by L and C operating as a series tuned circuit. At the series resonant frequency the only impedance offered by the crystal is that due to R which can, typically, be of the order of 1kΩ to 2 kΩ. The other resonant frequency is the parallel resonant frequency and is given by the combination of L and C in parallel with Ch. Since, in this second case, the actual capacitance across L is now C in series with Ch, and since this must obviously be smaller than C on its own, the parallel resonant frequency is higher than the series resonant frequency. The difference between the two frequencies is small and, for a typical practical crystal, can be less than 0.1% of the series or parallel resonant frequency. The series resonant frequency is fixed by the dimensions of the crystal slice and cannot be altered. On the other hand, the parallel resonant frequency can be adjusted over a very small range by connecting external capacitance across Ch.

A curve illustrating crystal performance at the two resonant frequencies appears in Fig. 4. Initially, a pronounced dip in the curve illustrates the very sharp fall in impedance presented by the crystal at the series resonant frequency. There is, then, a similarly sharp rise in impedance at the parallel resonant frequency. Both the dip and the peak are extremely pronounced and correspond to a very high value of Q in the equivalent tuned circuit of Fig. 3. Indeed, the performance of a crystal in this respect is comparable with that of a tuned circuit having a Q one hundred or more times greater than can be achieved with the most efficient of physical inductors and capacitors.

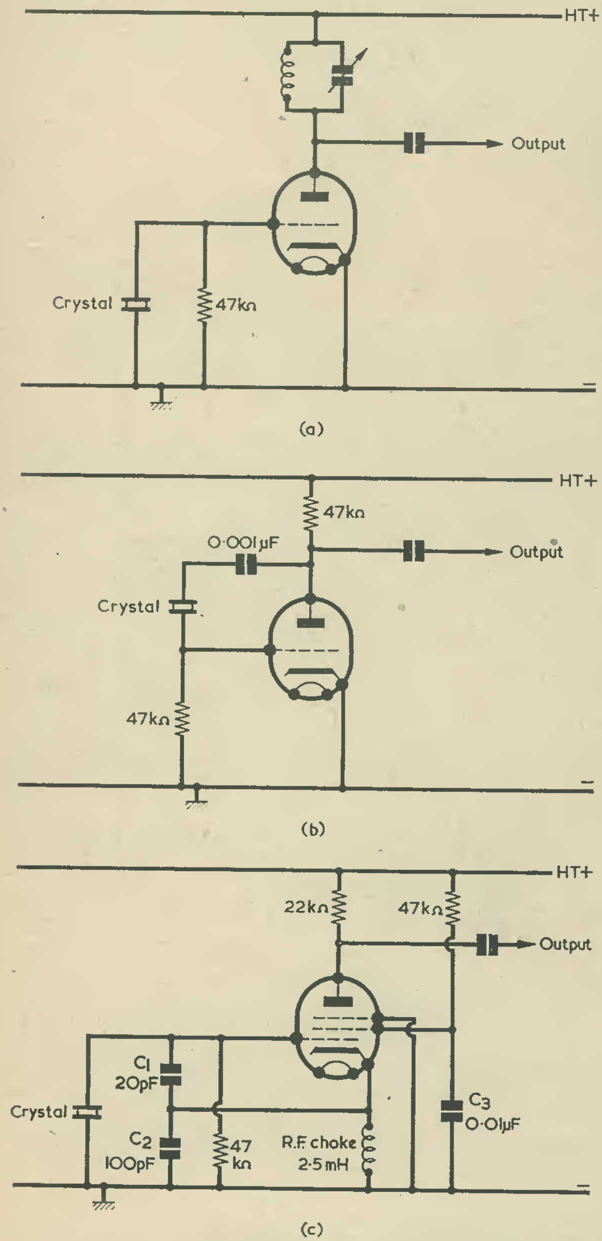


Fig. 5. Three commonly encountered crystal controlled oscillator circuits, with representative component values where these are of importance in circuit operation. The oscillator in (a) is basically a tuned anode-tuned grid type, whilst those in (b) and (c) are derived from the Colpitts oscillator

CRYSTAL CONTROLLED OSCILLATORS

A crystal provides an excellent means of controlling the frequency of an oscillator. For this application it is used at its parallel resonant frequency, whereupon it may be looked upon as though it were a parallel tuned circuit. A typical application is given in Fig. 5(a), in which the crystal appears in the grid circuit of what is basically a tuned anode-tuned grid oscillator. Feedback from the anode circuit to the grid circuit is by way of the internal capacitance between these two electrodes in the valve. The nominal resonant frequency of the anode tuned circuit is the same as that of the crystal.[2]

Another circuit is shown in Fig. 5(b), this being commonly referred to as the "Pierce oscillator" circuit. The circuit is based on the conventional Colpitts oscillator, in which the anode and grid couple to opposite ends of a parallel tuned circuit with a

2. Actually, the anode tuned circuit is made resonant at a frequency slightly higher than crystal frequency, this being necessary in order that the correct phase relationship for feedback can be obtained. The frequency of oscillation is still, nevertheless, controlled by the crystal.

cathode "tap" into the tuned circuit capacitance. Here, the crystal takes the place of the parallel tuned circuit, the requisite capacitances to cathode being given by the inter-electrode capacitances in the valve plus stray wiring capacitances. (The 0.001μF capacitor in series with the crystal is included for isolating purposes only, and has no effect on the r.f. operation of the circuit.) The oscillator of Fig. 5(b) has the advantage that no tuned circuit has to be set up; it is merely necessary to plug in the crystal whereupon the circuit oscillates at its parallel resonant frequency.

