RADIO and ELECTRONICS

ELECTRICITY — COMMUNICATIONS — SERVICE — SOUND

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PERFECT v. PLEASING REPRODUCTION

In the January, 1947, issue of *Electronic Engineering* there appears an illuminating article by Mr. J. Moir, M.I.E.E., under the same title as we have used here. Without bias, and with due regard to the published experimental work on the subject, Mr. Moir reaches a conclusion which, though supported by all the experimental evidence, and in fact based on it, is more than a little disturbing to engineers interested in the reproduction of sound. It is this: that in spite of the reduction of distortion to values which should be negligible, the non-technical public at large most emphatically prefers a restricted frequency response to a very wide one.

This conclusion can hardly be debated, as it rests on sound experimental evidence. Assuming for the moment that this is a fact, and pursuing Mr. Moir's argument a little further, we find that the history of musical instruments themselves helps to prove the point. Historical records, says Mr. Moir, show that the development of many modern instruments such as the oboe and violin, from their mediaeval counterparts, has been in the direction of increasing the harmonics produced in their low and middle registers, while simultaneously causing the notes in their higher range to become more nearly pure tones. The latter is nothing more or less than reducing their sound output at the extreme high frequency end of their range. This tendency, it should be remembered, began to be put into practice long before any question arose of *reproducing* the sound of the said instruments, and so can be taken as evidence that the average ear, though it can detect sounds of very high frequency, prefers not to when it comes to obtaining enjoyment from listening, whether to musical instruments themselves or to reproductions of them.

The reason for this strange fact is not yet known, just as a few years ago little or nothing was known of the types or extent of distortion which produces the worst effect in a reproducing system. Not a great deal is known about this particular subject even now, and estimates of the amount of distortion which is tolerable under given conditions vary considerably.

It is uncertainty on this point which alone casts any doubt on the validity of the listening tests cited by Mr. Moir in his article. It is known that with single pure tones emanating from a loudspeaker, the percentage of harmonic distortion which may be introduced without its being perceptible increases as the frequency range of the system is restricted. But pure tones do not make speech or music, and it has been found that a much more reliable test of a reproducing system, and one which ties in well with actual listening tests, is to measure intermodulation products emanating from the system. This is an advance, but it still remains to be ascertained what degree of intermodulation effect is just barely discernible by a listening test.

Thus the engineers' hope that if and when all forms of distortion can be reduced to negligible proportions, the public at large will prefer wide range reproduction to a restricted frequency range, is not yet completely banished. The audio expert's dream may yet be fulfilled, but he is still justified in being somewhat baffled as to why the listening public should prefer not only musical instruments without too much "top," but reproductions of them with still less! Doubtless the answer will come in due course, but in the meantime neither Mr. Moir nor the research workers themselves have found it.

ELECTRONIC MUSIC

By C. R. LESLIE, A.M.Inst.M.I.T. (Member Electronic Music Group).

INTRODUCTION

In July, 1943, English readers of "Electronic Engineering" suggested that a Discussion Group be formed by those interested in the design and performance of electronic musical instruments, particularly electronic organs and pianos. In September sufficient interest had been aroused to warrant the formation of such a group with a liaison with the Institute of Musical Instrument Technology whose headquarters are at the Northern Polytechnic in London. The reason for the formation of this group was that although the subject of electronically-produced music has been studied for many years— even prior to the advent of the thermionic valve—there is very little published literature on it in English as most of the research work had been carried out on the Continent.

Perhaps it is for this reason that a great many people, although quite accustomed to the reproduction of music from their radio sets, express surprise at the possibility of producing music directly electronically. Yet a moment's consideration should show that the "music" emanating from the loud-speaker is the result of a combination of audio frequency currents. The "mike" translates air vibrations (from a musical instrument, for instance) into audio frequency voltages which are then amplified to operate the speaker. If we replace the "mike" stage with a variable electronic frequency generator we shall produce musical notes from the speaker. Superheterodyne whistles and "birdies" are a case in point, though they cannot be classed exactly as musical efforts!

These articles are issued in the hope that readers in the Dominion will be sufficiently interested to carry out research work in harmony (pardon the pun) with the enthusiasts in the Old Country.

WHY ELECTRONIC MUSIC?

The question may be raised as to why research was made in the electronic field when perfectly good conventional instruments were already in existence. The reason is because of the limitations of traditional instruments, and to accept limitations as final is to stagnate. Great skill in manufacture and design have contributed to the present high standard of such instruments and with them some performers have managed to produce musical masterpieces. But all these instruments are limited by the quality of their mechanical resonators and this fact determines their size, cost, flexibility of control, loudness and range of tone colours. The attraction of being able to produce music, at least theoretically, of any desired tone colour, with a greater flexibility of control and loudness range by the generation of electric currents, started pioneers in the exploration of this field and a great many systems have been proposed, many of which have proved successful. There is undoubtedly almost unlimited scope for electronic and mechanical ingenuity in such work.

There is another aspect worthy of consideration and that is it is possible to arrange matters with an electronic instrument so that the playing technique is greatly simplified. This is quite as it should be, because an electronic version of an existing standard instrument would only have problematical advantage if the manipulation were not much simplified, with the exception of large instruments such as organs, where the electronic version would be more compact and considerably less costly to manufacture. This objective is further justified by the fact that there are a large number of people who have a genuine desire to play some favourite instrument but have not had the opportunity of acquiring the necessary training in technique. To this number we can add those who have been, through war or accident, incapacitated from further practice. To these and similarly placed people, a great service can be rendered by the production of electronic instruments whose control can be quickly acquired.

Research work in this field offers a refreshing change from the more usual "radio," and each instrument will inevitably produce its own intriguing problems for the satisfaction of the resourceful brain. It also opens up the possibility for the development of an entirely new instrument with a timbre or tone colour quite distinct from any traditional type. Its evolution is simplified by being mainly confined to electrical circuit design without much dependence on constructional material such as metal, wood, glue and varnish of the non-electronic instruments.

DEFINITION

Before enlarging on the subject it would be as well to be quite clear as to the meaning of the expression "Electronic Music"—the term only refers to music produced by electro-acoustical devices (such as loudspeakers) which are responsive to electrical waveforms generated entirely within the instrument and which are under the control of the player. Therefore, gramophone, sound-on-film reproducers and all instruments of a like nature are excluded.

LINES OF DEVELOPMENT

To give some idea of the lines along which development has been pursued the following table is appended:—

Group	Sub-group	Sub-division
Melodic or single-voice type	(a) Electric arc	..
	(b) Valve oscillators	..
	(c) Neon oscillators	..
Multi-note keyboard	(a) Struck string or tuning fork as generator	(a) Electromagnetic pick-up. (b) Electrostatic do.
Multi-note keyboard, organ type	(a) Maintained fork or vibrator as generator	..
	(b) Maintained strings as generators	(a) El. magnetic pick-up. (b) El. static pick-up.
	(c) Cathode ray generator	..
	(d) Multiple oscillator circuits using valves or neons	(a) Valve osc. circuits. (b) Neon osc. circuits.
	(e) Wind maintained reeds as generators	(a) El. Mag. pick-up. (b) El. stat. pick-up.
	(f) Rotary types of frequency or harmonic generators	(a) Photo-electric. (b) El. magnetic. (c) Electrostatic.

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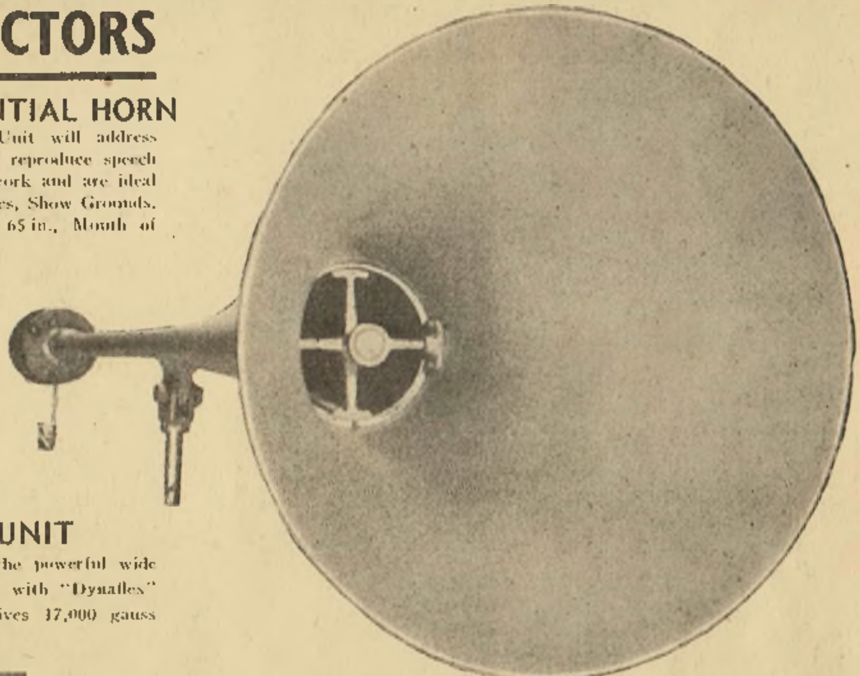

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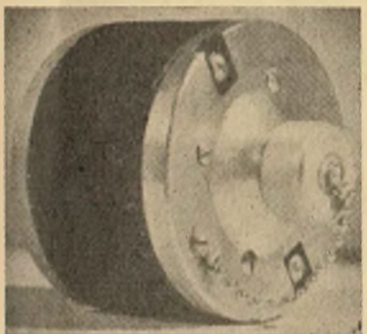

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The earliest attempts were confined in the main to the production of melodic or single-voice instruments. In 1915 Lee de Forest lodged the first patent application for a musical instrument utilising a thermionic valve oscillator, the frequency of which was controlled by variation of capacitance. The output of the oscillator was fed to a loud-speaker through audio amplification stages. This was rapidly followed by other inventions using various forms of oscillating circuits to include ranges of harmonics to simulate different orchestral instruments. The application of electromagnetic or electrostatic pick-ups to piano type actions (but minus the soundboard) was developed by Vierling and Miessner to produce tone colours of instruments differing widely from the piano, such as the violin, 'cello, flute, saxophone and organ. But the major proportion of energy and ingenuity has been displayed in the development of that "king of instruments," the organ. It may be of interest to readers to learn that an electronic organ has recently been constructed by Mr. Beavan at his home in Palmers Green in England. It was made out of the "works" of two pianos and a table-tennis table and comprises over 200 valves feeding into 12 loud-speakers. Such an instrument offers much that is of interest to the "circuit fan" as well as to the mechanically-minded!

SOME DEVELOPED INSTRUMENTS

Before discussing typical problems that arise in this class of work we will briefly describe some of the better-known instruments that have been developed. Mention has already been made of Lee de Forest's invention—a somewhat similar idea was designed by Trautwein in 1930 and 1931, using Neon lamps as relaxation oscillators in an instrument which he called a "Trautonium." Fig. 1 is a schematic of the circuit and it will be seen that the frequency or pitch is controlled by (1) a bank of condensers, and (2) by means of a variable resistance, thereby altering the time constant of the combination. The variable resistance consisted of a spun wire cord stretched over a steel band, the cord being pressed on to the band at any desired point by the performer. With such an arrangement staccato, glissando or vibrate playing can be easily achieved. Harmonics were stressed by a system of tuned circuits (called "formant circuits") in the plate circuit of the triode amplifier. A further amplification stage then fed a loud-speaker—in this portion of the circuit the volume control would be situated and be operated by a foot-pedal or a similar but smaller version for holding in the unoccupied hand. The playing technique is thus reduced to very simple proportions. In the actual instrument a dummy keyboard was painted under the steel strip to assist the player in the correct location of the notes. Fig. 1 represents the improved circuit of his second patent British No. 403,365 of March, 1932). This patent covered further developments in the playing manual to facilitate vibrato technique by means of specially shaped keys that could be rolled from side to side by the finger and so cause a slight frequency variation.

Another instrument of interest was developed by Goldberg and Sohne in 1924 using the familiar B.F.O. principle. It consisted of a triode oscillator of fixed frequency and a second variable frequency oscillator controllable by variation of capacitance—the output being then mixed and amplified in the usual way. The method of varying the capacitance made use of hand capacity. The instrument was fitted with an external short brass rod like a small aerial and the distance of the player's hand from this "aerial" altered the capacitance and hence the frequency. The quality of the playing was dependent on that of the performer's "musical ear." The single voice design is shown in

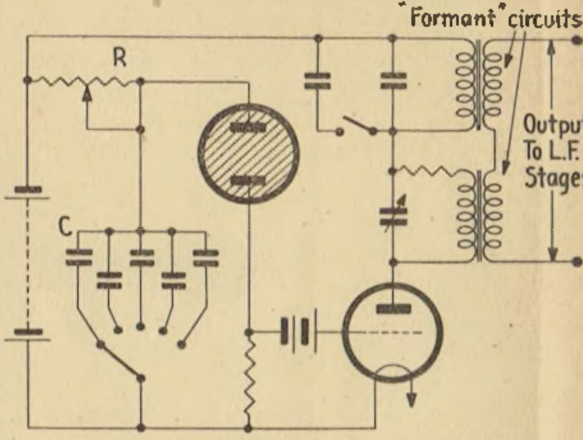


Fig. 1. Schematic of the "Trautonium."

Fig. 2 where 1 is the "Aerial," 2 the variable oscillator, 4 the fixed oscillator, and 5 the mixer. The reproduction portion is indicated at 11 which could be earphones or the usual amplifying and speaker stages.

A natural development was the addition of other "aerials" to create a 1-4 voice instrument—that is, four notes could be sounded simultaneously as a chord by the use of both hands and fingers. Accurate playing must have been very difficult judging from the description in the patent specification. Fig. 3 shows a schematic of this later instrument, which can be followed by reference to the previous circuit. The single voice edition was later commercially developed in the States both as a complete article and as home constructors' kits under the title of "Aetherophon" and enjoyed reasonable success.

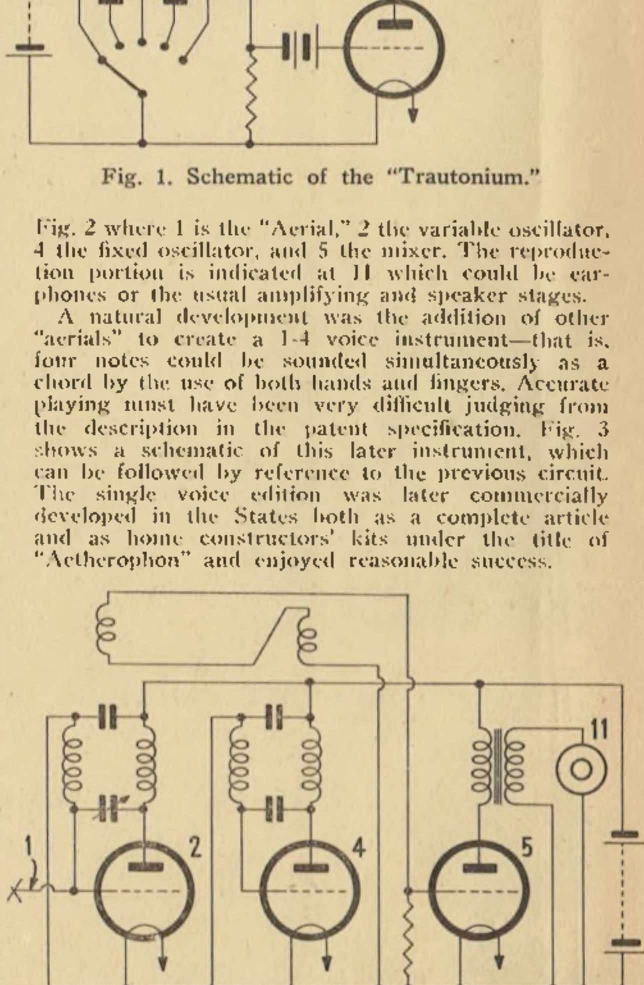


Fig. 2. The single-voice Goldberg and Sohne instrument.

Turning now to more ambitious efforts we find that the earlier workers rather jibbed at purely electronic circuits because of the difficulties encountered with the valves of the times, such as frequency drift, microphony, parasitic oscillations and amplitude/time delay and starting characteristics. Therefore research workers made more use of electromagnetic and static pick-ups, tuning forks, vibrating reeds and the like. However, some purely electronic instruments were completed, one of which was the "Novachord" which comprised 163 valves, 72 playing keys and with it the music of several traditional instruments could be simulated, such as the organ, piano, brasses, woodwinds, harp and bowed string effects. Each of the playing keys, with the exception of the top twelve semi-tones, had two valves allotted to it, one for control and one for frequency dividing. The top twelve octave frequencies were generated by fixed oscillators. By frequency division the octave next below was obtained, and the one below that by frequency division of the one above it, and so on all down the pitch range. Amplitude/time delay characteristics were determined by variations of grid bias at the instant of keying. Tone colour (timbre) was varied at the input to the 72 control valves and again in the common output circuits. The twelve frequency dividing systems of each octave provide the chromatic scale for that octave. These valves are not oscillators so that if the input ceases the output does also.

Another instrument, the Compleaux Brothers Electric Organ, employed 410 valves and had three playing manuals and 15 timbre stops. The various tone qualities were obtained by switching in 15 amplifiers and loud-speaker circuits, each with its own frequency characteristic.

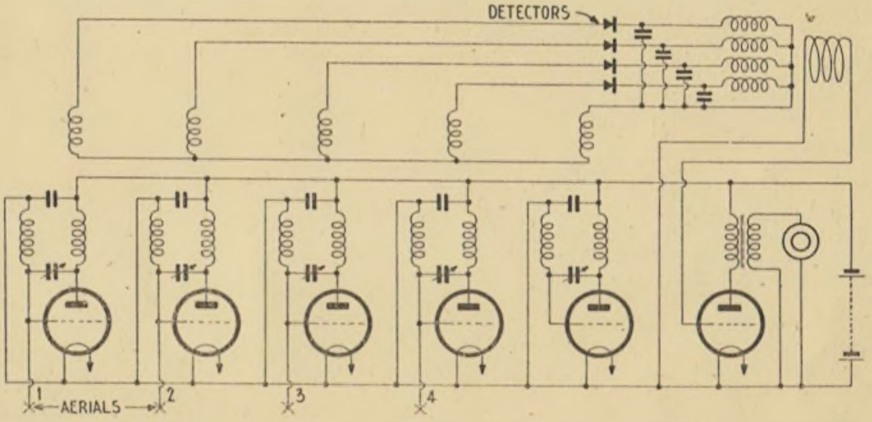


Fig. 3. Schematic of the four-voice Goldberg and Sohne instrument.

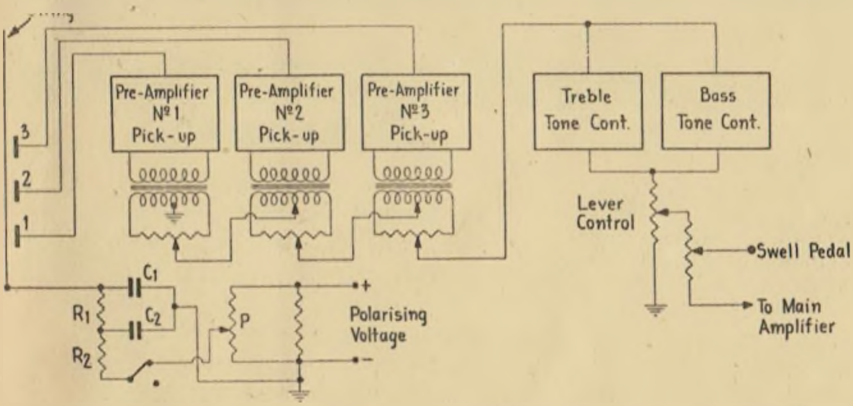


Fig. 5. Schematic for one string of the Electron Piano.

The earlier electromagnetical instruments aimed more at enlarging the scope of the ordinary piano by eliminating some of the limitations. For instance the Bechstein Electric Piano was a standard "grand," minus the sound board, and the hammers were smaller than customary. The steel strings were arranged in groups of five and at their ends small "microphones," made by winding coils round permanent magnets, were attached, the idea being to collect as many harmonics as possible, especially the super-sonic ones, for further amplification. The audible result was a much harder and more brilliant tone than the usual piano. The tone colour was then made further adjustable by utilising banks of by-pass condensers for elimination of higher harmonics.

The Foerster-Vierling Elektrachord was more like a normal piano in tone and playing, the volume being controlled by the manner in which the key was struck. As before, steel strings and normal hammers were used, but each string had two electromagnetic pick-ups, one for the fundamental and one for the harmonics.

The Electron Piano enlarged on this idea and employed electrostatic pick-ups, consisting of small metal plates placed beneath the strings—three to each string. It employed an 88-note keyboard, so that there were 264 pick-ups. One was placed at the end of the string, a second at about 1/6th of the length and the third at about ½ the length. Those at the ends are close to the node points of the harmonic vibrations and hence are rich in this commodity.

Fundamental pick-up is about equal for the other two positions and is high in comparison with the end placement. Harmonics are weak at the second place and almost absent from the third. Amplifiers receive the outputs of the pick-ups, which are then fed into phasing networks. By this means the three outputs can be made to oppose or assist each other to any desired extent. Fig. 5 shows a schematic of the general arrangement for one string.

As the equipment was intended to separately simulate many orchestral instruments in addition to the organ and piano, special means had to be devised to provide the correct "attack." For an organ effect the initial "thumps" of the piano had to be avoided, whilst for the plucked string (harp) effect a strong initial surge is essential and so on. To overcome this problem a polarising voltage was applied between the strings and the pick-up plates through a single-pole double-throw switch attached mechanically to each key. When a key is struck the voltage is altered by the switch and through a time delay network (R_1C_1, R_2C_2) so that a short time interval elapses before change over occurs. The voltage ratio applied is adjustable for each instrument simulated by means of the potentiometer P.

Later developments aimed at more compact construction by the use of either electromagnetic or electrostatic generators driven by synchronous motors to form scanning units. For instance a typical electromagnetic multi-frequency generator would consist of a rotatable iron disc on which are cut a large number of concentric ridges. On the face of each ridge, at right angles to the plane of the disc, sinusoidal waveforms are cut so that, progressing outwards from the innermost ring, each successively larger ring has twice the number of waveforms of the inner adjacent ring. Series of electromagnetic pick-ups comprising radial iron arms with radially adjustable pole pieces in the form of grub screws were positioned opposite the concentric waveform ridges. By adjusting the grub screws the relative strengths of the frequency pick-up by each, relative to each other, is controllable in a pre-set manner. The strength of the current of the complex waveform so generated is controlled in each radial bar by varying the electromagnetic excitation.

Space does not permit of descriptions of other types, but we may mention one form, due to Welte, in which photocells were used in association with rotating glass discs carrying photographic variable area sound tracks arranged concentrically. The photocells view these through stationary scanning slits illuminated by small bulbs.

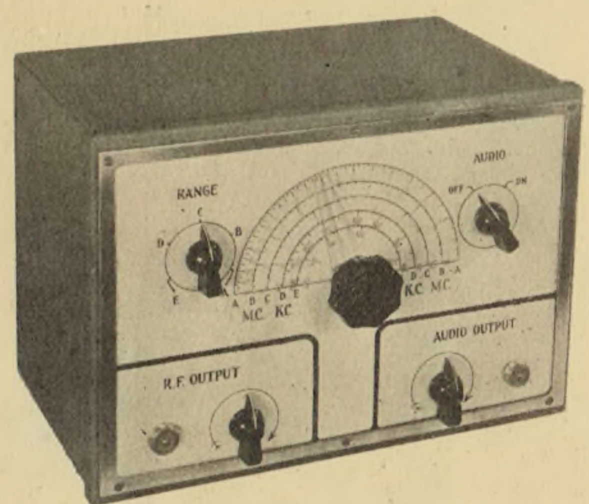
These very brief and inadequate descriptions give some idea of the various lines along which research work has proceeded and show that a great many different avenues may be explored—that the inventor is not restricted in any way and may incorporate parts of various systems, mixing electromagnetic generation with thermionic systems and so on. In a succeeding article we shall endeavour to give some idea of the general problems that have to find solution and the important part played by harmonics in the evolution of instrumental tone colour.

(To be continued.)

Rola "Anistropic" speakers will "speak" for themselves.

THE RADEL SERVICE OSCILLATOR

We have received many inquiries from readers for the design of a service oscillator suitable for the home constructor or serviceman to build, and with a performance equivalent to that of commercial oscillators in the medium-priced class. The design presented here fulfils these requirements admirably, being easy to construct, economical in cost of parts, and having an output and frequency stability well within normal requirements for this type of instrument.



DESIGN FEATURES

The oscillator provides the following features:—

Frequency Range:
280 kc/sec-30 mc/sec. continuous coverage on fundamental.

Modulation:
Separate 400 c/sec. oscillator with control of modulation depth and provision for separate audio frequency output.

Frequency Stability:
Very low drift after warming up, owing to heat-insulation of coils and wave-change switch.

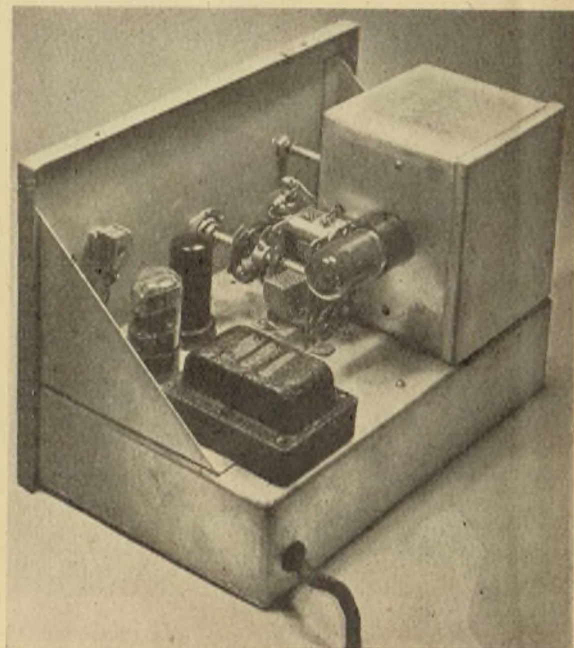
Output Voltage:
Substantially constant over all bands, due to the use of a buffer amplifier.

Leakage:
Not entirely eliminated, but small enough to be below the A.V.C. threshold of any receiver.

THE CIRCUIT

The oscillator itself is a 6V6-GT connected as a triode. The tube was used because a low-mu triode was considered the best for an oscillator of this nature, where the output was required to be as constant as possible over a wide range of frequencies in each band, and over five bands in all. A suitable triode of this nature was not available, so that the 6V6-GT was chosen, and is used with screen and plate tied together. The power input to the oscillator is very small, the plate current being of the order of 10 ma. only on all ranges. Using a fairly large tube, running lightly is good practice, too, from the point of view of frequency stability, since tube heating is kept to a minimum, and frequency variations due to geometrical changes in the tube structure are therefore minimised.

V_2 is a 6J7 used as an untuned buffer stage, whose purpose is to hold the output constant irrespective of frequency. It acts rather like the limiter stage in an F.M. receiver, and irons out the inevitable variation in oscillator output as the latter is tuned over a frequency range of about 3:1. The buffer also allows modulation to be applied with a minimum of undesired frequency modulation. The R.F. output is



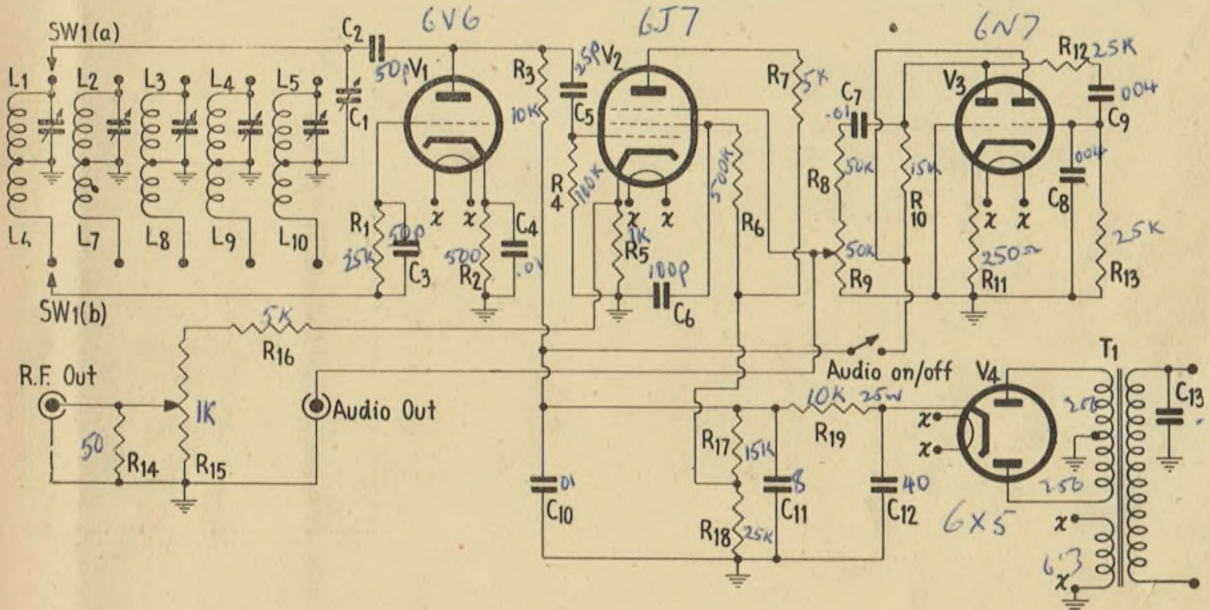
The completed oscillator. Left: In the case. Right: Out of case.

taken from the unbypassed 1000-ohm resistor in the cathode circuit of V_2. The amplitude at this point is less than at the plate, but is still much greater than is actually required, so that R_{16}, in conjunction with the output potentiometer R_{15}, is used to drop the maximum available output voltage to something in the vicinity of one volt.

It will be noted that V_2 has a plate load resistor R_7, in spite of the fact that output is taken from the cathode. This is necessary to provide proper limiting action, since, if it were omitted, V_2 would act more as a cathode-follower, and variations in input voltage would be reproduced at the cathode.

V_3 is a 6N7, and is the audio oscillator. It works on the phase-shift principle, and is, in fact, the phase-shift version of the two-terminal cathode-coupled oscillator circuit which has been used before in these pages. The elements which determine the frequency of oscillation are R_{12}, C_9, C_8, and R_{13}. The two halves of V_3 are connected as a two-stage amplifier in which the output is fed back to the input via this network. The values of the network components are chosen so that at a frequency of 400 c/sec. there is no phase shift through the network. This being the case, the system oscillates at this frequency, and no other. The output is taken from the plate circuit of the left-hand section of V_3 via a blocking condenser C_7 and the resistors R_8 and R_9. The latter is the potentiometer which controls the modulation percentage of the R.F. amplifier, and at the same time the audio voltage fed to the audio output terminal. The switch marked "Audio on/off" cuts the plate voltage to V_3 and prevents it from working.

It should be mentioned that, with the constants given, the wave-form of the audio oscillator is very good, but in this respect certain components, notably R_{10} and R_{11}, are quite critical in value. Similarly, if the values of C_7, R_8, and R_9 are not adhered to, the wave-form is likely to suffer rather badly.



R_1, R_{12}, R_{13}, R_{18} = 25k.
R_2 = 500 ohms.
R_3 = 10k.
R_4 = 100k.
R_5, R_{15} = 1000 ohms.
R_6 = 500k.
R_7, R_{16} = 5k.
R_8, R_9 = 50k.
R_{10}, R_{17} = 15k.
R_{11} = 250 ohms.
R_{14} = 50 ohms.
R_{19} = 10k. 25w. w-w.
L_1–L_{10}, see text.
Sw_1 = 2-bank 11-position wafer switch (see text).
C_1 = 350 mmfd. max. variable.
C_2, C_3 = 50 mmfd. mica.
C_4, C_7, C_{10} = 0.01 mfd. paper.
C_5 = 25 mmfd. mica.
C_6 = 100 mmfd. mica.
C_8, C_9 = 0.004 mfd. mica.
C_{11} = 8 mfd. 450v. electro.
C_{12} = 40 mfd. 450v. electro.
C_{13} = 0.1 mfd. paper.
T_1 = 250-0-250v., 6.3v. power transformer.
V_1 = 6V6-GT (screen tied to plate).
V_2 = 6J7.
V_3 = 6N7.
V_4 = 6X5-GT.

POWER SUPPLY

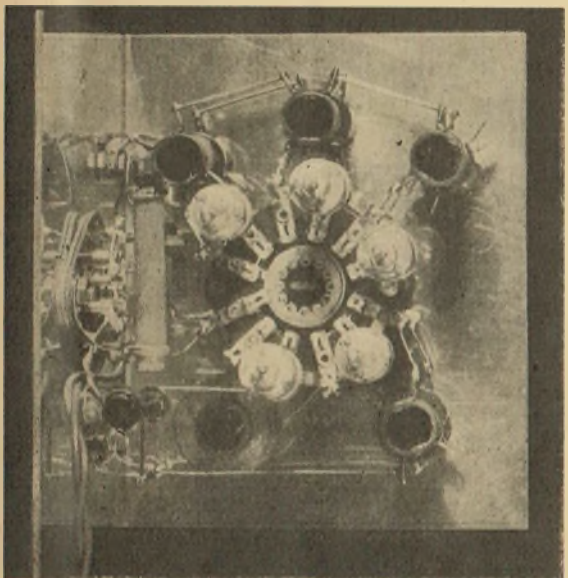
It will be noted that a small instrument type power transformer has been used, which has a high voltage secondary of only 250 volts a side. This is because the more usual 385 volts would provide much too high an H.T. voltage, which would have to be dropped. A resistance R_{19} is used in place of a smoothing choke with quite satisfactory results. This reduces the H.T. voltage to a suitable value at the same time as assisting in the smoothing, and results in appreciable economy in the power supply circuit. The high value of C_{12} (40 mfd.) ensures that the filter R_{19}, C_{11} has very little hum left to suppress.

CONSTRUCTION

The construction of the oscillator can be easily followed from the chassis diagrams and the photographs. The shield box inside the cabinet contains the complete oscillator circuit, except for the variable condenser and the tube itself, which is mounted on the side of the coil box. The method of mounting the oscillator circuit is illustrated in Figs. 1 and 2. The "chassis" is made from a piece of 16-gauge aluminium sheet, bent at right-angles and cut so as to fit exactly into the coil box. This makes the construction very simple, as all wiring can be done outside the box, and the complete unit slipped in afterwards. On one side of the aluminium sheet are mounted the wave-change switch and the five coils, while the 6V6 socket is mounted on the other. The coils are mounted in ring formation round the switch, making all leads to the latter very short and direct. It will be noted that all leads from the coil lugs to the switch are made from bare tinned copper wire. This is just one of the factors contributing to frequency stability. The less insulation that is associated with the oscillator circuit, the

smaller the chances of frequency creep, either permanent or temporary, on warming up.

The wave-change switch is an eleven-position one, in spite of the fact that only five ranges are covered by the oscillator. This allows the coil leads to be partially shielded from each other, by using alternate switch positions and earthing the intermediate ones. It has the further advantage that the Philips trimmers may be mounted on the intermediate



earthed contacts. This type of trimmer is strongly recommended, as it is much more satisfactory for mounting and has much greater stability than the pressure-type mica dielectric trimmers usually found in receivers. It is simply by attention to a number of small points of this nature that the excellent frequency stability of this oscillator has been achieved. Not the least of these factors is the mounting of the coils with great rigidity inside the coil box, where the heat from the tubes cannot get at them. If the present lay-out is not adhered to, the constructor can expect to find considerable trouble with frequency creepage for a long time after the oscillator has been turned on.

COIL DATA

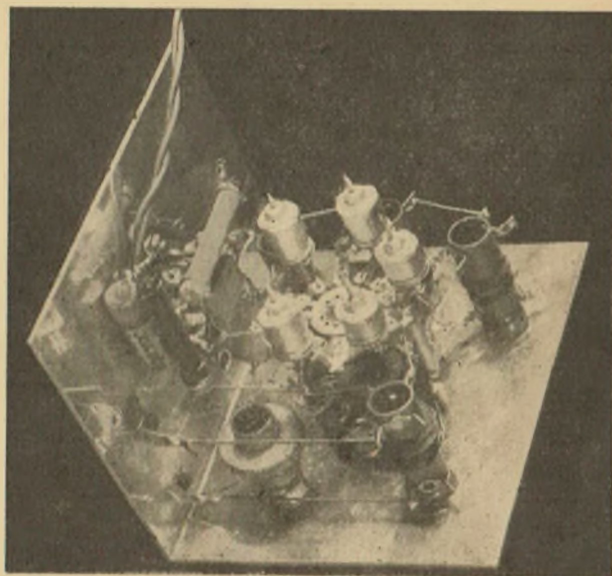
The coils used in the original model were hand made in each case, using as a starting point ordinary receiver-type coils bought in the open market. The frequency ranges are as follows:—

A	......	11-30 mc/sec.
B	......	4.3-11 mc/sec.
C	......	1.7-4.3 mc/sec.
D	......	665-1700 kc/sec.
E	......	280-670 kc/sec.