Another Colpitts circuit is shown in Fig. 5(c). This time there are two physical capacitors, C1 and C2, to provide the cathode "tap". The screen-grid of the valve functions as an anode and is coupled to chassis via C3 which has negligible reactance at radio frequencies. In consequence, the screen-grid (acting as an anode) couples to one terminal of the crystal whilst the control grid couples to the other, as is required of a Colpitts oscillator. The oscillator output is taken from the anode. A resistor appears in the anode circuit in Fig. 5(c), but a parallel tuned circuit resonant at crystal frequency could also be used. The circuit of Fig. 5(c) has the advantage that harmonics of crystal frequency appear at the anode at good strength, and this feature is of advantage in many applications. If a particular harmonic is required, the parallel tuned circuit in the anode circuit could be tuned to that harmonic.

In Figs. 5(a) and (b) a small variable capacitor with a maximum value of some 50pF or so may be connected across the crystal to provide frequency variation over a limited range. In Fig. 5(c) C1 may be made variable to provide a similar type of control. None of the circuits requires a series grid capacitor, as the function of this component is carried out by the internal capacitance in the crystal. In all these oscillator circuits it is important that the oscillations produced be at a relatively low power. If the amplitude of crystal oscillation is too high the crystal slice may suffer excessive rise in temperature or may even shatter due to its internal vibration.

NEXT MONTH

In next month's issue we shall return to the i.f. stages of the superhet and see how crystal filters may be employed to increase their selectivity.

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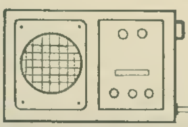


In your work-shop

Probably the only feline quality in Smithy's assistant, Dick, is his curiosity, but he tends to exhibit that characteristic at an exceptionally advanced level. In last month's episode, Smithy aroused Dick's curiosity to an almost intolerable degree by referring, without explanation, to circular oscilloscope traces, and the Serviceman now takes advantage of a convenient lunch-break to explain just exactly how such traces are formed

"I" INTONED DICK BITTERLY, "am rapidly entering the lists of the broken men."

Daintily, Smithy flicked a shred of sardine from his overall jacket then continued to munch at his lunch-time sandwiches.

"And," accused Dick, "it's all *your* fault."

The Serviceman's Adam's apple ascended and descended, covering an alarmingly extended distance, as he swallowed a prodigious mouthful of bread, butter and sardine. Hastily, he grabbed his tin mug and took an enormous draught of its contents in order to speed the masticated mass on its way.

"Watching you eat," commented Dick dispassionately, "is enough to put any normal person off food for the rest of his life."

"Then don't," returned Smithy irritably, "keep on looking at me. In any case, what's all this moaning about your being a broken man?"

"It's a result," explained Dick, "of what you told me at the end of the last gen-session we had together."

THE MAGIC CIRCLE

"Oh yes," remarked Smithy vaguely, as he picked up the final sandwich from the package on his bench, "and what was that?"

"If you remember," said Dick, "we were talking about using an oscilloscope without the usual horizontal timebase. Instead, the input signals are applied directly to the X and Y deflector plates of its c.r.t., or to those plates by way of suitable X and Y amplifiers. At that time, you showed me that if two sine waves of equal frequency and amplitude, and exactly in phase with each other, are fed to the X and Y plates respectively, the resultant trace is a straight line running from top right to bottom left. Also, that if the two signals are exactly 180° out of phase the straight line runs from top left to bottom right."

"I remember that now," replied Smithy. "Incidentally, Dick, you should also mention that the lines run in the directions you've just stated when the input signals are applied so that the right hand X plate corresponds to the top Y plate. Now let me think back a bit more. Ah yes, I also recall that I demonstrated that, if the signal applied to the Y plates has greater amplitude than that applied to the X plates, the resulting line has an angle to the horizontal of greater than 45°. And, further, that if the amplitude of the signal applied to the X plates was greater, the line had an angle to the horizontal of less than 45°."

Smithy chewed ruminatively at his sandwich.

"All this," he resumed "assumes, of course, that the deflector plates all have equal deflection sensitivities. When you're dealing with traces like this from the theoretical point of view, it's always helpful to make that assumption at the start. In practice it will usually be necessary to insert one or more attenuators between the input signals and the deflector plates to get what is effectively the same thing."