All coils are wound on ½ in. diameter formers, and the ones to be purchased are: 2 shortwave coils. These may be any coils (either aerial, R.F., or oscillator) intended for the shortwave range of dual-wave receivers. The coil for range C is made from a broadcast band oscillator coil designed for use with a 420 mmfd. maximum capacity gang.

The coil for range D is made from a broadcast band aerial coil, also designed for use with a 420 mmfd. gang condenser.

The low-frequency coil for range E is made from a single winding from an I.F. transformer designed for 465 kc/sec. The former is sawn through, as close as possible to the unwanted bottom winding, leaving space for the tickler winding, which is jumble-wound close to the tuned winding.



Figs. 1 and 2. The coil unit.

Band A 11-30 mc/sec.

L_1, 5 turns 24 S.W.G. enamelled, double spaced.

L_6, 3 turns 30 S.W.G. D.S.C. interwound at earthy end of L_1.

Band B 4.3-11 mc/sec.

L_2, 22 turns 24 S.W.G. enamelled, double spaced.

L_7, 10 turns 30 S.W.G. D.S.C. interwound at earthy end of L_2.

Band C 1.7-4.3 mc/sec.

L_3 and L_8. Standard broadcast oscillator coil designed for 420 mmfd. gang and 6K8 tube. Tickler used as L_8, unaltered. Grid winding used as L_3, with turns removed until, with all tuning capacity in circuit, frequency of oscillation is 1.7 mc/sec.

Band D 665-1700 kc/sec.

L_4 and L_9. Standard broadcast R.F. coil. Secondary, unaltered, used as L_4. Primary used as L_9, but modified by sliding along former till as close as possible to the primary. Turns are then removed until the winding depth is one-third that of L_9.

Band E' 280-670 kc/sec.

L_5, single winding from 465 kc/sec. I.F. bobbin, designed for 140 mmfd. tuning capacity.

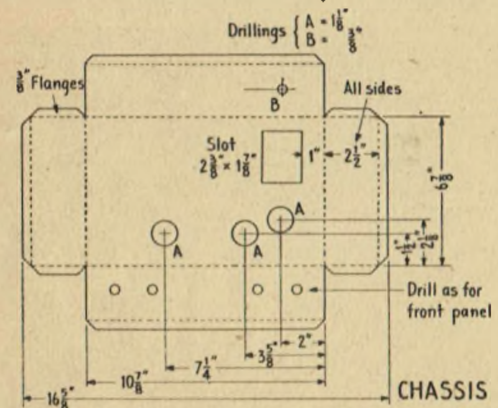
L_{10}, 130 turns of 34 S.W.G. enamelled wire, jumble-wound as close as possible to L_5.

CALIBRATION

Apart from calibrating the completed oscillator, it will be necessary to make sure that the ends of the various ranges meet, so that there shall not be any gaps in the frequency coverage. No special equipment will be required for this, since the overlap points all come within the range of a normal allwave receiver. Care will be necessary to ensure that image responses are not used accidentally on the high-frequency ranges, as this could give an erroneous answer. It is not intended here to go into any detail on the subject, since the question of images has been handled fairly extensively in our series of articles on the measurement of frequency.

However, once the oscillator has been completed, the question of proper frequency calibration crops up. The easiest method is to borrow, or obtain the use of, a signal generator whose frequency scale is known to be accurate. Calibration is then effected by the system of zero-beating the unknown with the calibrated oscillator at each frequency which it is required to mark on the dial. For this purpose, some sort of detector is required. A receiver could be used, but is not necessary. Perhaps the best scheme is to use a simple untuned diode detector and a pair of headphones or an audio amplifier. This will ob-

(Continued on page 48.)



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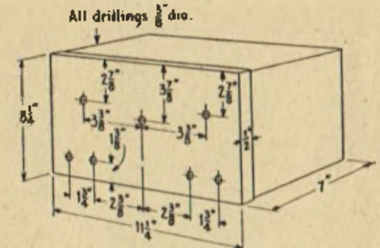
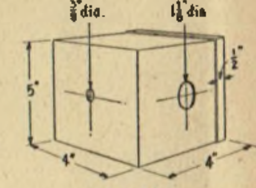


PANEL & CASE


COIL BOX

Working drawings of metal-work required for the oscillator.

TWO NEW USES FOR THE CATHODE FOLLOWER

There is little doubt that the cathode follower is the most versatile of all recently developed circuits. Radio literature is full of new applications for the circuit, and analytical articles describing its performance are still appearing. Here then are two uses for the circuit that readers may not yet have encountered.

AN AUDIO MIXER

Fig. 1 shows how two cathode followers may be used to mix the output of two separate audio channels. There is nothing new in using valves for this purpose, as everyone who has read the "Radiotron Designers' Handbook" will know. However, the circuit given here has a distinct advantage over the circuits which use either triodes or pentodes with common plate load resistors. These circuits provide appreciable gain at the same time as the mixing action. In designing new equipment this gain may be utilised, but if it is desired to add a second channel to an existing voltage amplifier system, the added gain can become an embarrassment, and it is poor practice to include a stage which amplifies, only to throw away the resultant gain by picking off a fraction of the output in order to reduce the overall gain to its previous figure. In addition, overloading problems will certainly accrue if an extra gain-producing stage is inserted in an already properly designed system. The cathode follower mixer system, however, has the advantage that it may be inserted at any point of an existing amplifier chain without necessitating the provision of extra pre-set gain controls, and without affecting to any appreciable extent the existing overall amplification.

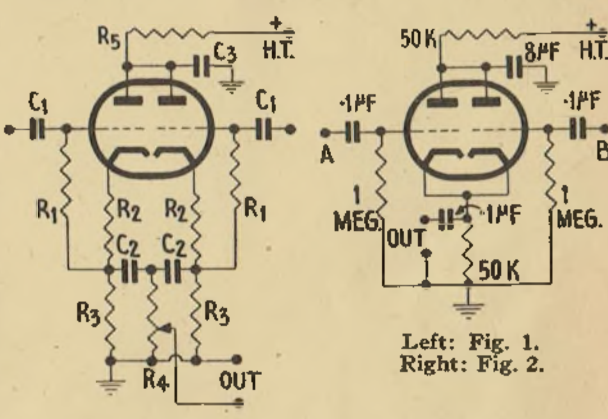
THE CIRCUIT

Fig. 1 shows a double triode such as the 6SN7 or 6F8 used in a mixer circuit. Each half is a conventional cathode follower, and the two are coupled together by means of the two condensers C_2 and the resistor R_4. The gain from each grid to the output terminal can be made to exceed 0.9 times, so that each channel has inserted in it a small but quite negligible loss. There will be no interaction at all between the two input terminals, because of the manner in which the output connection is made. The output from, say, the left-hand half is applied to both grid and cathode of the other half simultaneously, but this represents a net signal of zero, so that although the output of each half is connected to the input of the other, there is no mutual effect whatever.

In the circuit diagram R_4 has been shown variable, so as to form a main gain control which alters the total input to the remainder of the amplifier irrespective of the settings of the gain controls which are necessarily included in each channel. Of course, if the preceding channels are identical, as would be the case with two similar microphones, it would be possible so to design the preceding stages that individual gain controls were not necessary.

In general, however, the stages preceding the mixer will work from devices of differing output voltage, as, for example, a low-level microphone and a gramophone pick-up. In this case, the voltage amplifiers for each section can be designed to give approximately the same output voltage to the mixer stage.

If it is desired to modify an existing amplifier so as to include an extra channel, this can be done by breaking the existing voltage amplifier chain at a suitable point, and inserting one-half of the mixer stage. The new channel will now feed into the other half of the mixer, and the output of the latter will go to the main amplifier at the point where it was broken to insert the mixer.



Left: Fig. 1.
Right: Fig. 2.

$R_1 = 1$ Meg.
$R_2 = 1500$ ohms.
$R_3 = 50$k.
$R_4 = 100$k. Pot.
$C_1 = 0.05$ mfd.
$C_2 = 1$ mfd.

The circuit values given in the caption to Fig. 1 are suitable for type 6SN7 and 6F8-G, or for two separate 6J5's, 6C5's, 6P5's or any similar small triode. The reason why the one set of values will serve for almost any tube is that the cathode follower is very non-critical as to circuit values. The performances in all cases will be essentially the same.

A PUSH-PULL BALANCE INDICATOR

The second use described in this article is that of a balance indicator for testing resistance-coupled push-pull stages. The circuit is shown in Fig. 2. It consists of a simplified version of Fig. 1, in which the single load resistor forms a bias resistor for each cathode follower. A pair of headphones is connected across the output terminals, and the device is used as follows. The points A and B are clipped on to the input or output terminals of the push-pull stage that is to be tested for balance; and a single frequency input voltage is applied to the amplifier. If the push-pull voltages applied to the test device are accurately balanced, no signal will be heard in the headphones. Thus, the circuit can be used to balance the output voltages of a paraphase inverter stage, by connecting A and B to the plates of the paraphase stage, and then adjusting the balance control for minimum sound in the headphones. The scheme works because of the non-phase-reversing characteristic of the cathode follower. Thus, if the inputs at A and B are 180 degrees out of phase and equal in amplitude, each cathode follower will produce similar voltage across the 50k. common cathode resistor. If the amplitudes are unequal there will be a residual signal which will disappear on adjusting the signals for equality.

VALVE CURVES IN CLASS A AMPLIFIER DESIGN

PART II

In Part I of this series we showed how a load line drawn on the plate-voltage/plate-current characteristic of a triode may be used to find, in a qualitative manner, that the skeleton circuit given in Fig. 2 produces at the plate an amplified version of the signal applied to the grid. As yet, however, no mention has been made of how to use the valve curves for designing a resistance-coupled amplifier stage.

DESIGNING A RESISTANCE-COUPLED TRIODE AMPLIFIER

In an ordinary resistance-coupled triode amplifier stage, there are other components to consider in addition to the valve and its load resistor Rl. Of these, the most important are the cathode bias resistor, if one is used, its associated bypass condenser, and the coupling circuit to the grid of the following tube, consisting of a blocking condenser and the grid leak resistor for this tube.

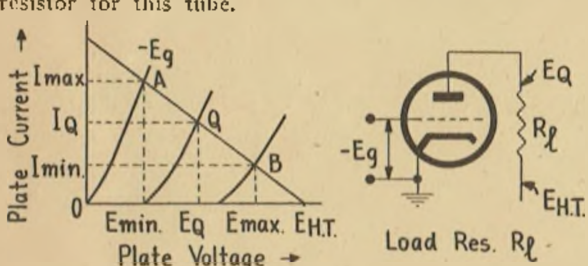


Fig. 2

Before the bias resistor is chosen, the desired grid bias voltage must be known, so that initially this component does not enter into the argument. The following grid resistor, however, does have an effect on the performance of the stage we are designing, since it is for all practical purposes in parallel with the load resistor Rl. This can be seen when it is realised that the H.T. end of Rl is at earth potential as far as signals are concerned, on account of the bypassing effect of the filter condenser which is connected to the same point. Thus, although for D.C. purposes Rl is the load resistor, when we come to consider the signal output of the tube, the actual load resistor is Rl in parallel with Rg, the following grid resistor. Thus the true A.C. load for the valve is smaller in value than Rl. This means that when the operating point Q has been found, by means of drawing a load line for the value Rl, the strictly accurate way to compute the signal output is to draw, through Q, a second load line whose slope represents the value of Rl and Rg in parallel. However, under most conditions, the extra accuracy given by this more complicated procedure is hardly warranted, so that we will neglect the effect of Rg.

The error introduced by this process is small enough to be neglected, as long as Rg is much greater in value than Rl, and this is usually the case. If distortion is to be kept to a minimum, or if the maximum possible output voltage is required, then the value of Rl must be kept as high as possible. But, since the value of Rg cannot be higher than the maximum recommended grid resistance for the tube which is to follow, Rg has an upper limit of about one megohm. Thus, if Rl is made too high in value, Rg is no longer very much greater than Rl.

The conflicting requirements of Rg and Rl, however, can be satisfactorily met by a suitable compromise. For instance, if Rg is made 1 meg., then Rl

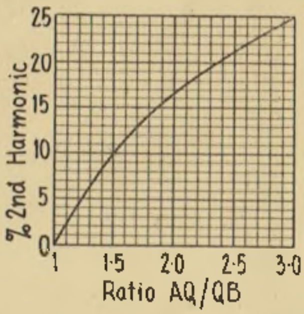


Fig. 3. This curve can be used to estimate 2nd harmonic distortion in any resistance coupled triode stage.

may be as high as 0.25 meg., and if Rg is made 0.5 meg., a satisfactory value of Rl is 100,000 ohms.

With these principles in mind, Rg and Rl are chosen. Next, the H.T. voltage, if not settled, is decided upon. This done, the load-line corresponding to Rl is drawn on the valve curves by the method outlined in Part I of this series, giving the equivalent of Fig. 2. The next question is to decide on the required operating bias. With power amplifiers (which we will consider later) it is customary to assume that when the grid is swung in the positive direction, grid current starts at the point where the grid voltage is zero. In this case, the permissible peak input voltage is exactly twice the grid-bias voltage. However, with voltage amplifiers, this process is not accurate enough, because in practice grid current starts at a grid voltage of − 1.

Thus, if the bias is, say, − 3 volts, the maximum permissible signal is 2 volts peak, and not 3 volts peak. Thus, if there is not a curve on the family for − Eg = 1, the next step is to note where this curve would cut the load-line if it were present. Suppose the top two curves on the sheet are for − Eg = 0, and − Eg = 3. Then a satisfactory estimate can be obtained by noting where the load-line cuts these two curves, and dividing the intervening part of the load-line into three equal parts. The two divisions thus formed give the places where the curves − Eg = 1 and − Eg = 2 would cut the load-line. Next, the point where − Eg = 1 cuts the load-line is called A, as in Fig. 2. The point A now gives I max. and E min., also as in Fig. 2, and these values may be read off the axes and tabulated. We are now in a position to find the points Q and B by a system of trial and error, aided by Fig. 3.

Earlier in this article, we saw that distortion is illustrated by the load-line and valve curves if the operating point, Q, is such that AQ is no longer equal in length to QB. It so happens in a resistance-coupled triode that such distortion as occurs is predominantly second harmonic, and that the amount of inequality in AQ and QB can be used as a measure of the amount of second harmonic distortion. Now, in any practical triode, as the bias and input voltages are increased to a point where distortion occurs, AQ always becomes longer than QB, so that Fig. 3 has been drawn as percentage second harmonic distortion against the ratio AQ to QB. Suppose, for example, that at full output we must have no more than 5 per cent. second harmonic distortion. Fig. 3 tells us that AQ : QB must not exceed 1.22 : 1. Now, armed with this information, we are in a position to re-examine our load-line on the valve curves. The first step in choosing the bias voltage is to make a rough guess, and see where this leads us. For example, suppose that in Fig. 2 the middle curve represents — 5 volts, and looks as though it would give a reasonable answer. This having been chosen as the bias voltage fixes the point Q, and at the same time the point B. In our example, the maximum peak input signal is 5 − 1 = 4 volts, because, if this value is exceeded, the grid voltage will exceed — 1, and grid current will

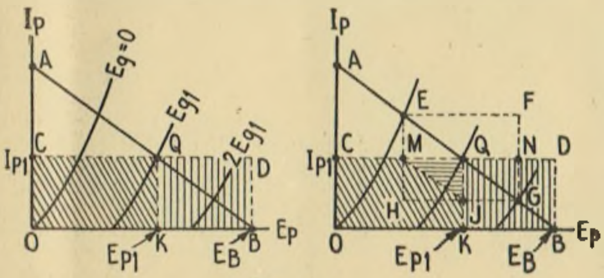


Fig. 4.

be drawn. Thus, on the negative half-cycle of the input voltage, the grid must reach — 9 volts. Where the curve for Eg = 9 cuts the load-line, we have the point B. AQ and QB are now measured as accurately as possible, and the ratio AQ : QB is worked out. If this value exceeds 1.22, then the distortion exceeds 5 per cent. of second harmonic. If this is found to be the case, the whole process is repeated for an operating bias of 4 volts and a peak signal of 3 volts. If this turns out to give 5 per cent. second harmonic at maximum signal, then the required bias is 4 volts. Should our first trial have shown a ratio of AQ : QB much smaller than 1.22 : 1, then the actual value of distortion produced can be found by reference to Fig. 3. In this case, the chances are that the output voltage at the grid-current point is too small. Whether this is the case or not can be checked by knowing the peak output voltage required to load fully the succeeding tube, since, as described earlier, the curves and load-line tell us that the peak output voltage of the stage is ½(E max. — E min.). If the output voltage is found to be sufficient, or more than sufficient, then the first value of grid bias may be used.

We have now reached the stage where we have fixed the following: (1) H.T. voltage, (2) load resistor, (3) following grid resistor, (4) operating bias in volts. All that remains is to decide what value of cathode resistor is needed to give this bias. This is done by referring once again to the valve curves. The point Q has been marked off, so that I_Q can be read off. This plate-current flowing through the bias resistor must produce in it a voltage drop equal to the required bias voltage. Thus if I_Q is in milliamps, and Eg is in volts, the bias resistance may be found from the formula:

$$Rc = \frac{1000\ Eg}{I_Q} \text{ ohms.}$$

The stage has now been completely designed, except for such matters as the values of the coupling condenser and cathode bypass condenser, which have no bearing on the stage gain at middle frequencies, or on the amount of distortion introduced. They do, however, affect the frequency response of the stage and must be properly chosen, but that is a matter which cannot be dealt with in this article, as it has no direct connection with the valve characteristics or their use. Part I of this article described how the voltage gain of the stage may be calculated from Fig. 2, and this same procedure may be used to find the gain in the case where the stage has been designed by the above method.

USEFULNESS OF THE METHOD

The method given above is particularly valuable in cases where H.T. voltages have to be used that are not close to any of those listed in the manufacturers' resistance-coupled data. The most important case of this is when more output voltage than normal is required, and is to be obtained by using a supply voltage of 500 or more.

In this case there is a danger of working the tube in excess of its ratings. For instance, either the maximum D.C. plate-voltage or plate-dissipation might be exceeded where a small triode is to be resistance-coupled with an H.T. supply of 500 volts or more. The design method we have outlined enables these things to be checked very readily. For example, as long as E_Q does not exceed the rated maximum plate-voltage for the tube, all will be well, and whether or not this occurs can be found merely by inspection of the graph used to fix the design.

In Fig. 4 we have this graph, re-drawn to show how the dissipation in various parts of the circuit may be calculated. AB is the load resistor and Q the operating point. Ip_1 is the D.C. plate-current, and Eb the H.T. supply voltage. Thus the D.C. power drawn from the supply must be $Eb \times Ip_1$, which is represented on Fig. 4 by the area of the rectangle CDBO. Now this power is dissipated partly in the load resistor and partly in the valve. The current through both is Ip_1, but the voltage drop across the valve is $OK = Ep_1$, so that the power dissipated in the plate-circuit of the valve is $Ep_1 \times Ip_1$, which is represented on Fig. 4 by the area of the rectangle CQKO. By similar reasoning, the power dissipated in the load resistor, Rl, is given by the area QDBK, which is $Ip_1(Eb - Ep_1)$. These two results are important, because the first tells us whether the plate-dissipation of the valve is being exceeded or not, and the second tells us the minimum wattage rating for Rl.

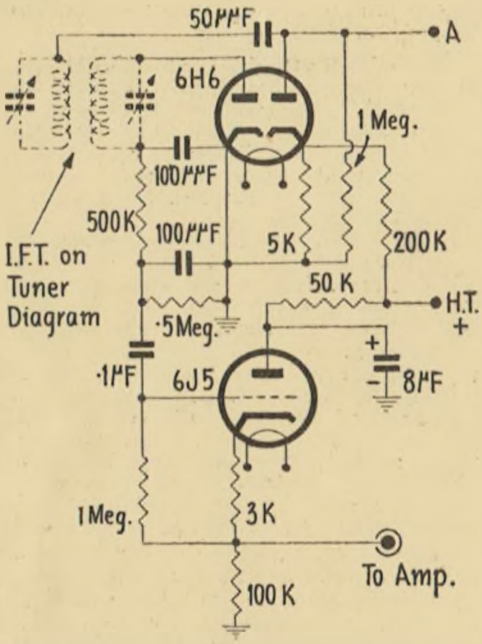
Thus, it can be seen that the valve curves tell practically the whole story of the amplifier stage when they are used in conjunction with the appropriate load-line drawn on them.

(To be continued.)

QUESTIONS and ANSWERS

J.E., Paeroa, writes:—

"I intend to build a radio-gram, using, if possible, the R.F. and I.F. stages of the 'Bandspread Six' and the 'High-quality 6A3 Amplifier.' I would be grateful if you could mark off on the 'Bandspread Six' circuit the parts that are not necessary, so that the modified arrangement will be suitable for feeding into the amplifier."



Modifications to 2nd detector circuit of Bandspread Six.

It is not possible to recommend a simple elimination of components from the "Bandspread Six" circuit, since, if the output stage only is omitted, there will be far too much audio output from the 6Q7 to feed into the amplifier. Also, it is not possible to modify the 6Q7 circuit so as to leave out the triode amplifier and still allow proper operation of the A.V.C. rectifier circuit.

It is recommended, therefore, that the accompanying circuit be used to follow the I.F. stage in the "Bandspread Six." A 6H6 is used to replace the 6Q7, and a 6J5 follows, used as an output cathode follower.

The circuit is ideally suited to this particular purpose, because the use of the cathode follower reduces practically to zero distortion which normally occurs at high modulation percentages when an A.C. shunt is placed across the diode load resistor. Also, the cathode follower's low output impedance makes it unnecessary to have the tuner close to the main amplifier. It will be noted that the audio volume control is not included in the tuner, so that the amplifier gain control may be used both for radio and for gramophone.

In adding this circuit to the remainder of the "Bandspread Six" circuit, it should be noted that the point A is connected to the wire which in the original goes to the "high" end of R_7. Also, no blocking condenser has been included in the output lead, because the 6A3 amplifier has one already, viz., C_1 on the circuit diagram.

J.R.P., New Plymouth, writes:—

"In the January, 1947, issue of 'Radio and Electronics' you give single and push-pull operating conditions for the EL33. In the push-pull data, a common cathode resistor of 140 ohms is specified, but I am using 75 ohms, which is half the value given for a single tube in the previous section. Can you tell me which of these values is correct, and why?"

The answer is, oddly enough, that both are correct. The push-pull operating conditions give class AB_1 operation, in which greater than normal class A bias is used, with consequent reduction in plate current. The conditions under which J.R.P. is working his amplifier give pure class A operation, which is best for quality of reproduction, although rather more plate current is taken by the tubes. In comparing the two sets of operating data given in "Radio and Electronics" for the EL33, it will be noted also that the load impedance for a single tube is given as 7000 ohms. Thus two tubes in class A push-pull should have a plate-to-plate impedance of 14,000 ohms. However, in the push-pull data, the plate-to-plate load impedance is given as 10,000 ohms. This reduction of plate load impedance is usually done in conjunction with the increase of bias, when valves are being worked in class AB_1. Frequently it allows greater power output to be obtained than does the higher impedance, while still keeping the distortion down to a reasonable level. However, as stated above, if the utmost in quality is desired, it is best to operate in pure class A, with the same bias as for single-ended operation, and with a plate-to-plate load impedance of twice the single-ended value.

B.T.H., Ngaruawahia, writes:—

"The series of articles in 'Radio and Electronics' on the five-inch service oscilloscope interested me greatly. So much so that I intend attempting to construct one. Unfortunately, I have no C.R. tube which would be suitable, but possess a 5FP7, which is a magnetic deflection and focusing type. Could you advise me on modifying your design to suit a tube of this type?"

Unfortunately, a magnetically-deflected and focused tube is not very satisfactory for use as a testing oscilloscope. The reason for this is to be found in the deflection system. If adequate sensitivity is to be provided at medium and low frequencies, iron-cored deflecting coils must be used. This makes good high-frequency performance as difficult to obtain as in an audio transformer, and gives the overall amplifier a performance similar to that of a transformer coupled audio stage. This state of affairs is not very satisfactory, since the oscilloscope, to be used for audio testing, needs to have a much better phase and frequency response both at high and low frequencies than any device likely to be tested. This is the reason why magnetically-deflected tubes are hardly ever used in test oscilloscopes.

Even if such a 'scope was desirable, it would not be possible to modify the design of our own instrument, as a magnetically-deflected tube would require a completely different time-base and amplifier design.

TUBE DATA

THE 815 PUSH-PULL BEAM TETRODE TRANSMITTING TUBE

This is one of the more recently developed tubes suitable for amateur transmitting applications. It has recently become available in this country.

GENERAL

The 815 is a dual beam-tetrode, containing two complete electrode assemblies in one envelope. Its maximum D.C. plate input power (I.C.A.S.) is 75 watts, which rating is retained to a frequency of 150 mc/sec. It is capable of a carrier power output under these conditions of 45 watts as a plate-modulated amplifier, or 56 watts under C.W. conditions. It is therefore almost ideal for medium-powered transmitters on any amateur band up to and including the 166-170 mc/sec. band, where it may still be used at slightly reduced ratings. Its driving power requirement is exceedingly small, in common with other beam tubes, and is less than half a watt, thus rendering oscillator and frequency multiplying circuits particularly easy to provide.

A very attractive feature of the 815 is its low plate voltage, which has a maximum of 500. Considering its power and frequency capabilities in conjunction with its low plate voltage requirement, the 815 is very economical to run, and to provide power supplies for, so that its slightly higher first cost compared, say, with an 807, is amply compensated.

APPLICATIONS

The 815 may be used as a Class AB_2 audio amplifier, grid or plate modulated Class C amplifier, or an unmodulated Class C amplifier. In the first-mentioned service it can produce 54 watts of audio power with only 500 volts on the plate.

This tube is no more difficult to use than any transmitting beam tetrode, and any conventional push-pull circuits may be used with it. Inter-electrode capacities are small, and in most applications neutralisation is unnecessary, as long as proper circuit shielding is employed.

Screen voltage may be obtained from a voltage divider or through a dropping resistor from the plate supply. If a dropping resistor is used, the plate supply regulation should be such that the plate voltage will not exceed 600 under key-up conditions. Any of the normal methods of obtaining grid bias may be used, assuming that the usual precautions are taken against loss of bias.

Each unit in the tube has its own heater, and the two heaters have one common terminal on the valve base. Thus, the heaters can be operated either in series or parallel. If the latter connection is used, 6.3v. at 1.6 amps. is required, and the former needs 12.6v. at 0.8 amp.

CHARACTERISTICS AND RATINGS

(Unless otherwise stated, values are for both units.)

Heater (A.C. or D.C.):

Voltage per unit	6.3v.
Current per unit	0.8 amp.
Mutual Conductance (at plate current of 25 ma.)	4 ma./v.
Grid-screen amplification factor	6.5
Inter-electrode capacities (each unit)—	
Grid-plate (with external shield)	0.2 mmfd.
Input	13.3 mmfd.
Output	8.5 mmfd.
Maximum height	$4\frac{9}{16}$ inches.
Maximum diameter	$2\frac{1}{4}$ inches.
Socket	Standard Octal.

MAXIMUM C.C.S. AND I.C.A.S. RATINGS WITH TYPICAL OPERATING CONDITIONS

(1) As Push-pull R.F. Amplifier and Oscillator:

CLASS C TELEGRAPHY—KEY DOWN

	C.C.S.	I.C.A.S.	
D.C. Plate Voltage	400 max.	500 max.	volts
D.C. Screen Voltage	225 max.	225 max.	volts
D.C. Grid Voltage	—175 max.	—175 max.	volts
D.C. Plate Current	150 max.	150 max.	ma.
D.C. Grid Current	7 max.	7 max.	ma.
Plate Input	60 max.	75 max.	watts
Screen Input	4.5 max.	4.5 max.	watts
Plate Dissipation	20 max.	25 max.	watts

TYPICAL OPERATION

	C.C.S.	I.C.A.S.	
D.C. Plate Voltage	400	500	volts
D.C. Screen Voltage—			
Fixed	145	200	volts
or Series Resistor	15k.	17.5k.	ohms
D.C. Grid Voltage—			
Fixed	—45	—45	volts
or Cathode Resistor of	260	265	ohms
or Grid Resistor of	10k.	13k.	ohms
Peak R.F. Grid-to-grid Voltage	116	112	volts
D.C. Plate Current	150	150	ma.
D.C. Screen Current	17	17	ma.
D.C. Grid Current (approx.)	4.5	3.5	ma.
Driving Power (approx.)	0.23	0.18	watt
Power Output (approx.)	44	56	watts

(2) As Plate Modulated Push-pull R.F. Amplifier:

CLASS C TELEPHONY

Carrier conditions per tube for use with a maximum modulation of 100 per cent.

	C.C.S.	I.C.A.S.	
D.C. Plate Voltage	325 max.	400 max.	volts
D.C. Screen Voltage	225 max.	225 max.	volts
D.C. Grid Voltage	—175 max.	—175 max.	volts
D.C. Plate Current	125 max.	150 max.	ma.
D.C. Grid Current	7 max.	7 max.	ma.
Plate Input	40 max.	60 max.	watts
Screen Input	4 max.	4 max.	watts
Plate Dissipation	13.5 max.	20 max.	watts

TYPICAL OPERATION

	C.C.S.	I.C.A.S.	
D.C. Plate Voltage	325	400	volts
D.C. Screen Voltage—			
Fixed	165	175	volts
or Series Resistor	10k.	15k.	ohms
D.C. Grid Voltage—			
Fixed	—45	—45	volts
or Grid Resistor of	11.25k.	15k.	ohms
Peak R.F. Grid-to-grid Voltage	112	116	volts
D.C. Plate Current	123	150	ma.
D.C. Screen Current	16	15	ma.
D.C. Grid Current (approx.)	4	3	ma.
Driving Power (approx.)	0.2	0.16	watt
Power Output (approx.)	30	45	watts

(3) As Push-pull A.F. Amplifier;

CLASS AB_2

	C.C.S.	I.C.A.S.
D.C. Plate Voltage	400 max.	500 max. volts
D.C. Screen Voltage	225 max.	225 max. volts
Max. Signal D.C. Plate Current	150 max.	150 max. ma.
Max. Signal Plate Input	60 max.	75 max. watts
Max. Signal Screen Input	4.5 max.	4.5 max. watts
Plate Dissipation	20 max.	25 max. watts

TYPICAL OPERATION

	C.C.S.	I.C.A.S.
D.C. Plate Voltage	400	500 volts
D.C. Screen Voltage	125	125 volts
D.C. Grid Voltage	−15	−15 volts
Peak A.F. Grid-to-grid Voltage	60	60 volts
Zero-Signal D.C. Plate Current	20	22 ma.
Max. Signal D.C. Plate Current	150	150 ma.
Max. Signal D.C. Screen Current	32	32 ma.
Load Resistance Plate-to-plate	6200	8000 ohms
Max. Signal Driving Power	0.36	0.36 watt
Max. Signal Power Output	42	54 watts

BASE CONNECTIONS

The base connections to the standard octal socket for the 815 are as follows: Pin 1, heater; Pin 2, grid of unit 2; Pin 3, cathode and internal shield; Pin 4, screen (common to both units); Pin 5, heater centre-tap; Pin 6, cathode (must be connected externally to Pin 3); Pin 7, grid of unit 1; Pin 8, heater. Note that the top cap on the sides of the tube corresponding to Pins 2 and 7 are the plate connections of unit 2 and unit 1 respectively.

(Concluded on page 48.)

THE NEW ZEALAND ELECTRONICS INSTITUTE

Auckland Branch.—The March meeting of this branch was held at the Auckland University College when Mr. H. A. Whale, M.Sc., addressed the members on the subject of loud-speakers and reproduction. This meeting followed a discussion at the University on the subject of audio amplifiers. Mr. Whale added the practical touch to his address with demonstrations on audio apparatus. At the first April meeting members will continue their special consideration of audio frequencies with an address by Mr. S. J. MacDonald, B.Sc., A.M.I.E.E., on "The Automatic and Carrier Telephone System."

Christchurch Branch.—The April meeting of this branch was held at the Canterbury University College when Messrs. Unwin and Davies presented a paper on the radar meteorological project at Canterbury. A sequel to the meeting was the arranging of a special visit to Ashburton on Sunday, 27th April, for an explanation of the equipment being used in connection with the project.

Dunedin Branch.—At the March meeting of this branch Mr. A. R. Harris addressed members on the subject of radio direction-finding. Notes of the address are in course of preparation for later distribution. At the April meeting Mr. J. P. Pickerill addressed members on the subject of frequency modulation transmission and principles. The May meeting is to be held at the King Edward Technical College when Mr. W. G. Collett, M.Sc., is to continue his address given at the December meeting on the subject of principles of cathode ray oscilloscope operation.

Wellington Branch.—The April meeting of this branch coincided with an extension of the lighting restriction hours with the result that the meeting had a late start and had to be closed at an earlier hour than usual. Mr. S. C. Shea kindly consented to postpone his address until the next meeting. The chairman raised several points for discussion in connection with branch affairs and recommendations are to be brought forward for consideration at the May meeting.

A special evening for student members was held on 16th April when Mr. J. L. Hasnip gave a talk on three-phase distribution. He mentioned that although the subject selected for him may not be considered as coming under the heading of "electronics," it was an important subject since many electronic devices depended on the low-frequency supply for their operation.

General Matters.—Advices received from the branches indicate that meetings are being planned for the second year of the Institute commencing on 1st January, 1947. Some of the subjects are: R.F. Heating; North Island Power System; Technical Information and How to Fnd It; Motors and Signalling; Hill and Dale Recording; Plastics; Diffraction of X-rays; X-ray Equipment. One branch has arranged for a demonstration of the X-ray plant at one of the hospitals.

The May meeting of all branches will include elections for representatives on the council; also the elections of branch officers and committees. For these initial elections voting powers are exercisable by all those who have made application for membership.

Applications for student membership have been considered. Applications for other grades are still under consideration and on receipt of the grading

(Concluded on page 48.)

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PART IV
CONSTRUCTIONAL DETAILS
(Continued.)

A.V.C. WIRING

V_7, similarly to V_8, has above its socket a piece of terminal strip, which in this case carries C_{25}, C_{26}, C_{27}, and C_{28}, as well as R_{30}, R_{32}, R_{31}, R_{33}, and an H.T. + tie-point. The two A.V.C. lines from C_{28} and C_{27} respectively are then taken round the side and front of the chassis to the A.V.C. on/off switch SW_2. R_{29} is mounted on the V_7 socket, and R_{35} is mounted between the cathode pin and the H.T. + tie-point on the terminal strip.

SOME POINTS ABOUT COMPONENTS

The above remarks should cover most of what readers require to know about the detailed wiring of the set. However, some of the components require special mention. First, there is the four-gang condenser. There are two types on the market at the moment, one of which is an English gang with a 532 mmfd. maximum capacity. This is **not** the one to buy, as this capacity is too high for the coils available, which are mostly designed for gangs with either a 375 or 420 mmfd. maximum capacity. The right condensers are those which are ex-war assets stock, as these have a maximum capacity in the region of 430 mmfd., and suit admirably the unshielded coils which are being sold for use with 420 mmfd. gangs.

The coils to buy are therefore those designed for a 420 mmfd. gang. If the high-capacity gang is used with these coils, the coverage on the low-frequency end of the band will be too great, taking the tuning range to 500 kc/sec. or even less. If this happens, constructors will experience trouble due to the low-frequency end of the band approaching the I.F. too closely. The trouble, should it occur, will be in the form of oscillation, almost incurable at the extreme low-frequency end of the dial—which is off the broadcast band in any case!

L_2, the B.F.O. coil, is made from an iron-cored I.F. transformer by cutting off the lower winding and re-gluing the iron core for the remaining coil, should this come out during the cutting operation. C_{32} is the front-panel pitch control, and is made from a 0-25 mmfd. or larger midget condenser by removing plates until there are four stators and three rotor plates left. The unmarked condenser across L_2 is the I.F. trimmer inside the can. The B.F.O. on/off switch, SW_3, is not a separate component, but is built into C_{32} simply by bending the tip of one of the plates enough to cause it to short-circuit the condenser when it is fully meshed.