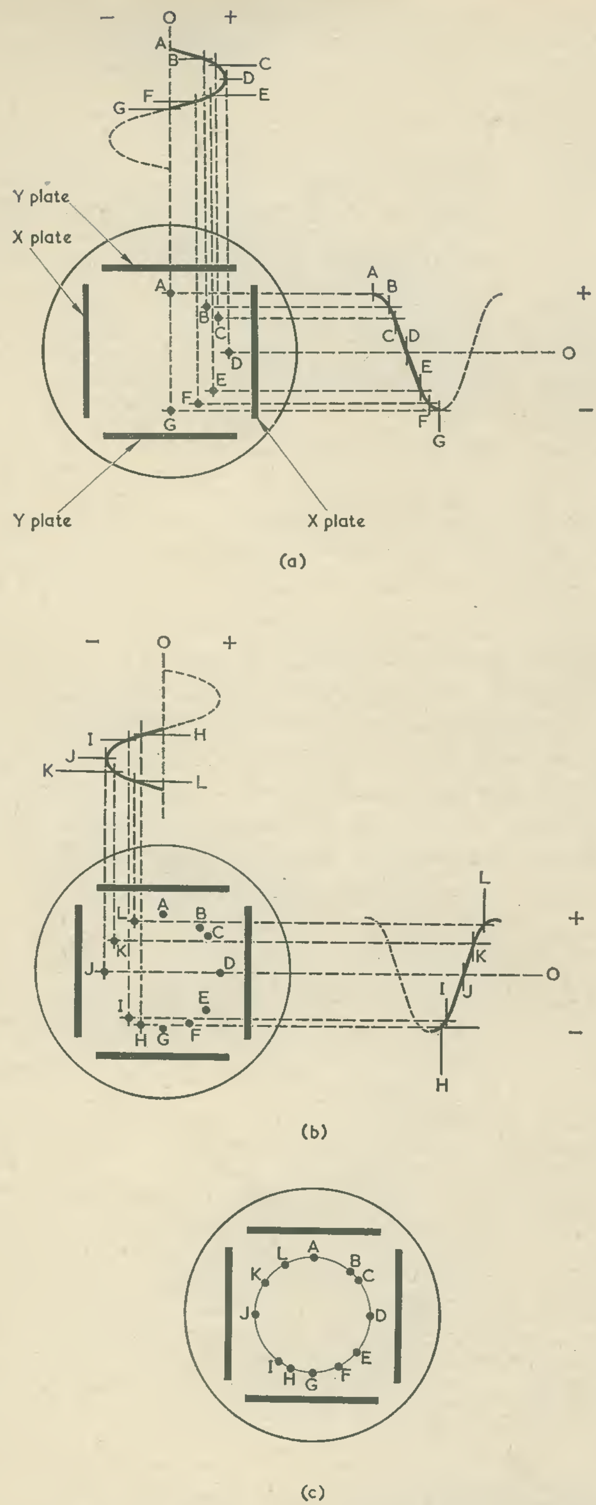


Fig. 1(a). Plotting corresponding points along two sine waves 90° out of phase, in order to determine the resultant display produced on a c.r.t. screen
(b). Completing the process over the second half-cycle of the waveforms
(c). The points in the c.r.t. screen trace out a circle

"Right," said Dick briskly. "Now, let's get down to what's been worrying me ever since. After we'd dealt with signals which are in phase and with signals having a phase difference of 180°, I next asked you what happened when the signals were out of phase by 90°. Whereupon you came out with what, to my mind, is the quite incredible pronouncement that the oscilloscope tube displays a circle!"

"Which," pronounced Smithy, "is completely true. Indeed, if the X and Y deflection fields are exactly at right angles to each other, the trace given by the two 90° signals is a *perfect* circle."

Dick cast a tormented glance at the Serviceman.

"I just," he wailed despairingly, "don't get it. Ever since you made that statement I've been racking my brains to see how on earth you can get a trace which consists of a *circle*. I've been puzzling my head over it in bed, even. Dash it all, Smithy, I've started having *nightmares* about that flaming circle!"

"It looks," chuckled Smithy, "as though I'd better put you out of your misery and show you how that circle really *is* produced. Incidentally, this should be an interesting exercise because it will enable you to pick up a bit of basic gen concerning sine waves as well. If, therefore you'll be good enough to get me a spot more tea, I'll proceed to raise the veil from that circular oscilloscope trace."

Eagerly, Dick took Smithy's mug to the Workshop teapot for replenishment. At the same time, the Serviceman gulped down the last of his sandwich, then pulled his note-pad towards him and started to sketch out a diagram on it.

"Well now," said Smithy, after Dick had returned and settled down alongside him. "I'll follow the same procedure as I did last time, and I'll draw the X input sine wave above the tube screen and the Y input sine wave on the right. Don't forget that both these sine waves are at the same frequency and have equal amplitude. Then, I'll next take corresponding points along the sine waves and draw vertical or horizontal lines from them into the tube screen, whereupon the point at which each set of lines crosses gives the position of the resultant spot on the c.r.t. screen. Okay?"

"Definitely," said Dick warmly. "I'm just *dying* to get to grips with this circular trace mystery!"

"Fair enough," replied Smithy. "The first point I'll choose on both sine waves is at A. (Fig. 1(a)). On the top sine wave this occurs at the point where the waveform is just going through zero volts. We'll assume that the right hand sine wave is leading, with a phase difference of 90°, whereupon the corresponding point A appears at its positive peak. If we draw lines into the tube screen we will then find that the resultant spot A on the screen is in the middle horizontally, and is as high as it can go vertically. We'll follow this with points B, C and D in order, putting D at the positive peak of the top sine wave. The corresponding point D on the right hand sine wave is at the point where the waveform passes through zero voltage. Points B and C are the same distance along both waveforms, as measured along the zero voltage lines."

Gravely, Smithy drew in the points he had referred to.

"I'll carry on," he continued, "through three more points, these being E, F and G. G is at the point in the top sine wave where it passes through zero voltage and, because of the 90° phase difference, it is at the negative peak of the right hand sine wave. There we are—that's got all the points from A to G drawn in. Now, what do you think of that?"

Smithy turned and beamed at his assistant. That worthy looked at Smithy's sketch suspiciously.

"Well?" queried Smithy.

"So far as I can see," complained Dick, "all you've obtained is a series of dots on the screen which go out to the right and then come back in again. What do they prove?"

"That series of dots," returned Smithy irately, "traces out a semi-circle."

"Does it?" said Dick, in a tone which betrayed an utter lack of conviction. "I thought you were going to show me how to get the complete circle."

"Very well, then," snorted Smithy. "If you're not going to be satisfied with half a circle I'll give you a full darned circle! The series of dots we've already produced represents the half circle resulting from a half-cycle of the two sine waves. I'll now continue the process by plotting a second set of dots for the next half-cycle, and I'll call these H, I, J, K and L. Notice, incidentally, that point J is at the negative peak for the top sine wave and is therefore at zero voltage for the right hand sine wave."

Smithy's ruler clattered once more over his note-pad as he plotted the new set of points for the second half-cycle. (Fig. 1(b)). When these were finished he triumphantly drew a circle through them. (Fig. 1c)).

"Are you," he queried, "satisfied *now*?"

"I'll agree," said Dick reluctantly, "that what you've just done is very impressive and that the resulting trace certainly has the *appearance* of a circle. But how can you be certain that it's a *true* circle?"

"It's bound to be," retorted Smithy heatedly. "You've got two sine waves displaced in phase by 90° and they're applied to two sets of deflector plates positioned physically at right angles to each other. The result *must* be a true circle."

"*Why* must it be?" persisted Dick doggedly. "For instance, how do you know that, assuming it had a centre, all the radiuses to the circumference are equal?"

"The plural of 'radius'," said the pedantic Smithy, "is 'radii'."

"Well," continued Dick, firmly maintaining his position, "all the radii, then."

"Do you," asked Smithy in his turn, "know why a sine wave is so called?"

"Not really."

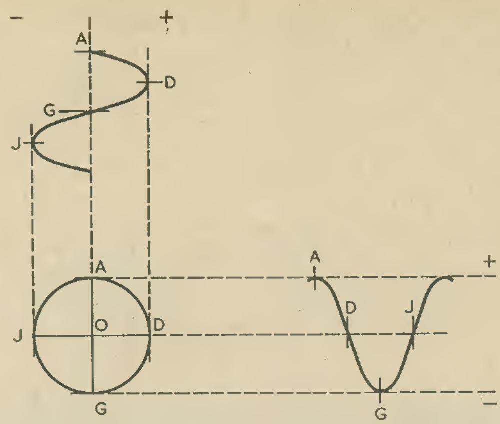
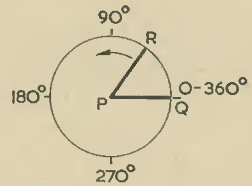


Fig. 2. By inspection, the four radii in the circle are equal in length and are at right angles to each other



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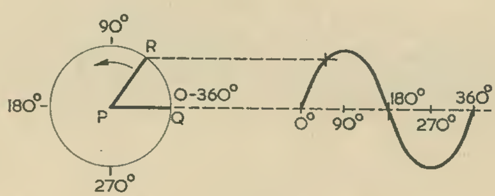

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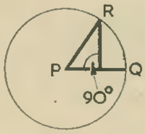

(c)

Fig. 3(a). In this circle, radius PR rotates anti-clockwise at constant angular velocity

(b). Plotting the height of R along a linear axis produces the cycle shown on the right

(c). By dropping a perpendicular from R to PQ, it can be demonstrated that the height of R is proportional to the sine of the angle between PR and PQ

"Fair enough," commented the Serviceman. "In that case we'll next have a dig at some elementary a.c. theory, after which I'll be in a better position to convince you that the trace really *is* circular. At this stage, though, we can at least establish that there are four equal radii in this trace of ours. I'll draw in the two lines AG and JD and we'll identify the point at which they cross as O. (Fig. 2). Are you with me so far?"

"I think so," said Dick dubiously.

"Good," replied Smithy. "Now, line JD corresponds to two points of zero voltage in the right hand sine wave, and so it must be horizontal. Similarly, line AG corresponds to two points of zero voltage in the top sine wave so this must be vertical. In consequence, lines JD and AG must be at right angles to each other."

"I'll give you that," conceded Dick.

"Simple inspection," Smithy went on, "also shows that point O corresponds to zero voltage on both sine waves. Whereupon both the lines OA and OG are equal in length to the zero-to-peak voltage of the right hand sine wave whilst both the lines OJ and OD are equal in length to the zero-to-peak voltage of the top sine wave. Since both sine waves are equal in amplitude, it follows that all the four lines OA, OG, OJ and OD are equal in length, whereupon they become four equal radii inside what you continue to maintain is not a true circle."

Dick looked impressed.

"I must say," he remarked, "that you've got a very good point there. What about radii going out to points in the circle *between* A, D, G and J?"

BASIC SINE WAVE

"To find out about them," said Smithy, "we next take a short shufti at the elementary bit of a.c. theory I mentioned a few moments ago."

Smithy returned to his note-pad and drew a further sketch on it. (Fig. 3(a)).