Apart from these few exceptions, all components in the receiver are standard.

ORDER OF CONSTRUCTION

With a set of this nature it is excellent policy to start the wiring from the loudspeaker backwards. This enables every stage to be tested as it is wired up, and ensures that any "bugs" are localised and dealt with before the set is complete. Of course, the method should not be adhered to quite slavishly. For instance, it is a good plan to wire up all heater circuits first, simply to prevent access difficulties after the components of a given stage have all been wired in.

The power supply and two audio stages should be wired up first, and tested with the audio output of a signal generator or with a record player, to ensure that everything is working correctly. After this, the best order is V_6 and V_5, followed by V_8 and V_7, the A.V.C. amplifier and rectifier.

It should be noted that with the A.V.C. switch in the "on" position, adjustment of the T_8 trimmers should be made for **minimum** signal at the output of the receiver. Thus, when V_5-V_8 inclusive have been wired up, this section can be tested with the signal generator by feeding 465 kc/sec. into the primary of T_6 through a blocking condenser. The secondary trimmer of T_6 and both of T_7 are then aligned for maximum receiver output. Next, the A.V.C. switch is turned to the "on" position, and the signal level is brought well up. Then T_8 is aligned for **minimum** receiver output. This adjustment is correct, because, as T_8 is brought on to frequency, the A.V.C. control voltage increases, and cuts down the gain and output of the receiver. The alignment is most sensitive when, with T_8 properly tuned, the gain of the receiver just begins to be decreased by A.V.C. action.

The next step is to wire up V_4 and V_5, thus completing the I.F. amplifier. At this stage a thorough check should be made for stability. This is done by temporarily shunting 500-ohm resistors from cathode to earth on both V_4 and V_5, and aligning all the I.F. trimmers except the primary of T_5, into which the signal generator is fed through a blocking condenser. The shunted cathode resistors will increase the gain of V_4 and V_5 to their maximum, so that any instability or tendency to oscillation will be shown up by this test. If the amplifier is not properly stable, it is worth while going to some trouble to render it so. Points to be watched in this connection are: Earthing all bypasses for each stage to a single chassis point, making certain that all bypass condensers are mounted right at the points they are intended to bypass, mounting the associated de-coupling resistors right up to their bypass condensers, and making sure that I.F. is not being passed through the audio amplifier and causing a large voltage at this frequency to appear across the primary of the output transformer.

To check whether the last-mentioned effect is occurring, a large condenser (say, 0.1 mfd.) is connected across the output transformer primary. If this cures the trouble, the condenser is replaced by as small a one as will still effect a cure. This ensures a minimum effect on the higher audio frequencies.

When the I.F. stages are proved to be inherently stable, the temporary cathode resistors are taken off, thus reducing the gain to the right value for the set, with the positive assurance that whatever may subsequently go wrong, I.F. instability is not the cause of the trouble.

After this point, V_1, V_2, and V_3 can be wired up, and the set is complete. No attempt should be made to put the S-meter into operation until the complete receiver has been wired up and aligned. This will be

dealt with later, but the complete circuit should be wired up, merely omitting one of the meter connections temporarily.

ALIGNMENT

Although this set is rather more comprehensive than the average and definitely needs a signal generator for proper alignment, this is not at all tricky, and follows normal procedure exactly. Since the set has a 0-100 dial only, there is no question of making the set track with a pre-calibrated dial. The alignment procedure is therefore as follows: First, the I.F. stages are trimmed up. The oscillator is rendered inoperative by short-circuiting the grid to earth. This can be done at the oscillator section of the condenser gang. Next, I.F. is fed in to the plate pin of the V_4 socket, via a blocking condenser. Then, with the A.V.C. switch in the "off" position and the audio gain control fully on, the output meter is connected across the output transformer primary, and the two trimmers of T_7 and the second trimmer of T_6 are adjusted for maximum output. Care is necessary to see that V_5 is not overloaded, and that as the level increases due to the circuits coming into line, the output of the signal generator is backed off to keep the output level approximately constant.

Next, the signal generator output is shifted to the plate pin of V_3, and both trimmers of T_6 and the second one of T_5 are adjusted. After this, the signal generator is fed into the grid of V_3, and all I.F. trimmers are given a final adjustment. This will need to be done very carefully, because the I.F. selectivity is very high, and a symmetrical response curve is quite important.

The next stage is to align the A.V.C. amplifier transformer, T_8. To do this, the A.V.C. switch is turned to the "on" position. This will bring the A.V.C. into operation as long as T_8 is approximately adjusted. The trimmers of this transformer are now adjusted for minimum output from the set, as described earlier. This is the best method of adjusting T_8, as it does not upset the high-impedance A.V.C. circuit. An alternative method is to insert a micro-ammeter in series with R_{30} at the earthed end, and to tune T_8 for maximum current through this meter. This will give the same answer as the previous method, but entails more trouble, and the possession of a sensitive meter. If the A.V.C. I.F. transformer is not properly aligned to the same I.F. as the remainder of the receiver, a peculiar effect becomes apparent, which does not show up in ordinary receivers. What happens is that the A.V.C. comes into action much closer to the carrier on one side of resonance than on the other, with the result that the correct tuning point is not in the centre of the apparent range covered by the signal when the tuning dial is turned. Also, it results in the tuning meter giving an indication at a different dial reading from the one obtained if tuning is done by ear. However, the alignment procedure given above completely obviates the possibility of this defect occurring, and the signal tunes in exactly at the maximum reading of the S-meter.

R.F. AND OSCILLATOR ALIGNMENT

This is quite straightforward, and should not give any trouble. The first step is to set the oscillator trimmer at about half-way in. Next, a signal is fed into the aerial at 1450 kc/sec. The set is tuned to receive the signal, the A.V.C. is turned off, and the manual gain control is turned back until overloading ceases. The signal level should not be too high. The three R.F. trimmers are adjusted, starting with the mixer grid and working back to the grid of V_1. If necessary, the signal generator output is reduced as the circuits come into line, so that the set does not overload. Incidentally, if the manual gain is too far advanced, the R.F. stages produce too great a signal for the mixer to handle, so that the latter overloads before the I.F. stages if either too much signal or too high a setting of the manual gain is employed.

PADDER ADJUSTMENT

When the trimmers have been peaked up, the signal generator is turned to 600 kc/sec., and the receiver tuned to receive this frequency. A slight adjustment of the oscillator padder is made in either direction, after which the gang is retuned for maximum output. If this output is greater than the previous value, the padder is shifted again, in the same direction as before, and the gang retuned again. This process is carried on until the output meter begins to drop, when the padder is turned back to the position that gives maximum output.

If the padder is a long way out before the adjustment process is started, it is a good idea to make a rough initial adjustment as follows: The gang condenser is set about ten dial divisions out from the fully-closed position. Then, with the signal generator turned to 570 kc/sec., or with an aerial, if 2YA is on the air, 2YA or 570 kc/sec. is tuned in by means of the padder only. This procedure places the set in a suitable condition for performing the proper adjustment as described above.

After the padder has been adjusted, the set should be retuned to 1450 kc/sec., and the aerial, R.F., and mixer trimmers peaked up again to allow for the slight alteration in oscillator tuning brought about by adjusting the padder. This completes the alignment of the signal circuits.

B.F.O. ADJUSTMENT

This simply entails adjusting the B.F.O. to oscillate on 465 kc/sec., but if not carried out in the correct manner, a misleading result can be obtained in which a beat is obtained, but with the B.F.O. on some entirely incorrect frequency.

The best method is to render the set oscillator inoperative, exactly as when the I.F. stages are being aligned. Then, a signal at 465 kc/sec. is fed into the mixer grid. The amplitude of the signal should be kept very small—say, 20 microvolts or so. Next, the B.F.O. pitch control C_{32} is turned so that the condenser is half-meshed. The trimmer in the B.F.O. can is then tuned until a beat is obtained with the I.F. signal, and is finally adjusted for zero beat. At this stage, the B.F.O. has been properly aligned, so that a movement of C_{32} on either side of its centre position will give a beat note whose pitch can be adjusted to suit the listener. The B.F.O. is turned off by turning C_{32} until one of the rotor plates, with its tip suitably bent, short-circuits to the stator, and stops the oscillator from functioning.

Another workable method of adjusting the B.F.O. is to tune the receiver to a low frequency station such as 2YA. The B.F.O. trimmer is then screwed hard down, and the pitch control set to the centre of its

A BASIC INDUSTRY EMERGES!

MR. CHARLES E. FORREST, Chairman and Managing Director, International Radio Co. Ltd., New Zealand Industries Ltd., Bobbie Pins Ltd., and New Zealand Wires and Cables Ltd.

Undoubtedly one of the most important industrial developments of recent date is the establishment in New Zealand of the basic strategic industry of the manufacture of insulated wires and cables. Experts hold that future plans for Empire defence must be based on the decentralisation of basic strategic industries.

What industry is more indispensable, in peace or in war, than that of the manufacture of Insulated Wires and Cables?

During the war period New Zealand was in a desperate position for insulated wires and cables; the Armed Forces, Munitions programme, Power Boards, Public Bodies, and Transport were all severely handicapped by shortage of insulated wires and cables. This industry is, therefore, a basic strategic industry of the highest importance.

While on a business tour overseas in 1939, Mr. Charles E. Forrest realised the necessity for the establishment in New Zealand of this particular industry. He immediately collected all necessary information relating to the purchase of latest types of machinery and the correct raw materials for the initiation of this basic and all-important industry in New Zealand.

The compilation of this information was a real task in itself and took some considerable time, as Mr. Forrest's investigations overseas convinced him that only the most modern machinery and materials should be used.

At this stage of his activities war broke out, and it immediately became apparent that such an industry was of primary strategical importance to New Zealand and vital to its war effort.

After discussions with the authorities in New Zealand, orders for the machinery were placed in June, 1942. The New Zealand War Cabinet and the Department of Supply were impressed with the importance of establishing this industry, and in their letter to Mr. Forrest dated 24th July, 1942, asked "that this industry be established as soon as humanly possible." Credit should be given to the Supply Mission in Washington, which, in co-operation with Mr. Forrest's own connections overseas, was able to obtain remarkably good delivery, and the first machinery arrived in New Zealand during October, 1943.

With the plant about to be shipped, due to inability of obtaining raw materials under lease-lend or by bulk purchase, it appeared that the new industry would be stillborn. The Minister of Supply at the time, the late Honourable D. G. Sullivan, realising the seriousness of the position, then directed that import licences be issued to Mr. Forrest's company so that materials, if possible, could be obtained by a direct negotiation. Mr. Forrest, through his well-established connections abroad, was able to have delivered to New Zealand, within six months, the raw materials necessary for the launching of this basic strategical secondary industry in New Zealand.

Factory premises were secured in Auckland, and New Zealand engineers, working in close co-operation with technicians in Mr. Forrest's Australian factory, installed all the machinery in short time. The first Insulated Wire and Cable ever made in New Zealand was produced on 12th February, 1945, and for the first time in history an Insulated Wire and Cable Factory was in production in New Zealand. Since the factory commenced operations, ten thousand miles of Insulated Wires and Cables have been produced in it.

It is worthy of note that large quantities of household wiring cables have been produced, and it is more than probable that, without the company's production, the progress of the housing industry in New Zealand would have been considerably retarded.

Also, owing to the severe shortage of automobile cables in New Zealand, the factory decided to manufacture a range of electrical cables for the automotive replacement market. The large quantity of such cables sold indicates that, unless this company had established itself in New Zealand and produced automobile cables, the servicing of the electrical wiring systems on automobiles would have been drastically curtailed.

Radio Hook-up Wire, electrical flex for appliances, heavy-duty electrical cables, have all been produced in large quantities, and such production has been instrumental in enabling the various electrical industries to keep in production in spite of grave shortages of electrical wires and cables from overseas sources.

Further machinery is being added to enable the factory to produce sufficient insulated wires and cables to satisfy New Zealand's entire requirements. New Zealand personnel have been trained in technique and production, and to-day New Zealand wires and cables are the equal in quality of any produced in the world.

Mr. Charles E. Forrest, by his vision, courage, tenacity of purpose, and resourcefulness, was able to establish this essential basic industry at a most critical time. A large measure of hostility from various sources was overcome and the industry is now firmly established, and has already proved its worth to the country.

It is basic strategic industries of this type which must be encouraged and protected in New Zealand, as, come peace or come war, they are indispensable to this country's economy and well-being.

"FOUNDERS OF THE INSULATED WIRE AND CABLE INDUSTRY IN NEW ZEALAND."

travel as before. Then the trimmer is slacked off until a beat note is heard, and final adjustment to zero beat is made.

The possible trouble referred to above works in this way: It is possible to adjust the B.F.O. to oscillate at 565 kc/sec., whose second harmonic is 1130 kc/sec., the frequency of 2ZB. Thus when the set is tuned to the latter station, a beat note is audible. However, it is not a beat between B.F.O. and the I.F., as it should be, but is caused by the 2nd harmonic of the B.F.O. beating directly with the signal frequency. Thus when the set is tuned to another station no beat is heard. This behaviour serves to identify the trouble, should it occur. It should be made clear, though, that the circuit constants of the B.F.O. have been so chosen that the amplitude injected at the 2nd detector is quite small. This has the effect of producing a loud beat note when a weak carrier is being received, but only a very weak one on a station of any strength. This adjustment was chosen because the purpose of the B.F.O. in this set is to assist in locating weak carriers and not to give a good beat note on strong ones. Thus, if the B.F.O. is being adjusted by the second method, it is necessary to listen carefully for a very weak beat note, or the correct adjustment might be passed over. In addition, with a strong signal, the incorrect beat oscillator frequency will give a louder beat note than the correct one. It is for these reasons that the first method of adjusting the B.F.O. is much to be preferred, compared with the second. With the former, no spurious indications are possible.

ADJUSTING THE TUNING METER

Since the 0-1 ma. meter is the most expensive single item in the receiver, it is good policy to leave its operation until everything else in the set is known to be working satisfactorily. However, for proper operation of the set, all the resistors associated with the meter should be in circuit from the start, otherwise the proper bias is not provided for any of the R.F. tubes or for the output stage. The circuit should therefore be wired up, and the meter simply disconnected at one terminal. This does not upset the valves in any way, and ensures that no harm can come to the meter while the set is being lined up. When the alignment is complete, the meter may be put into operation.

To do this the A.V.C. switch is turned "on," the manual gain control is fully advanced, and a short is placed between the grid of V_1 and chassis. This is to prevent outside noise from working the meter. Next, a 5000-ohm resistor is temporarily connected in series with R_{41} and the meter. R_{40} is now adjusted until the meter reads zero. The additional series resistance is included because if the meter circuit is far out of adjustment, a quite heavy current may flow in the reverse direction, taking the meter to the stop in the direction of the zero.

However, when the preliminary adjustment has been made, as above, the 5000 ohms may be eliminated. This may necessitate a slight readjustment of R_{40} to bring the meter exactly to zero. The meter circuit is now completely adjusted. The short-circuit may now be removed from the 1st R.F. stage grid and the aerial connected. It will now be found that the strongest local station will swing the meter to about 0.8 ma. on the scale, if there is such a station within a few miles, and that no signal, however strong, will ever drive the pointer of the scale.

With no signal at all, the outside noise will be found great enough to produce a deflection on the meter, which will swing about an average reading in a more or less random manner. However, even a very weak carrier will give a noticeable increase in the meter reading, so that the meter is a great help in "spotting" such carriers. If an increase of meter reading occurs at a particular spot on the dial, the presence of a carrier can be confirmed by turning on the B.F.O.

USING THE RECEIVER

When the receiver has been built and aligned, the constructor will no doubt heave a heartfelt sigh of relief and settle down to a little steady knob-twiddling. If everything has been done according to plan, there should be no dearth of stations to listen to, but for real DX listening there is no doubt that the best results will be obtained by a proper understanding of the operating characteristics of the set.

Being a broadcast band receiver, A.V.C. will naturally be in use most of the time, but under certain conditions better results will be obtained without it. An example of this is when a weak station is being copied, very near in frequency to a much stronger one. In these circumstances it may be better to turn the A.V.C. off, and use the manual gain control. The selectivity of the set is sufficient to rule out most possibility of the strong station operating the A.V.C. and thereby decreasing the set's sensitivity for the desired station, as long as the two stations are 10 kc/sec. apart. However, overseas stations may be found which are only 5 kc/sec. away from some of our own stations, or from fairly strong Australian ones. If this is the case, the best answer is given by going over to manual gain control. When the latter is being used, the audio volume control may be left set at the position which gives the desired volume when the A.V.C. is in use, and the R.F. gain control is then cut back so that overloading in the mixer stage is avoided. This mixer overloading can be recognised by the fact that as the manual gain control is wound up, a point is reached where the signal volume starts to decrease instead of increase. This is the point at which overloading commences, and is very easily recognised. The right point at which to work the manual control for any station is just below where overloading is found to occur.

MANUAL GAIN AND A.V.C.

The manual gain control may also be used while the A.V.C. is on in order to cut back the gain to a suitable level for searching. This prevents blasting on running over strong stations, and yet enables the B.F.O. to be used without too much noise coming through when no carrier is being received. Thus, the best search procedure is to leave the A.V.C. on, cut back the manual gain control by an appreciable amount and turn on the B.F.O. Then if the dial is turned, a noticeable beat occurs as each carrier is crossed, while the whole search process is accomplished without undue noise from the loud-speaker. When a carrier has been located, the B.F.O. is turned off, the carrier accurately tuned in, and the listening level adjusted with the manual gain control.

The audio volume control need be used only to give the appropriate volume, once the position of the manual gain control has been fixed. When the carrier has been finally tuned in, the A.V.C. can be rendered most effective by turning the manual gain full on. This enables the A.V.C. to have full control, and prevent much fading. If the fading is not severe, or is non-existent, there is no need to bring the A.V.C. fully into action, and manual gain control may be used.

The general rule to be followed in the use of the two gain controls, manual R.F. and audio, is that the combination is found which gives the most pleasing tuning characteristic, or, when listening, the best signal-to-noise ratio. If the band is full of signals, tuning across the band may comfortably be done with A.V.C. on and the manual control at maximum, since the stations at all points on the dial will prevent the inter-station noise from coming up to too high a level as the dial is turned from one place to another.

The receiver will be found very smooth to control, and has really outstanding A.V.C. performance. Any signal that is usable will produce strong A.V.C. action, and if it is decided that a particular signal would be better copied without, the A.V.C. may be switched off or partial A.V.C. can be used simply by backing off the manual gain control while leaving the A.V.C. switched on. This action provides a higher threshold for the A.V.C. action, without in any way impairing its performance on very strong signals.