"Here," he announced, "we have a circle, and inside that circle we have a radius which rotates anticlockwise at a uniform angular velocity. In oher words it rotates around the centre at a constant speed, and is similar to a spoke on a wheel which is likewise turning at a constant speed. I'll call the centre of the circle P and I've drawn in a horizontal radius, PQ, for reference purposes. The rotating radius is PR. Now, as the radius rotates, the angle between PR and PQ starts from zero degrees, goes through 90°, 180° and 270° until it reaches 360°, which is the same as the starting position. When the radius has gone through 360° we say that it has completed a cycle."

"Rather," commented Dick, "like a sine wave."

"It's very much like a sine wave," replied Smithy, "as you'll see in half a jiffy. What I'm next going to do is to draw a horizontal axis alongside that circle and number it off from zero to 360, whereupon it corresponds to the number of degrees in the circle. After that, I'll draw a curve along that axis which corresponds in height to the extreme end of the radius as it rotates in the circle, each point in the curve corresponding, along the zero to 360° axis, to the number of degrees in the angle between PR and PQ. And here it is!" (Fig. 3(b)).

"That curve looks," stated Dick, "quite a bit like a sine wave."

"It's *exactly* a sine wave," pronounced Smithy, "and I'll now explain why. If I draw a line from point R perpendicular to PQ I have a right-angled triangle. (Fig. 3(c)). In that triangle, what's the sine of the angle between PR and PQ?"

Dick looked baffled.

"How d'you mean?" he asked. "Positive or negative?"

"Not positive or negative, you great twit," expostulated Smithy. "The *sine*, like you get in trigonometry."

Dick thought for a moment, and his lips moved as though he were silently reciting a mystic incantation.

"Why," he said brightly, "it will be the perpendicular divided by the hypotenuse. And the hypotenuse will, in this case, be the radius PR."

"Blimey," said Smithy, startled. "I didn't think you'd give me as quick an answer as that."

"I've got brains I haven't even used yet," boasted Dick. "If you did but know it, I often get the old trig tables out when I feel like a spot of light reading."

Smithy shot a suspicious glance at his assistant, but forebore to make any further comment.

"We are now," he said, returning to his theme, "nearly at the end of this little diversion with the circle and the rotating radius. And we have produced an equation which states that the height of the perpendicular divided by the length of the rotating radius, PR, is equal to the sine of the angle between PR and PQ. If, in this equation, we take the radius over to the other side we can next say that the height of the perpendicular is equal to the radius multiplied by the sine of the angle. Since the radius is constant at all angles it follows that the height of the perpendicular is proportional to the sine of the angle."

A sudden gleam of understanding blazed in Dick's eyes.

"Hell's teeth," he exclaimed, "I've just seen what it is you're driving at, Smithy. The amplitude of any point on that cycle you drew along the horizontal axis is equal to the height of the perpendicular. It follows from this that the amplitude of any point in that cycle is proportional to the sine of the angle it corresponds to."

"Precisely," confirmed Smithy. "So let's take an overall look at what we've just learned. To start off with, we divide a cycle into 360 degrees. If, then, the instantaneous amplitude of all points in the cycle under consideration is proportional to the sine of the corresponding angle, we say that the cycle is a sine wave. The cycle I drew alongside the circle is obviously a sine wave because it meets this requirement. This exercise with the circle also illustrates why the sine wave is such a fundamental concept in electronics. The sine wave is equivalent to pure circular motion."

"Stap me," said Dick. "I've been talking about sine waves as being 'pure waves' for years up to now, but I've never realised before why they *are* so pure!"

"Well, you do now," commented Smithy. "So let's return to our cir-

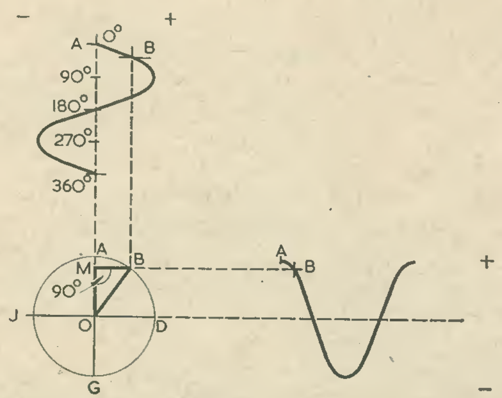

Fig. 4. This diagram illustrates that the trace produced in Fig. 1 is truly circular

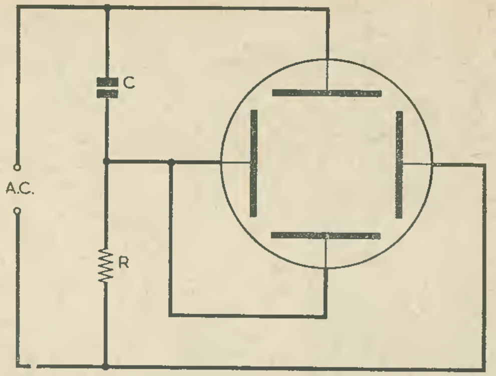

Fig. 5. A circular timebase. The reactance of C must be equal to R, and the input must be a pure sine wave

cular trace on the oscilloscope screen. We've already seen that this has the four equal radii, OA, OD, OG and OJ. Let's take a radius to point B, which I drew in earlier, then draw a line from B perpendicular to OA and meeting it at point M. (Fig. 4). What's the length of the line BM?"