TONE CONTROL AND NOISE SUPPRESSION

If the outside noise level is particularly bad, or if a weak signal is partly obscured by the "hash" type of noise, the noise limiter may be brought into use. Needless to say, the noise will not be entirely eliminated, but all that part of it which is greater in amplitude than 100 per cent. modulation of the carrier to which the set is tuned will be cut off, greatly reducing the most annoying part of the noise.

A further improvement in difficult cases is made by using the noise limiter and the tone control in conjunction. The limiter is turned on, and the tone-control is turned to the full bass position. The manner in which the tone control functions has been previously described; since it leaves the higher frequencies un-attenuated, and actually boosts the middle and lower frequencies, this part of the audio signal is strengthened and results in increased intelligibility. The reason is that the most troublesome part of the noise remaining after the limiter has been brought into action is on the higher audio frequencies. Thus, boosting the middles and lows gives the effect of decreasing the noise.

The increase in readability given by the bass boost control in conjunction with the noise limiter is quite remarkable and must be heard to be believed. As stated previously, this system, like all others intended to reduce the troublesome effect of noise, cannot be regarded as a panacea or cure-all. It works best only on a specific type of noise—high-frequency impulsive noise, to be precise—and derives its virtue mainly from the fact that the majority of noise encountered in practice is of this nature. However, whenever noise is troublesome, the best plan is to switch in the noise limiter. It can do no harm to the reproduction of the signal, and the operator will soon learn to recognise the type of noise with which it deals most effectively.

If the noise-limiter is left on while the set is being tuned, it will be noticed that peculiar gaps in the reproduction occur when tuning over a carrier. This is due to the time-constant of the noise-suppressor, which will cut off the modulation for a fraction of a second, until the noise-limiter plate condenser has had time to charge up to the D.C. carrier voltage provided by the detector. The cure is to turn the noise limiter off while tuning. If reception is noisy, it may be left on, and the above effect prevented by turning the tuning dial very slowly. In any case, the cutting off effect works only on the audio signal, and not on the R.F. end of the set at all. Thus, even if the limiter is on, the tuning meter will indicate correct tuning of the set.

FINAL REMARKS

It has come to our ears, both by letters from readers, and other means, that many constructors would like to use the circuit of the "Broadcast 12" as the basis of an all-wave receiver.

There are several difficulties introduced by this idea. In the first place, the layout, which is entirely suitable for a single-band receiver, does not lend itself well either to band switching or to the plug-in coil type of construction. Secondly, the catdode-coupled R.F. stage, though workable at any frequency if its coils are properly designed, does not work well with the standard short-wave coils that are used in dual and all-wave tuning units currently on the market. At frequencies higher than about 7 mc/sec. it would be necessary to use a specially designed coil in the plate circuit of this stage, and a different type of tube, if substantial gain is to be realised. Thus, the circuit "as is" is not entirely suitable for a wide-coverage receiver.

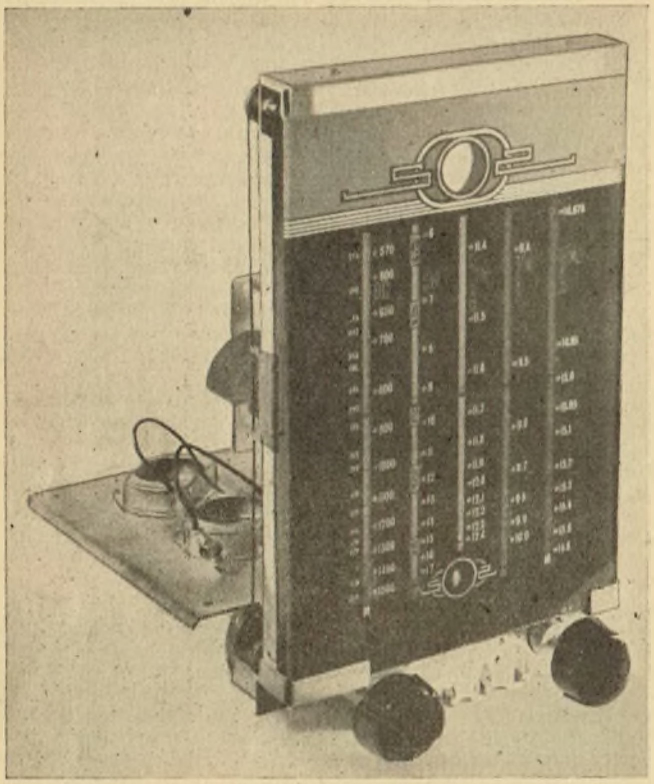
We hope to present at a later date a communications receiver using a very similar line-up to that of the "Broadcast 12." The design and construction of this set will have to differ in several important respects from that of the present one, so that its production will represent considerable time and effort. However, the communications receiver is definitely on our programme, and will be presented as soon as is practicable.

AMATEUR USE

One way in which the "Broadcast 12" could be successfully modified, however, would be to convert it to cover the medium-short-wave range of 1.6-6 mc/sec., covered in the intermediate range of available triple-wave units. This could be done with exactly the same layout as that of the "Broadcast 12," only using the appropriate set of coils. If desired the receiver could be made into an outstanding single-band job for the 3.5-4 mc/sec. amateur band, and used in conjunction with a suitably designed converter, would give outstanding performance on 40 and 20 m. For this purpose, a series-parallel band-spread condenser arrangement could be used to give full dial coverage on the 80 m. band, and an I.F. of 4 mc/sec. would be very suitable for the converter.

Any reader who may have specific problems in connection with the "Broadcast 12" is invited to write to us for advice. In the meantime we wish all builders of this set the best of luck with it, and good broadcast DX-ing.

BE SURE TO USE . . .
THE DE-LUXE BAND SPREAD TUNING UNIT FOR THE RADEL DUAL WAVE 6



BECAUSE—

- It has been purchased by really satisfied constructors in all parts of New Zealand.
- It is completely aligned and tested before leaving the factory.
- It has spin tuning, magic eye and Plessey Isolantite gang condenser.
- Can now be supplied with infinite impedance mixer using 6F8 and EF39 in R.F. stage.
- Has Broadcast Band. Shortwave Band 19 to 49 metres with 19, 25 and 31 metres fully spread.
- It has an attractive etched glass dial—a different colour for each scale.

PRICE

Unit only £10-7-6

Please specify if using 6K8 or 6F8 infinite impedance.

Chassis 12/6

(Available in two types—one for mounting unit on end of chassis and other for mounting in centre.)

Complete Kit for Radel Dual Wave 6. Everything, including magic eye, valves and 8 in. speaker. Freight Free.

PRICE £23-19-6

(retail only)

Two Type Mantel Cabinets for 6 Valve Model take 8in. Speaker £4-0-0 & £5-0-0

MAIL A MONEY ORDER FOR A UNIT OR KIT NOW.

Obtainable only from

S.O.S. Radio Service
283 Queen St. Auckland

S.O.S. RADIO SERVICE,
283 Queen St., Auckland.

Pease send to me full information on the De Luxe Band Spread Tuning Unit.

Name ....

Address ....

Town ....

OUR GOSSIP COLUMN

Since their discharge, numbers of ex-air force men have commenced business on their own account in the radio industry. Among these are Benson and Wills of Auckland. George Benson was a Spitfire pilot in the R.A.A.F. and was stationed in Darwin for some time. Perce Wills was an R.N.Z.A.F. electrician in the Islands. Recently they have been joined by Ray Walker, who was one of the first Kiwis to be attached to the R.A.F. in connection with OBOE activities. Benson and Wills manufacture Autocrat Car Radios and will be going wholesale on a New Zealand-wide basis as soon as production and supply problems ease up.

* * *

George Wooller, of Auckland, has been making a complete tour of New Zealand preaching the "Akrad" gospel. After making calls through the Central North Island and Taranaki, George returned to Auckland, from whence, after a short stay at home, he travelled by air to Christchurch, this time accompanied by Ted Grant, Akrad's Design Engineer.

They made a goodwill tour of the South Island, calling on all their radio and cycle dealers, who now number many hundreds. Colin Moore, George Wooller's South Island representative went through to Invercargill with them. Concluding the South Island tour via the West Coast and back to Christchurch, George and Colin returned to Auckland by air. Next on their list is a trip to the Capital City.

George and his organisation are certainly going places!

* * *

Fred Noad, of Photo Engravers, Ltd., Auckland has been in these parts for a week. He came on general business, and Mrs. Noad took the opportunity of coming with him on holiday.

Probably Fred is one of the industry's best-known figures, as Photo Engravers are associated with radio owing to their prominence in glass-dial etching. Fred called on as many of his clients and friends as time would permit, and, as both are numerous, he had his time pretty well cut out.

Another of his activities—brought about by war production associations—is the presidency of the now famous "4 x 2 " Club. You may take our word for it, Fred executes his duties in a very admirable manner.

* * *

Eveready dealers in the North Island will be interested to hear that M. O'Sullivan, National Carbon's Representative, has entered the "Matrimonial Stakes," due to be run on 21st June next. His numerous friends may send congratulations to him at 106 Willowpark Road, Hastings.

* * *

TRADE WINDS

PHILIPS OPEN NEW AUSTRALIAN FACTORY

The opening of the vast Philips electronic production centre at Hendon marks the culmination of twenty-two years of careful planning, organisation, and production of electrical equipment, which has placed Philips as one of the really big names in Australian industry.

From the early days of radio, Philips supplied components from the Dutch factory. So great was the demand for these, and so many were the difficulties encountered in importation that soon it became apparent that Philips must plan for local manufacture.

With the outbreak of war, Philips was immediately engulfed in the war production machine. In peace, the company was faced with a great production programme, with which the three Sydney factories were unable to cope with any high degree of efficiency. Increased floor space became an urgent necessity, and the answer was found at Hendon, where a former munitions factory became available. Immediately, Philips entered into negotiations with the authorities, with the result that they have now moved to a modern factory covering seventy-five acres—a factory with ample room for expansion.

Co-ordinating the transfer of three factories a distance of 1000 miles was no small undertaking, but, with full realisation of the inevitable loss of trade during the transition period, Philips looked with confidence to the future, knowing full well that the unlimited expansion would provide continuous and ever-increasing supplies of their products.

Philips's vision is evident in Governing Director F. N. Leddy's remarks when opening the new factory. He stated: "To-day we are embarking on the first stage of a long-range programme. Hendon is merely a means to that end, and not a goal in itself. Not only can we manufacture more electronic equipment, but we are expanding the scope of productivity."

There are five divisions at Hendon—Administration, Tubes, Special Products, Instruments, and Apparatus. The subsidiary departments connected to each of the five divisions are organised with such precision and versatility that one section of any department may be called upon to perform efficiently a task required by any of the divisions. For example, the Tube-manufacturing division, by virtue of its particular function, must necessarily utilise the services of skilled chemists. The Chemical Laboratory, although primarily formed for the tube division, is at the service of other production divisions. The Mechanical Maintenance Section has the responsibility for the smooth running of the factory, and the task of the maintenance men is second to none in importance, for their service includes Gas Boosters, Compressors, Vacuum Pumps and Blowers, as well as a refrigerated water-tower and refrigerator. The same men are responsible for a gas room, where hydrogen, nitrogen, and oxygen equipment must be maintained.

Unfortunately, space will not permit a description of each division, but each in itself would be an interesting story. Throughout the factory, the carefully-planned sections are welded together for the efficient output of Philips products.

The men behind Hendon are: Governing Director, Mr. F. N. Leddy; Director and Commercial Manager, Mr. A. E. Poll, who will be remembered as New Zealand's Managing Director until just recently; Resident Director in Adelaide and Technical Manager, Mr. S. O. Jones; Factory Manager, Mr. J. C. Oliver; Factory Administrator, Mr. H. J. Van Steenis; and in charge of design engineering is Mr. F. G. Canning. Under the guidance of these men, the blue-print which was Hendon has been transformed into a permanent contribution to Australia's industrial future.

The Service Section

PRACTICAL TROUBLE-SHOOTING

By C. R. LESLIE, late Technical Officer, Royal Aircraft Establishment

PART IV—Continued

ADJUSTMENT OF TRACKING

Having completed the alignment of the I.F. stages, it is time to tackle the oscillator, starting with the broadcast band. Keeping the output indicator connected up and the tuning condenser at minimum capacity, inject a modulated signal corresponding to the highest frequency marked on the dial. This may vary from 1500 to 1700 kc/sec., according to the make of the set. Open the oscillator trimmer to about half open and then tighten down slowly till a peak response is obtained. Always work from less to more capacity, as there are two response points, one where the oscillator frequency is above the I.F. and one where it is below. Practically all receivers have the oscillator frequency above the I.F., and this requires the smaller capacity. Now turn the generator frequency to 1400 kc/sec., tune the set to this marking, and adjust the oscillator trimmer exactly for maximum output. Then inject a signal of 600 kc/sec., tune the set to this dial marking, and adjust the padder condenser for maximum. This adjustment will affect the high-frequency end, so we now return to 1400 kc/sec. and make a further exact adjustment here; there will be no need to return to the 600 kc/sec. point. We should now make a tracking check at some mid-point, say, 1000 kc/sec., and if the response at this point drops we can either bend the last-to-be-meshed section of the outer vane of the tuning condenser of the oscillator section in or out, whichever is required for increased response, or we can make adjustments at the H.F. and L.F. ends of the dial to give an even response at all three points. For all-wave receivers the latter is the better procedure, as we shall not upset the tracking on the shortwave bands.

The S.W. bands can be treated in a similar manner by injection of corresponding suitable signal frequencies. Where fixed padders are incorporated, it is usually only necessary to trim at one point about a third round the dial, such as 10 or 12 mcs., unless, of course, the padder capacity has changed its value. It should be remembered that the generator's dummy aerial should be changed to suit the band under adjustment—that is, use the medium wave dummy (or a .0002 mfd. condenser) for the broadcast and a S.W. dummy (or a 500-ohm resistor) for the S.W. bands.

PART V

THE ALIGNMENT OF RECEIVERS

(Continued)

In our previous article we discussed methods for the determination of the designed intermediate frequency, where this is unknown, as opposed to the I.F. to which the set is actually tuned, and different systems for the alignment of the I.F. stages by the use of test meter and signal generator, or by the use of a "wobbulated" signal generator and oscilloscope for visual "precision" trimming. We concluded with the adjustment of the oscillator tracking by employing a signal generator and output meter.

The adjustment of tracking may be also carried out by the use of the frequency modulated signal generator and oscilloscope in a manner similar to that described for I.F. trimming. For this purpose the generator output is connected across the aerial and earth terminals and the same frequencies are used as before (except that they are "wobbled" by the correct amount) and the same form of response curve

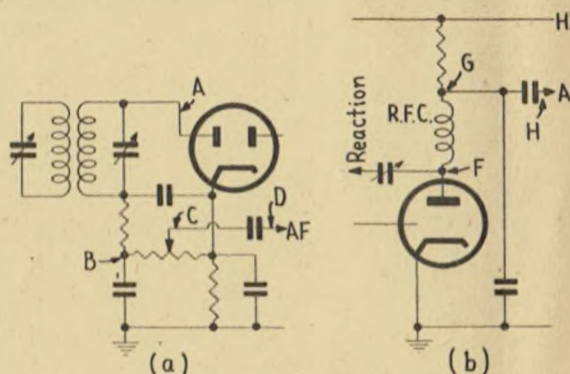


Fig. 5.

will be seen on the screen. For the B/C. band, first inject a 1400 k.c. "wobbled" signal and adjust the oscillator trimmer till the response curve is centralised on the screen as this corresponds to the maximum response adjustment when a meter is used as an indicator. A moment's thought will show that the harmonising of the oscillator frequency with the incoming signal, i.e., centralising, must give maximum response. Having centralised the curve, adjust the R.F. trimmers in turn for maximum height, working towards the aerial. If the circuits are in order, the shape of the curve will not alter, but if band-pass circuits are incorporated, the curve shape will alter with the alteration of each trimmer. We have, in such cases, to trim for maximum height combined with minimum distortion of the curve.

Now deal with the padder condenser by injecting a 600 kc/sec. wobbled signal and tune the set to this value until the curve is centralised, then adjust the padder for maximum image height. While doing this, it will be found that the trace will shift off-centre and perhaps disappear off the screen, so that it must be re-centred by means of the main tuning condenser. As before, we shall have to return to the 1400 k.c. point and reset the oscillator trimmer to counteract the effect of the padder adjustment. The other wavebands may be dealt with in a similar manner by injection of the appropriate signal frequencies.

The T.R.F. set may be aligned in a like manner, but naturally the oscilloscope connections will be somewhat different. For the sake of comparison we give skeleton circuits for the detector stages of a superhet. (Fig. 5(a)) and a straight set (Fig. 5 (b)), and show the various points for oscilloscope connec-

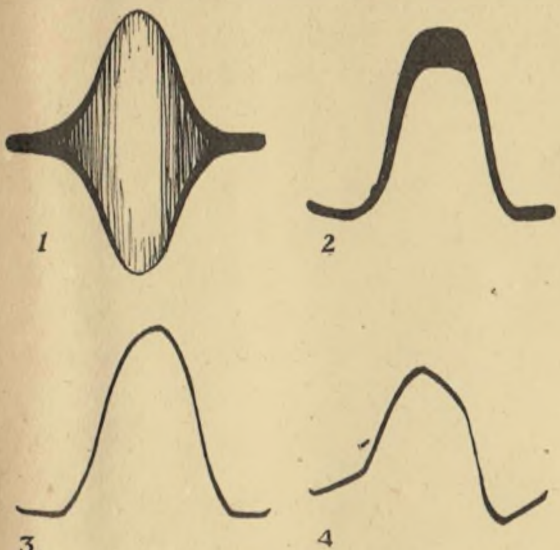


Fig. 6.

tion. Taking Fig. 5 (a) first, connection between A and chassis will give an "envelope" response as shown in Fig. 6 ($_1$). For this the normal dummy aerial should be replaced with a very small condenser of 1-2 mmfd., which can be conveniently "manufactured" at the bench by twisting together two short lengths (about 1 in. to 1½ in.) of insulated wire with a couple of turns. Point B will give the detected but unfiltered A.F. response which will have the residual I.F. superimposed on it to give an effect like that of Fig. 6 ($_2$). Point C will give the filtered A.F. curve of Fig. 6 ($_3$), which should be bright, fine, and clear, and is probably the best connection to make. The signal generator coupling condenser for the latter two curves should be of generous proportions of .25-.5 mfd. Point D is not quite so good because the receiver's coupling condenser may introduce some phase distortion and give a curve somewhat as shown in Fig. 6 ($_4$).