"Humph," said Dick, stroking his chin reflectively. "It's possible to say it's equal to two things. First of all, and working directly from the triangle BOM, you can say that it's equal to OB multiplied by the sine of the angle between OB and OA. And, secondly, you can say it's equal to the amplitude of the top sine wave at point B."

"Which," put in Smithy quickly, "is proportional to the sine of the angle along the sine wave, from zero to 360°, at which point B appears. Both these factors agree with each other if we state the obvious truth that the angle between OA and OB is equal to the angle along the sine wave at which point B appears, whereupon the radius OB must be equal to any of the other equal radii we have already established in the circle. We can clinch the argument by repeating the process with point B on the right-hand sine wave, whereupon we have to drop a perpendicular from B to OD. We then use the same procedure, but we have to remember that the angle whose sine we are now concerned with is that between OJ and OB. This is because of the 90° phase difference between the two sine waves."

ELLIPTICAL TRACES

"You've convinced me," grinned Dick. "I need no further persuasion whatsoever to be quite certain that the trace on the c.r.t. screen *is* a true circle!"

"Good show," chuckled Smithy. "Speaking off the record I wasn't at all surprised when you initially found the formation of that circular trace very difficult to accept. The concept is by no means easy to understand and I haven't encountered a text-book yet which, apart from stating baldly that a circular trace is produced under the circumstances, explains *why* it is produced and why it is circular. Incidentally, there is a very simple timebase circuit which produces that circular waveform, and all it comprises are a capacitor and a resistor plus a source of sine wave a.c. (Fig. 5). When the reactance of the capacitor at the frequency of the applied sine wave is equal to the resistance of the resistor — that is, when $\frac{1}{2\pi fc}$ is equal to R—you then get a circular trace. This is because the voltage across the capacitor, which is applied to the Y plates, is 90° out of phase with that across the resistor, which is applied to the X plates. The advantage of this timebase is that the c.r.t. spot travels continually around the circle without any flyback, as occurs with normal horizontal timebases. By modulating the beam in intensity or deflection, the trace can then be used to continually illustrate the effects given by higher frequencies."

"How," asked Dick, "do you modulate the beam intensity?"

"By applying a modulating voltage to the tube grid or cathode."

"And the deflection?"

"By modulating the e.h.t. voltage applied to the c.r.t. final anode. As the e.h.t. voltage drops the deflection efficiency increases, giving the 'blooming' effect that we get in TV receivers. If the modulating frequency is an exact multiple of the circular timebase frequency you get a cog-wheel trace like this. (Fig. 6). The number of 'teeth' in the cog-wheel tells you the ratio between the two frequencies."

"Blow me," exclaimed Dick enthusiastically, "that's neat! But let's get on next to phase differences other than 90°. What sort of trace

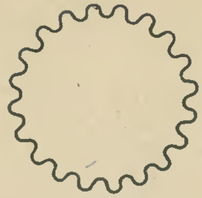

Fig. 6. The trace obtained by modulating a circular trace by a frequency which is a multiple of trace frequency. The modulating signal varies deflection sensitivity

do you get for phase differences between zero and 90°?"

"You get an ellipse," replied Smithy. "Which is to be expected since the trace shape will lie between the straight line given for zero phase difference and the circle given by 90° phase difference. Actually, you can draw a little family of traces, working from zero to 180° phase difference. (Fig. 7(a)). Starting at zero phase difference you have the sloping line. This then breaks into an ellipse whose major axis slopes in the same direction as the straight line for phase differences up to 90°. At 90° we have the circle, after which we go into an ellipse sloping the other way, and we eventually get the straight line again at 180°."

"Hang on a minute!" interrupted Dick. "You haven't said anything about whether one of the signals is leading or lagging. Won't that affect the slope of the ellipse at 45° and 135°?"

"In point of fact, it doesn't," replied Smithy. "To show you what I mean, let's go through the traces for phase differences from 180° to 360°. (Fig. 7(b)). We once more go from a straight line through an ellipse to the circle at 270°, after which we get a further ellipse and go back to the original straight line at 360°. The ellipse for 315° is, for instance, the same as that for 45°, and it follows that you'll get the same ellipse slope for any particular phase difference, regardless of which signal is leading or lagging."

APPLICATIONS

Dick absorbed this information. A sudden thought struck him.

"What," he asked, "can you use phase difference measurements for in practice?"

"There are quite a few laboratory applications," replied Smithy. "So far as our rather more mundane field of work is concerned, an oscilloscope connected up in the manner we've been discussing can be very useful for measuring phase shift in an a.f. amplifier. What we do here is to couple one set of deflector plates to the amplifier output and the other to the output of a sine wave a.f. generator, which also feeds into the amplifier input. (Fig. 8). There is almost certain to be negligible phase shift in the amplifier at mid-frequencies around 500Hz or so, and so we initially set up the signal generator to that frequency. We then adjust the signal generator output and the input attenuator to the a.f. amplifier so as to get a nice straight line on the c.r.t. screen sloping at 45°. All that is needed after that is to swing the frequency of the a.f. generator above and below the mid-frequency until the straight line breaks into an ellipse. This indicates the frequency at which phase shift in the amplifier is starting to occur. The phase shift is 90° when the ellipse becomes a circle. Should it be possible to get 180° phase shift in the particular amplifier being examined, this will be indicated by a straight line sloping in the opposite direction to the original one."