Fig. 5 (b) represents a typical detector stage in a straight set, and the two main oscilloscope connections are at F and G. If the connection is made through a very small condenser and the oscilloscope amplifier, we shall get an R.F. envelope curve like Fig. 6 ($_1$), because the small condenser will block the A.F. If a large condenser is used we shall get both the R.F. and A.F. with an image like Fig. 6 ($_2$). Connected at point G through a large condenser, we should obtain a clear-cut curve like Fig. 6 ($_3$), while the point H is comparable with the point D of Fig. 5 (a). By the way, as the oscilloscope is not fussy about which way it paints the picture, there is no cause for alarm if the response curve is inverted, for the alignment operation will not be affected in any way. The "Y" shift will be used to centralise the curve, as a whole, on the screen by altering the level of the base line.

There is another point to watch for, and that is to see that the detector stage has a resistive load as in the diagram—if the load is the primary of an R.F. transformer we must disconnect the primary and replace it with an equivalent resistor, that is, one of about twice the value of the internal resistance of the detector valve. Otherwise we shall only get a distorted curve due to the iron core and phase shift. It may be argued that we are now only getting cooked-up results and not what is actually produced in normal operation with the R.F. transformer in use. The answer is that a trace distorted by phase shift may be very misleading and unsatisfactory to work with, but the ear is not conscious of moderate changes in phase, and therefore no harm is done by its introduction from the use of an iron-cored inductance.

1 2 3

Fig. 7.

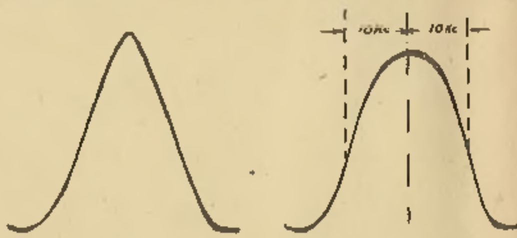
Wavetrap or second channel filter operation may also be checked by switching the generator to amplitude modulation and injecting the required signal and adjusting the trimmer for minimum response in the usual way. The action of the wavetrap should not affect the shape of the curve.

Generally speaking, where superhets. are concerned, the A.V.C. should be made inoperative for alignment work, and for both types of receivers the input signal should be kept as low as possible to avoid any chance of overloading any of the stages. We therefore make use of the oscillopscope "Y" amplifier for the regulation of picture size. During the alignment work, we may find that at one step a jiggle or "squeg" will appear on the curve as shown in Fig. 7 ($_1$ and $_2$); this will be due to parasitic oscillation at (1) and L.F. pick-up at (2), and the cause of either can then be hunted for by watching the effect of our efforts on the screen.

ALIGNMENT OF SIGNAL CIRCUITS

Many of us will not possess this delightful but expensive gear and so be compelled to do all our work with a modest test meter and plain signal generator, but very good results can be obtained with them. The first method we will discuss is only suitable for circuits fitted with A.V.C., in that it makes use of the A.V.C. voltage. It is also very convenient for calibrating home-constructed sets, as the resonant point is sharply defined. Suppose the oscillator is rendered inoperative by shorting the grid circuit or removing the anode voltage; then, if we inject a signal at the aerial terminal of such strength as to overload the R.F. valves, they will pass grid current proportional to the signal intensity. The grid current could be read directly by means of a microammeter, but we are assuming we do not possess such an instrument. But if grid current flows, it must pass through the A.V.C. resistors in such a way that the polarity of the A.V.C. line becomes negative with respect to earth and so produces a "synthetic A.V.C." to bias the controlled valves in the usual way.

The procedure now becomes clear. We put the oscillator out of action, connect a milliammeter in the anode circuit or a voltmeter across a bias resistance of one of the controlled valves to act as an indicator. Connect the signal generator to the aerial and earth terminals and inject a large unmodulated signal of about one volt. The receiver tuning condenser is turned to minimum and the signal frequency set to this value, which may be from 1500-1800 kcs., depending on the circuit, and adjust the R.F. trimmers C1 and C2 for resonance. At resonance the grid bias will be at a maximum and the anode current will be at a minimum. The minimum point is sharply defined so that the trimmers can be adjusted with great



a *b*

Fig. 8.

nicety. Then tune the set to 1400 kcs., i.e., the frequency at which the oscillator was tracked with the dial, and repeat the adjustment of the R.F. and aerial trimmers. With a single-band set we can now go right round the dial at points corresponding to the meshing of each condenser split vane section and adjust the capacities at these points exactly. Where there is more than one band we must not monkey with the split vanes, but rely on compromise if the coils and condenser sections are much mismatched. The trimming for the other bands is carried out in exactly the same way by using suitable signal frequencies.

T.R.F. ALIGNMENT

Where a set is not fitted with A.V.C., as in the usual type of T.R.F. receiver, we must use an output meter or other indicator and set all the trimmers to about half-unscrewed, and open the main tuning condenser fully. Connect the generator to the grid of the last pre-detector H.F. valve and inject a suitable signal frequency. Then adjust the trimmer of the last section of the gang condenser for maximum response. Set the generator to 1400 kcs. and tune the receiver to this exactly, remove the generator clips back to the grid of the next valve, and adjust the next trimmer for resonance, and repeat the process at the grid of the next valve and so on till the aerial circuit is trimmed. In an existing receiver it will probably not be necessary to trim in such detail as this, but merely connect the generator to the aerial circuit and adjust each trimmer in turn, starting with the last R.F. stage and working back towards the aerial. In single-band receivers, the tracking can be checked all round the dial by injecting suitable frequencies and bending the split vanes as required for each point.

If the receiver is fitted with reaction, the trimming will be complicated by the fact that the setting will be affected by the reaction control. As reaction is used to obtain maximum sensitivity and selectivity, it is obvious that we must align under these conditions. Reaction is usually employed only on the last pre-detector stage, so that when trimming this stage the reaction must be increased to near oscillation and the trimming and reaction combined for optimum operation—the final setting will be found to be quite critical. The other R.F. circuits are then brought into line, and it will be found that their settings are also more critical; in fact, it is probable that the receiver will break into oscillation before maximum response is obtained. In such cases our old friend the compromise adjustment must be resorted to by reducing the criticalness of the setting for the pre-detector stage. If properly carried out, it should be found that we can screw all trimmers THROUGH the resonant point. When all adjustments have been satisfactorily completed, it is advisable to melt a spot of wax on to each screw to prevent any subsequent rotational movement due to receiver vibration.

AURAL TESTS AND ADJUSTMENTS

When receivers have been accurately lined up by visual methods, the aural reproduction should be as perfect as possible, and it should not be necessary or advisable to attempt further adjustments. But where the alignment has been checked by a meter, it is possible—perhaps we should say probable—that the response curve is not as good as it should be, and this would be specially so if our I.F.'s have been sharply peaked, thus giving a response like that shown in Fig. 8 (a). This curve gives maximum response at one point and attenuates rapidly on each side. In this case it is advisable to check the performance against broadcast programmes, keeping the volume of the output at a low level, as low as possible compatible with clearness when the ear is held fairly close to the speaker. The I.F. settings should be checked by slight and careful rotation of the adjustment screw in both directions. If a slight turn effects an improvement in quality (keeping to the usual order of the secondary of the last I.F. first), do not turn the screw more to try and get still more improvement, but stop and turn the set screw of the primary trimmer—this will usually be in the opposite direction. If this improves matters, then return to the secondary trimmer, and so on till no further improvement is noticeable, and then tackle the other I.F.'s in like manner. The check should be made for both musical and speech programmes, as we have already mentioned earlier. The piano recital is probably the best music to select because of the greater pitch range, and quality of reproduction is more readily appraised. With poor-quality performance the piano sounds rather tinny, while our aim should be towards the richness of the concert grand.

The operation of the S.W. bands should be similarly checked over, preferably in the evening, when reception is likely to be at its best. In this case, we do not fiddle with the I.F.'s any more, but concentrate on the settings of the R.F. trimmers, especially at the shorter wavelengths round about 15 metres. Selectivity is the aim here, to cut out interference from adjacent programmes which blurs or confuses the clarity of the wanted station.

When all is in order, we should give the receiver a final test of some four hours' duration. During this period the various bands should be tried out (not necessarily at full blast) and the receiver switched on and off every so often. If the set "gets all its sums right" with this final test, we can be confident that our work has been well carried out and that the set can be safely returned to its owner.

EYE APPEAL

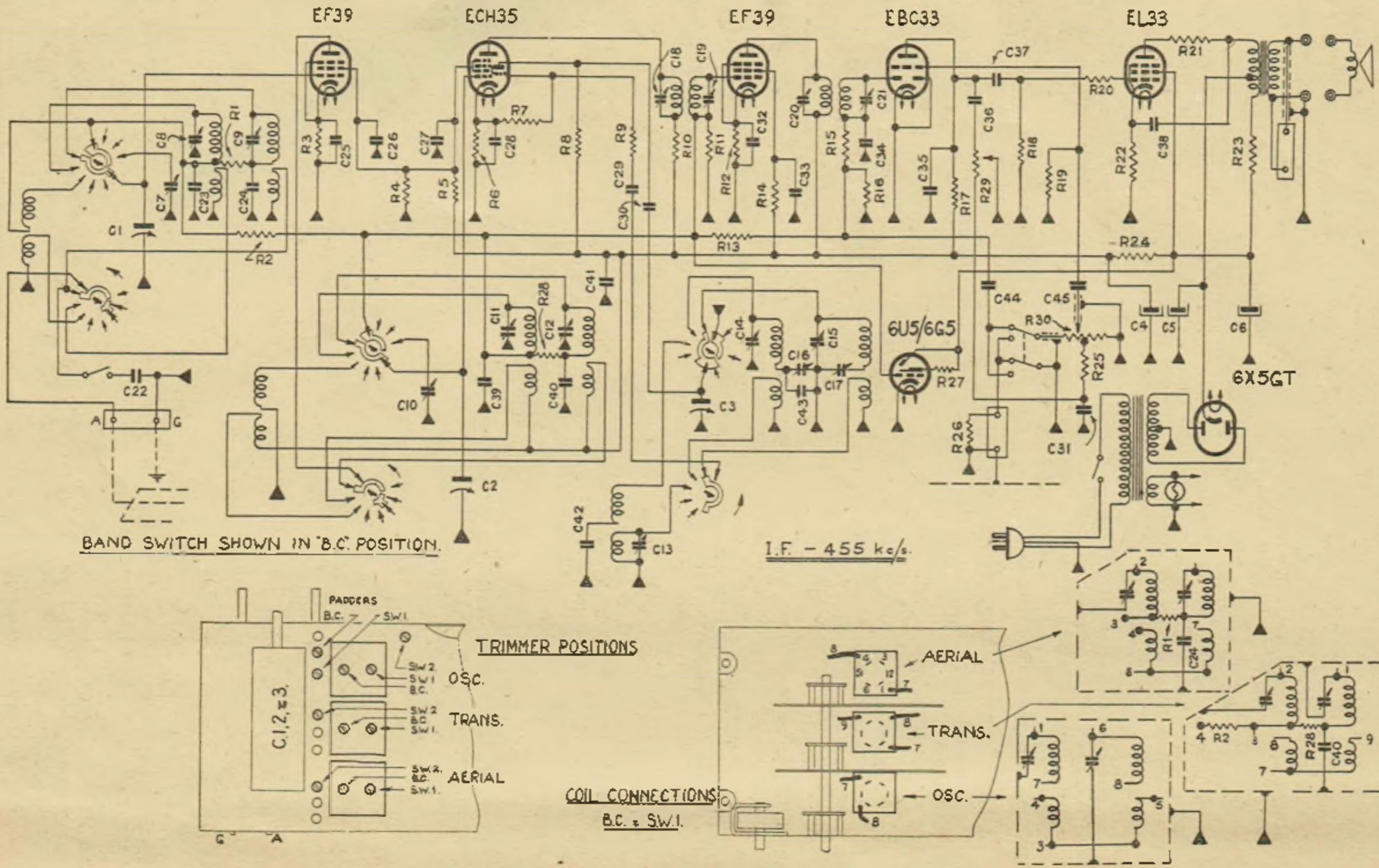
As a final "frill," we may polish the cabinet with a suitable polish, and if the model is a high-quality job and has been reasonably well looked after, we can touch up any unsightly scratches or dents, as this additional service will certainly be much appreciated. The retouching of scratches depends on the cabinet material and its finish—that is, whether it is lacquered or hand-french-polished. It will not be possible to go into detail here, but the general idea is to fill the scratch by some suitable coloured means and then polish it up to match the surrounding surface, as, for instance, making a creamy paste with a tinted fine powder (dry stain powder, ground water-colour, or distemper, etc.) with varnish or clear lacquer, and then "painting" the scratch with a fine brush or feather edge to apply the mixture to the scratch only—if any of the filler gets on to the surrounding surface, wipe it off immediately with a soft cloth. If the scratch cannot be matched exactly in colour, it is better to err on the dark side. When the scratch is fully filled, allow it to harden thoroughly before doing any polishing. Scratches in the cabinet finish, i.e., not into the woodwork, can be stain-varnished as above and then polished.

(Continued on page 48.)

Philips Radioplayer Model 594 and Mullard Model 736

COIL CODE NUMBERS

Aerial Coil—BC and SW1	..	VK 469 31
Translator Coil—BC and SW1	..	VK 473 06
Oscillator Coil—BC and SW1	..	VK 471 12
Aerial Coil—SW2	.. .. ..	VK 469 32
Translator Coil—SW2	.. ..	VK 473 07
Oscillator Coil—SW2	.. ..	VK 471 13
1st I.F. Coil	.. ..	VK 476 00
2nd I.F. Coil	.. ..	VK 476 01



VOLTAGE TABLE

Valves	Plate	Screen	Cath-ode	Fila-ment
EF 39	175 Osc. 65	80	1.75	6.1
ECH 35	170	80	1.3	6.1
EF 39	175	70	1.5	6.1
EBC 33	30	—	—	6.1
EL 33	260 Target 220	220	5.2	6.1
6U5	25	—	—	6.1
6X5 GT	245 per Plate	—	270	6.1

The above voltages were measured with a voltmeter of resistance 1,000 ohms per volt. The receiver was switched to the broadcast position, and the tuning condenser was at maximum capacity.

The voltages given are the average of a number of receivers, and may vary slightly from the Table Values.

RESISTORS

R1	Resistor	100,000 Ohm.	1/3 Watt.
R2	,,	100,000 Ohm.	1/3 Watt.
R3	,,	330 Ohm.	1/3 Watt.
R4	,,	27,000 Ohm.	1/3 Watt.
R5	,,	15,000 Ohm.	1 Watt.
R6	,,	180 Ohm.	1/3 Watt.
R7	,,	47,000 Ohm.	1/3 Watt.
R8	,,	27,000 Ohm.	1/3 Watt.
R9	,,	180 Ohm.	1/3 Watt.
R10	,,	1,000 Ohm.	1/3 Watt.
R11	,,	2.2 Megohm.	1/3 Watt.
R12	,,	330 Ohm.	½ Watt.
R13	,,	2.2 Megohm.	1/3 Watt.
R14	,,	68,000 Ohm.	1/3 Watt.
R15	,,	47,000 Ohm.	1/3 Watt. In I.F. Can
R16	,,	270,000 Ohm.	1/3 Watt. In I.F. Can.
R17	,,	220,000 Ohm.	1/3 Watt.
R18	Resistor	470,000 Ohm.	1/3 Watt.
R19	,,	15 Megohm.	1/3 Watt.
R20	,,	1,000 Ohm.	1/3 Watt.
R21	,,	56 Ohm.	1/3 Watt.
R22	,,	150 Ohm.	2 Watt.
R23	,,	1,800 Ohm.	2 Watt.
R24	,,	2,200 Ohm.	1 Watt.
R25	,,	56,000 Ohm.	1/3 Watt.
R26	,,	220,000 Ohm.	1/3 Watt.
R27	,,	1 Megohm.	1/3 Watt.
R28	,,	100,000 Ohm.	1/3 Watt.
R29	,,	600,000 Ohm.	T.C. Pot.
R30	,,	2 Megohm.	V.C. Pot. with Sw.

CONDENSERS

C1	Condenser	3-Gang.	
C2	,,		
C3	,,		
C4	Condenser	20 Mfd.	Electrolytic 400V.
C5	,,	40 Mfd.	
C6	,,	40 Mfd.	
C7	,,	Trimmer.	
C8	,,	,,	
C9	,,	,,	
C10	,,	,,	
C11	,,	,,	
C12	,,	,,	
C13	,,	,,	
C14	,,	,,	
C15	,,	,,	
C16	,,	,,	
C17	,,	,,	
C18	,,	,,	
C19	,,	,,	
C20	,,	,,	
C21	,,	,,	
C22	,,	.01 Mfd.	400V.
C23	,,	.05 Mfd.	200V.
C24	,,	7,000 Mmfd.	Mica.
C25	Condenser	.05 Mfd.	200V.
C26	,,	.05 Mfd.	400V.
C27	,,	.05 Mfd.	400V.
C28	,,	.05 Mfd.	200V.
C29	,,	50 Mmfd.	Mica.
C30	,,	100 Mmfd.	Ceramic
C31	,,	.01 Mfd.	400V.
C32	,,	.2 Mfd.	200V.
C33	,,	.05 Mfd.	400V.
C34	,,	100 Mmfd. in I.F. Can.	
C35	,,	250 Mmfd.	Mica.
C36	,,	.02 Mfd.	400V.
C37	,,	.01 Mfd.	400V.
C38	,,	.002 Mfd.	600V.
C39	,,	.05 Mfd.	200V.
C40	,,	7,000 Mmfd.	Mica.
C41	,,	.1 Mfd.	400V.
C42	,,	.004 Mfd.	Mica.
C43	,,	1,200 Mmfd.	Mica.
C44	,,	.01 Mfd.	400V.
C45	,,	.002 Mfd.	600V.

IMPORTANT NOTES

Since this circuit was last published the following notes have come to hand.

(1) In some receivers C38 may be found connected across the output transformer primary instead of as drawn.

(2) In receivers with serial numbers above 30,001 for Philips and 40,001 for Mullard, the mechanical layout of trimmers has been altered, and air-dielectric trimmers have been used in place of compression-type mica-dielectric trimmers.

(3) In all receivers after the above-mentioned serial numbers, the tone control circuit has been changed to allow the use of a circuit which does not need a tapped volume control.

AN ELECTRIC POWER BOARD USES TWO-WAY RADIO TELEPHONY

By L. G. Francois.

Back in pre-war days, the engineer of the Waimea Electric Power Board investigated the possibility of two-way radio-telephony between the board's vehicles and the head office. However, war intervened, and the idea was dropped until early in 1946, when application was made to the Post and Telegraph Department for a licence. This was granted, and was the first licence issued to an electric power board in New Zealand. The frequencies allotted

were 1710 kcs. for the base station and 3360 kcs. for all mobile units.

Most of the necessary equipment was purchased from the War Assets Realisation Board, the principal items being a type 4025 ex-naval unit for the base station, and a number of ZC1 units for mobile use.

The 4025 unit required considerable modification before it was considered suitable for this class of service, and the whole job was rebuilt into a steel rack, converted for two-channel crystal frequency control, separate A.C. and D.C. power supplies, switching panel, and remote-control circuits. This work was carried out in our own workshops, and provided a very satisfactory and inexpensive transmitter (see Fig. 1), with a normal power input of up to 60 watts.

Tests were made with various types of aerials for the base station, and the most satisfactory was found to be a half wavelength Hertz fed with a 600-ohm line.

The base receiver is a six-tube communications type supplied with the complete 4025 unit, and is located at the operator's desk (see Fig. 2). The whole installation can also be remotely controlled from the chief engineer's office.

The ZC1 units for mobile installations were converted to crystal frequency control, and the receiver sections of these units also required some alteration to tune the frequency of 1710 kcs. These modified ZC1s were installed in vehicles, and loaded up on an 8 ft. or 12 ft. whip aerial.

Coverage surveys were made throughout the board's area, and completely satisfactory results obtained over the whole district. Vehicles have been worked while mobile up to 25 miles from the base without difficulty, and with additional length of aerial greater distances, and so-called "dead spots" or poor localities may be worked with ease.

During the months the scheme has been in operation it has proved of great value, enabling vehicles to be informed of consumers' faults in that particular locality, facilitating the tracing of faults on transmission lines, and the switching and isolating of sections of line under repair. The consequent saving of time and greatly reduced truck mileage has made this installation well worth while.

Right: Fig. 1.
Left: Fig. 2.

A Practical Beginners' Course

PART 12

Last month we saw that the simplest kind of valve, the diode, is nothing more than an electric lamp with a metal plate inside it near to the filament. A wire is brought from the plate through the bulb, of course, so that the plate may be connected in an external circuit. The device so constructed has the property, when the filament is hot, of passing a current in one direction only, and acting as an electronic valve. It is not able to act as an amplifier, however, and this month we commence with a description of how a diode may be made into a triode or three-element tube which is able to amplify.

THE TRIODE OR THREE-ELECTRODE VALVE

Let us now examine Fig. 16, which contains as well as three batteries and a meter, the usual symbol for a triode valve. From Fig. 16 we can see that the triode is very similar to the original diode, in that it has a filament and a plate. The third element, called the **grid**, is represented by the dotted line drawn between plate and filament. In practice, the grid consists of a number of fine wires, sometimes made in the form of a sheet of fine netting, which is mounted inside the bulb between the filament and the plate, very much as in the diagrammatic representation. When the plate is positively charged, or connected to the positive terminal of a battery, electrons can still flow from the filament to the plate, but in doing so they must pass between the holes in the grid mesh. In Fig. 16 we have illustrated the effects that may be obtained by making the grid either positive or negative in polarity, simply by connecting a third battery between grid and filament in the appropriate manner. In the top diagram, we have

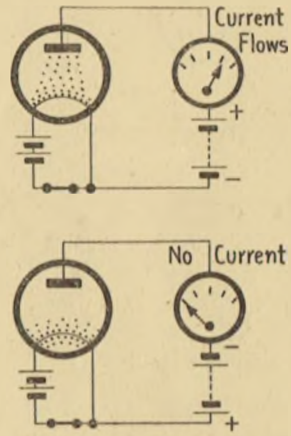


FIG. 15

shown the negative terminal of the battery connected to the grid. At the same time, the plate battery is connected as in Fig. 15 (top diagram), with its positive terminal to the plate, and the meter in series as before. Here, however, there is no current flowing in the plate circuit. This is because of the action of the grid. Now the grid is nearer to the filament than is the plate, so that a small negative voltage placed on the grid by the grid battery causes the grid to repel

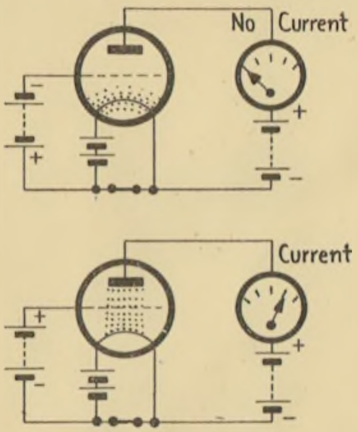


FIG.16

the free electrons surrounding the filament, and prevents them from flowing to the plate, **even though the plate is charged positively, and is attracting the electrons.**

Thus, the grid can be seen to **control** the flow of current in the plate circuit. In the bottom diagram of Fig. 16, everything is as before, except that the grid battery has been reversed, and that current is now seen to be flowing through the valve. In this case, the electrons are strongly attracted by the grid, which is now positively charged. Some of the electrons strike the wire of the grid and flow through the grid battery, but due to the open structure of the grid mesh, most of the electrons pass through and finish up on the plate in the usual manner.

HOW AMPLIFICATION OCCURS

The foregoing explains how the grid can control the flow of electrons in the plate circuit, but not how amplification takes place. The secret of this lies in the fact, already mentioned, that the grid is much closer to the filament than is the plate. In this way, a very small voltage on the grid can produce the same effect on the plate current as a large voltage on the plate. In some triodes the grid is as much as 100 times more effective than the plate in controlling the plate current. In such a valve, a one-volt change in grid voltage can cause almost 100 volts change in plate voltage (when the appropriate circuit arrangements are made) so that the valve **amplifies** voltage changes applied to the grid by approximately this amount.

DIODES AGAIN

This small discussion of triodes has been introduced here to give readers some idea of how modern valves were developed from Fleming's simple diode, which was unable to amplify. However, we have by no means exhausted the subject of diodes, which is a very important one, and it is time we did our first experiments with valves. This first practical work will entail the use of a diode instead of a crystal detector.

DIRECTLY AND INDIRECTLY HEATED VALVES

The only valves we have so far discussed are those which have filaments. These are called **directly heated** valves, because the filament really performs two different jobs at the same time. The first is that it heats itself, and the second is that it provides the electrons which make the valve operate. However, by far the most valves that are in use to-day are of the **indirectly heated** type, which although it consists of three parts, is still only a diode (for instance) because the third part is only a **heater**, and plays no direct part in the operation of the valve.

Fig. 18 is a diagram of an indirectly heated diode. At A we have a metal sleeve, which is simply a hollow thin-walled nickel tube on which is coated at B some special material which is particularly good at emitting electrons. Since valves were first invented several special materials of this nature have been developed. Their main virtue is that they give a copious supply of electrons without having to be heated nearly so much as a plain tungsten filament does. However, these materials are in the nature of a powder, which is held together with some binding material, and are entirely unsuitable with which to manufacture a filament. Thus, the only way in which they can be used is to coat them on to a metallic filament——which still makes a directly heated valve

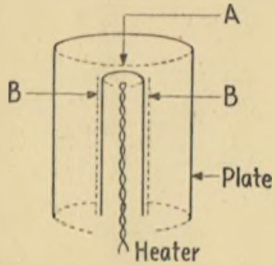


FIG. 18

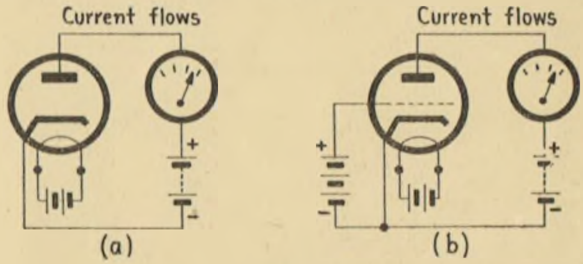


FIG. 19

—or to do as in the indirectly heated type, and coat them on to a sleeve of nickel or similar material. Then, inside the sleeve, **but insulated from it electrically**, is placed a separate filament, whose only job is to heat the sleeve hot enough to enable it to emit electrons. Then the two working parts of the valve become the plate, as before, and the sleeve, which is known as the **cathode**. In this way the circuit for heating the sleeve becomes entirely separate from the plate-cathode circuit through which the electrons flow. In the directly-heated valve the filament is both heater and cathode at the same time. Fig. 19 shows the diagrammatic way of representing (a) an indirectly heated diode and at (b) an indirectly heated triode. In order to see the difference between this and the directly heated equivalent, the symbols in Fig. 19 have been drawn in the same circuits as Figs. 15 and 16.

By comparing Fig. 15 (top) with Fig. 19 (a) we can see that though the indirectly heated valve has three things—plate, cathode, and heater—as against two—plate and filament—for the directly heated one, the circuit of the former is really the simpler of the two. This is because the heater has no **electrical** connection with the cathode. Thus, the electrodes flowing in the plate circuit do not touch the heater circuit at all, and the plate circuit is not connected to the heater in any way. In the directly heated type, however, the electrons flowing in the plate circuit must also flow through the filament, so that the plate battery must be connected to one side of the filament battery. However, for our first experiments we will use directly heated valves, since these can be heated from an inexpensive torch cell or battery. Indirectly heated types need either a transformer or an accumulator to run them, since they take much more current than a torch battery can economically supply.

ANODE AND CATHODE

Sometimes the plate of a valve is called the **anode**, and in most English radio books this is done. The term **anode** really means "an electrode to which electrons flow inside the valve" and cathode means "an electrode **from** which electrons flow inside the valve. The last three words of these definitions must be included, because if we look at the external wiring which completes the circuit, we find that there the electrons flow **to** the cathode and **from** the anode.

FIRST EXPERIMENT WITH A VALVE

Our first valve experiment will be to show that a diode can and does do exactly what the crystal detector will do in a receiver—i.e., detect the radio currents collected by the aerial and selected by the tuned circuits. It should be explained at this point that substituting a diode for a crystal detector will not give us any more volume in the headphones. Nor will it improve the selectivity of the set which has been converted. In fact all that we gain by so doing is to remove the nuisance of having to find a sensitive spot on the crystal with the cat's-whisker, and the even greater nuisance of hardly daring to move once it has been found, in case a slight jar should cause the cat's-whisker to slide off the sensitive spot. Of course, if you use a crystal set for actual listening, as well as for experimenting, this is quite an advantage. As against that, the valve needs a small cell or battery with which to heat its filament, and this must be replaced when it is worn out. However, modern battery valves are very very light on filament batteries, and the right sort can be expected to last for a long time.

PURCHASING A VALVE

Before buying your first valve, it is an excellent idea first to invest in one of the valve manuals. These will be our constant companions now we have started to use valves, and they contain all the information we need to know about the various valve types. They are very inexpensive considering the large amount of useful data contained therein, and no one interested in valves should be without one.

For our first valve experiments, any one of a great number of valve types will do. It will be a good plan to buy one of the modern 1.4 volt filament types, if you are able to afford a new valve.

The first thing to note is that we are not going to buy a diode but a triode. There is a very good reason for this. Before very long we will have finished our diode experiments and will be needing a triode in any case. In addition, any triode can be converted into an excellent diode by the simple process of connecting the plate and grid terminals together at the socket and using the joined pair of elements as the plate of the diode.

(To be continued.)

MR. CORNEY INVESTIGATES

Each month we present a servicing problem all the relevant facts of which will be given by our tame investigator, "Mr. Corney" (with humble apologies to Inspector Hornley of BBC fame). Readers are invited to solve the problems and submit their ideas to our office, marking the envelope "Problem" in the top left-hand corner. Correct solutions will be given in each succeeding issue, together with the names of those whose efforts were successful.

THE CASE OF THE NEW ASSISTANT

Hullo folks—how's tricks? That's fine! Did I ever tell you that yarn about my assistant, Jack? He was a likely lad, keen as mustard, but he did complicate matters at times. Once, I put him on to a set to put in new smoothing electrolytics, check up on the valves and re-trim. The bottles were screened with those close-fitting and shaped split cases with a wire cir-clip round the tum tum—you know the type. Anyway after Jack had broken a few fingernails I showed him a better way to get them off and left him to it. Later on he came to me and said he'd finished the job but couldn't line the set as it seemed to be dead although all the valves had tested O.K. Told him to make complete juice checks and then get busy with the sig. generator and locate the dead spot. After an hour or so he reported all correct except that the bally set was still dead. The L.F. was active and he got an I.F. signal from the anode of the I.F. bottle but not from the grid and yet he was certain that the valve had tested as good with no shorts and full emission. Now the funny thing is that before Jack got busy with it the set was definitely "on the air" although below par plus a fair amount of mains hum. What do you think the silly coote had done? Here comes old Jenkins with a bulky parcel and an apoplectic complexion—wonder what's stung him?

Any attempted solution should be posted so as to reach our offices not later than the 15th of the current month.

PUBLICATIONS RECEIVED

THE TECHNIQUE OF RADIO DESIGN

By E. E. Zepler, Ph.D.

This volume is devoted entirely to the design of receivers. It is an excellent demonstration of the working hand in hand of pure theory which Dr. Zepler uses freely, and purely practical considerations, with which the author is thoroughly familiar through his work as a commercial designer. To quote from the preface: "The technique of design . . . consists in foreseeing complications, and in being able to work out on paper the electrical circuit and mechanical construction so that serious trouble is not likely to occur." This is the thesis round which the volume is written. Dr. Zepler's presentation of his material is admirable, and follows a somewhat original plan. Chapter I, "Some Fundamental Theoretical Facts," presents, without mathematical proofs, the basic formulae upon which the whole of his design material is based. The reader can see at a glance the standard of pure theory he is expected to attain if the succeeding chapters are to be of use to him. If in reading the later chapter he finds a result that is not quite self-evident, a reference to Chapter I will put him right. This makes for admirable clarity and conciseness in dealing with such relatively complex matters as the design of aerial coupling circuits. Throughout the book liberal use is made of practical examples that arise in actual design problems, in such a way that a great deal of generalised argument is dispensed with, and the comparatively non-mathematical reader is shown very clearly how the basic formulae of Chapter I are applied to specific problems.

Noteworthy are the author's chapters on "The Principles of Screening" and "Undesired Feedback." These important annoyances are dealt with in a logical and scientific manner. Feedback is no longer presented as something mysterious that happens with poor designs and is absent from good, but is treated from the practical viewpoint that coupling—mutual inductive, capacitative, or resistive—is the cause of all unwanted feedback. The author shows how undesired couplings of these types can cause instability in radio frequency and audio frequency amplifiers. Better still, he gives equivalent circuits with representative values and works out the order of gain required to produce instability in various cases of ineffective shielding, etc.

This is a book that no professional designer will wish to be without, and will appeal to the many amateur designers who take pride in their engineering approach to design problems.

LA RADIO REVUE

This monthly publication may be regarded as our Belgian opposite number. It is, of course, written in French, but this should not present much difficulty to anyone who can remember a little of the language from his school days. Most of the terms used are self explanatory, or become so by virtue of their context, so that the language difficulty should not debar a keen radio worker from deriving considerable benefit from its excellent technical, theoretical and practical articles. Our copies from the publishers, 28 Rue du Prince Leopold, Auvers, Belge.

TUBE DATA

(Continued from page 22.)

ULTRA-HIGH FREQUENCY OPERATION

Full ratings as a class C amplifier in the types of service detailed above may be used at frequencies up to and including 150 mc/sec. However, at frequencies higher than this, for C.W. telegraphy and plate-modulated telephony, the 815 may be used at percentages of the maximum rated plate voltage and plate input power given in the following table:—

Frequency	175	200 mc/sec.
Percentage	80	70 per cent.

N.Z. ELECTRONICS INSTITUTE

(Continued from page 22.)

by the Admissions Committee, advices will be sent to members.

Applications for the first Institute examination close on 30th May, 1947. Forms and details of the examination are available upon application to any branch secretary, or to the office of the Institute.

RADEL SERVICE OSCILLATOR

(Continued from page 14.)

viate any image response difficulties in the final calibration. Even so, it will be necessary to take care that harmonic beats are not used by mistake, since these would give an entirely wrong calibration.

However, the likelihood of making this mistake is fairly remote, since the approximate frequency range of each band of the oscillator is already known. The procedure is to choose a frequency close to one end of the band to be calibrated and set the known oscillator to this frequency. The one under calibration is then tuned until a beat is heard, adjusted for zero beat, and the pointer or dial reading recorded. The next point which is to be calibrated is chosen, the calibrating oscillator is set to frequency, and zero beat found again by tuning the "unknown" oscillator.

When performing this calibration, it is best to start at the low frequency end of the range that is being calibrated, since this minimises the possibility of harmonic beats.

DIALS AND DIAL MECHANISMS

The choice of a dial for an instrument such as this is governed mostly by what is available, rather than what is considered best! However, a number of dials are available which would suit the purpose admirably. For instance, the 0-100 dial with a vernier scale and planetary reduction drive would be quite suitable, if one does not mind referring to calibration charts, instead of having the convenience of a direct-reading dial. This method entails rather less work than making a direct calibration, as all that has to be done is to draw a graph of frequency against dial reading for each frequency range. On the graphs it is a good idea, for quick reference, to mark in red the most commonly used frequencies, such as 465 and 456 kc/sec., 600 and 1450 kc/sec., and any others that are used a good deal.

The scheme illustrated in our prototype is that of making a perspex pointer for a small planetary reduction gear, and drawing a direct calibration on five scales. In our case, the whole of the front panel was drawn on a piece of good quality drawing paper. This was then covered with sheet celluloid and held in place by the thin aluminium escutcheon. A professional-looking job may be obtained using this method if the calibration points are marked in on the paper with a very fine pencil-point and then inked over and lettered by a professional draughtsman. Even if the latter's services are not available, a neat job can be made by careful hand lettering, and, even if this is not quite up to professional standard, it still has the advantage of being a band-calibrated, direct-reading dial, which, after all, is the main thing as far as efficacy is concerned.

Printed by Harry H. Tombs Ltd., 22 Wingfield St., Wellington, N.Z.