"That sounds quite a fascinating procedure to me," remarked Dick. "Wait a minute, though. I've just thought of a snag!"

"What's that?"

"Well," said Dick, "you set up everything so that you get a straight line at mid-frequencies, this line sloping at 45° and corresponding to equal input amplitudes to the X and Y plates. What happens if, when you get to the frequency which causes 90° phase shift, the gain offered by the amplifier has decreased? There won't be equal inputs to the X and Y plates then, and you won't get a circle."

"True enough," agreed Smithy. "In this case you'd get an ellipse having its major axis vertical or horizontal according to which set of plates had the stronger signal. But you'd know it was 90° shift because the major axis wouldn't be sloping. Blimey, I'm getting thirsty. How about some more tea, Dick?"

MNEMONIC

Hurriedly, Dick rushed to the teapot to obtain a further quantity of the life-saving fluid for the failing Serviceman.

After several sips, Smithy was sufficiently revived to put a query to his assistant.

"I think," he remarked initially, "that we've covered quite a bit about oscilloscope traces during this session, including in particular that circular trace which has been plaguing you so much. There are, of course, other traces which can be reproduced by an oscilloscope when there is access to both X and Y plates but I feel we've covered enough ground on this subject for the time being. So let me now ask you a question."

"Fire away!"

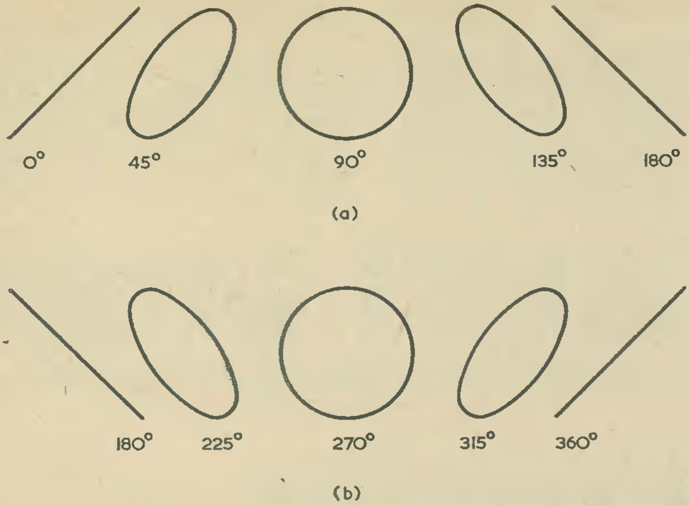

Fig. 7. The 'family' of traces given by phase differences ranging (a) from 0° to 180°, and (b) from 180° to 360°

"When I asked you what the sine of that angle in the circle was," said Smithy, "you seemed to go into a state of suspended animation, after which you suddenly emerged and immediately produced the right answer."

"I was reciting to myself," explained Dick, "a little mnemonic which I used to use at school for memorising trigonometry functions. It goes 'Peter has been here playing billiards before Paul'."

Smithy looked mystified.

"If," Dick went on, "you take the capital letters out of that little lot you get the relationship for sine, cosine, tangent and cotangent in order. P stands for 'perpendicular', H for 'hypotenuse' and B for 'base'. So, the 'Peter has' bit stands for 'perpendicular over hypotenuse', which is the sine; whilst the 'been here' bit stands for 'base over hypotenuse', which is the cosine. And so on. Got it?"

"Indeed I have," replied Smithy appreciatively. "I must admit that you do come out with some quite useful little bits of knowledge every now and again, Dick."

"I tell you," responded Dick proudly.

"I suppose," continued Smithy, "you could say that a mnemonic like that represents a roundabout way of locating information."

"Oh, definitely."

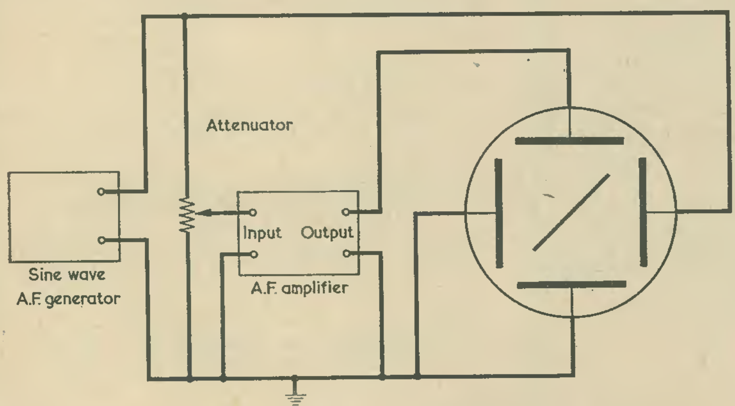

Fig. 8. Using an oscilloscope to check the frequencies at which phase shift occurs in an a.f. amplifier

"In fact," concluded Smithy brightly, "it's rather like a circular trace."

After which statement, and accompanied by the groans of a shuddering Dick, we hurriedly draw this month's episode to its final conclusion.

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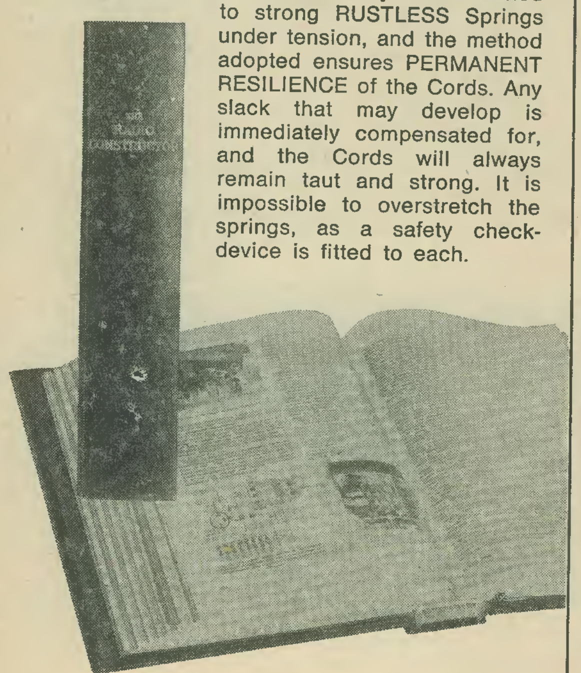

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20L1	13/-	ECH42	10/-	PC900	8/3	U191	12/6	AC127	2/-	OC23	5/-
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30PL13	15/-	EF183	6/-	PCL86	8/6	UCH81	6/6	BA130	2/-	OC75	2/-
30PL14	15/-	EF184	6/-	PEN45DD	12/-	UCL82	7/-	BC107	4/-	OC78	3/-
AC2PEN	19/6	EH90	6/6	PFL200	12/-	UCL83	10/-	BC108	3/6	OC78D	3/-
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CY31	7/6	EL41	9/3	PL82	6/6	UF80	6/9	BCY33	5/-	OC82	2/3
DY87	5/9	EL84	4/6	PL83	6/6	UF85	6/9	BCY34	4/6	OC83	2/-
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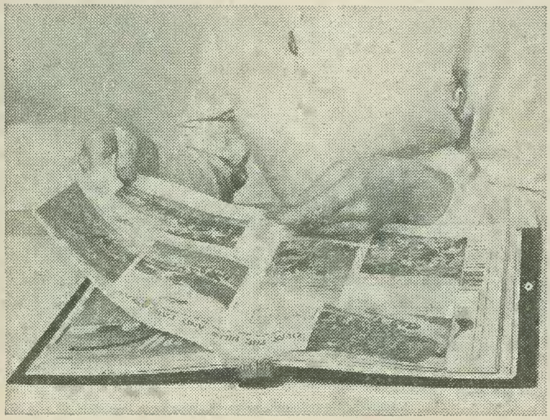

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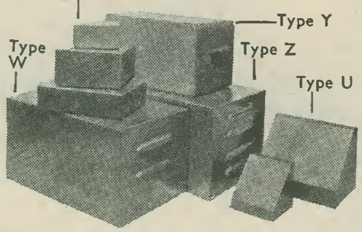

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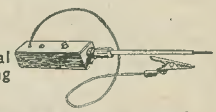

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ROUND FIGURE VALUES FOR $2\pi f$

It is frequently necessary to carry out calculations involving the expression $2\pi F$. When approximate solutions only are required, however, calculations become tedious after the unwieldy figure for π has been introduced. The Table provides an answer to this problem by listing round figure values for $2\pi f$, whereupon subsequent calculations are eased. The Table is used by finding the frequency nearest that under consideration. Thus, the approximate value of $2\pi f$ when f equals 700kHz is 450×10^4.

$2\pi F$	Hz	$2\pi f \times 10$	Hz	$2\pi f \times 10^2$	kHz	$2\pi f \times 10^3$	kHz	$2\pi f \times 10^4$	kHz	$2\pi f \times 10^5$	MHz
100	15.9	100	159	100	1.59	100	15.9	100	159	100	1.59
150	23.9	150	239	150	2.39	150	23.9	150	239	150	2.39
200	31.8	200	318	200	3.18	200	31.8	200	318	200	3.18
250	39.8	250	398	250	3.98	250	39.8	250	398	250	3.98
300	47.7	300	477	300	4.77	300	47.7	300	477	300	4.77
350	55.7	350	557	350	5.57	350	55.7	350	557	350	5.57
400	63.7	400	637	400	6.37	400	63.7	400	637	400	6.37
450	71.6	450	716	450	7.16	450	71.6	450	716	450	7.16
500	79.6	500	796	500	7.96	500	79.6	500	796	500	7.96
550	87.5	550	875	550	8.75	550	87.5	550	875	550	8.75
600	95.5	600	955	600	9.55	600	95.5	600	955	600	9.55
650	103	650	1,030	650	10.3	650	103	650	1,030	650	10.3
700	111	700	1,110	700	11.1	700	111	700	1,110	700	11.1
750	119	750	1,190	750	11.9	750	119	750	1,190	750	11.9
800	127	800	1,270	800	12.7	800	127	800	1,270	800	12.7
850	135	850	1,350	850	13.5	850	135	850	1,350	850	13.5
900	143	900	1,430	900	14.3	900	143	900	1,430	900	14.3
950	151	950	1,510	950	15.1	950	151	950	1,510	950	15.1
1,000	159	1,000	1,590	1,000	15.9	1,000	159	1,000	1,590	1,000	15.9