

# The Wireless World

THE  
PRACTICAL RADIO  
JOURNAL  
25<sup>th</sup> Year of Publication

No. 858.

FRIDAY, FEBRUARY 7TH, 1936.

VOL. XXXVIII.

No. 6.

Proprietors : ILIFFE & SONS LTD.

Editor :  
HUGH S. POCOCK.

Editorial,  
Advertising and Publishing Offices :  
DORSET HOUSE, STAMFORD STREET,  
LONDON, S.E.1.

Telephone: Waterloo 3333 (50 lines).  
Telegrams: "Ethaworld, Sedist, London."

COVENTRY: Hertford Street.

Telegrams: "Autocar, Coventry." Telephone: 5210 Coventry.

BIRMINGHAM:

Guildhall Buildings, Navigation Street, 2.  
Telegrams: "Autopress, Birmingham." Telephone: 2971 Midland (4 lines).

MANCHESTER: 260, Deansgate, 3.

Telegrams: "Iliffe, Manchester." Telephone: Blackfriars 4412 (4 lines).

GLASGOW: 26B, Renfield Street, C.2.

Telegrams: "Iliffe, Glasgow." Telephone: Central 4857.

PUBLISHED WEEKLY. ENTERED AS SECOND  
CLASS MATTER AT NEW YORK, N.Y.

Subscription Rates :

Home, £1 rs. 8d. ; Canada, £1 rs. 8d. ; other  
countries, £1 3s. 10d. per annum.

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## CONTENTS

	Page
Editorial Comment .. ..	125
Feeding Push-Pull Amplifiers .. ..	126
Current Topics .. ..	129
The "By Request" Receiver .. ..	130
"Quality" .. ..	133
Signal-to-Noise .. ..	135
New Apparatus Reviewed .. ..	137
Challenger 8 .. ..	138
Listeners' Guide for the Week .. ..	140
Unbiased .. ..	142
Readers' Problems .. ..	143
Letters to the Editor .. ..	144
Broadcast Brevities .. ..	145
Principal Broadcasting Stations .. ..	146
Recent Inventions .. ..	148

## EDITORIAL COMMENT

### High-note Boosting

#### Would It Be Worth While?

**O**VERCROWDING of broadcast transmitters sets a limit to the quality of reproduction which our sets can provide, since it becomes impossible to reproduce frequencies above a certain point without introducing heterodyning with adjacent transmissions and "sideband splash."

In last week's issue a reader put forward the suggestion that high notes could be reproduced without heterodynes if the transmitting station deliberately boosted top and receivers were fitted with a simple filter in the loud speaker feed to readjust this to a linear response.

Our correspondent recognises that all receivers would have to be fitted with a suitable filter for this purpose and that this filter would have to be put out of action when it was desired to listen to another station not employing the high-note boost arrangement.

Whilst our correspondent's idea is extremely interesting and would undoubtedly produce the improvement in the way of reducing heterodynes which he predicts, the scheme is one which we do not suppose will be adopted by any broadcast transmitter. It is well known that this arrangement works well in practice in the case of recording where background noise becomes very troublesome at high frequencies. The scheme here adopted is to employ an amplifier for recording with a rising characteristic so that the signal-to-noise ratio is favourable in the record; then when this record is used for broadcasting or other purposes a correction circuit is used to restore the response to its proper proportions throughout the range.

If, however, we attempt to do this in the case of a broadcast transmission

we shall, whilst reducing heterodynes, increase the tendency to the even worse trouble of sideband splash, for we cannot visualise such a scheme being adopted only by the stations we want to listen to!

The subject is interestingly discussed by a correspondent in this issue, who points out some of the objections and expresses the hope that no experiments of this nature will be introduced.

In the interests of quality it has often before been suggested that at the transmitting end adjustments to the response of the amplifier should be made to correct for the average deficiencies of receivers. Fortunately, these suggestions have not been adopted. A deplorable state of affairs would result if designers of receivers had to take into account a non-linear output from the transmitter, and when it is remembered that different transmitting authorities would probably fail to standardise their outputs we should be faced with having to design elaborate variable correcting circuits on all our receivers and adjust them afresh for every station to which we tuned.

### The Crystal Set

#### Revival of Interest

**I**N this issue we describe the construction of a crystal receiver for the first time for many years. The "By Request" Crystal Set was made as a result of the very many requests we have received for such an instrument.

The endeavour has been made to take advantage of any recent developments which could improve performance, and those readers who construct the set will, we think, be surprised to find how greatly adequate selectivity and the increase in power of transmitting stations have added to the repertoire of a crystal set since the days when its use was so general.

# Feeding Push-Pull Amplifiers

## Methods of Phase Reversal

By W. T. COCKING

**R**ESISTANCE-COUPLED push-pull amplification is now commonly employed in cases where the highest possible standard of reproduction is required. Some difficulty is often experienced, however, in obtaining a satisfactory method of phase reversal in the input circuits, and in this article the chief methods are discussed in detail and a new system is described.

**I**N low-frequency amplification the push-pull system is widely recognised as giving a smaller degree of amplitude distortion than the more usual single-sided amplifier. It is consequently becoming more and more commonly employed in all cases where the attainment of the highest standard of reproduction is given serious attention. At one time its use was confined to transformer-coupled amplifiers, but it is now often used with resistance coupling. If the best results are to be secured particular attention must be paid to the input circuit. No difficulty arises when using transformer coupling, of course, for the usual push-pull transformer provides the necessary phase reversal in a straightforward manner. When resistance coupling is employed, however, matters are not quite so straightforward and there are many alternative arrangements possible.

The input circuit of a typical resistance-coupled push-pull amplifier is shown in Fig. 1, and in practice  $C_1$ ,  $C_2$  and  $R_1$ ,  $R_2$  are given identical capacities and resistances respectively. In feeding an amplifier of this nature the problem resolves itself into obtaining an input voltage between A and E which is at any instant of the same value and of opposite sign to

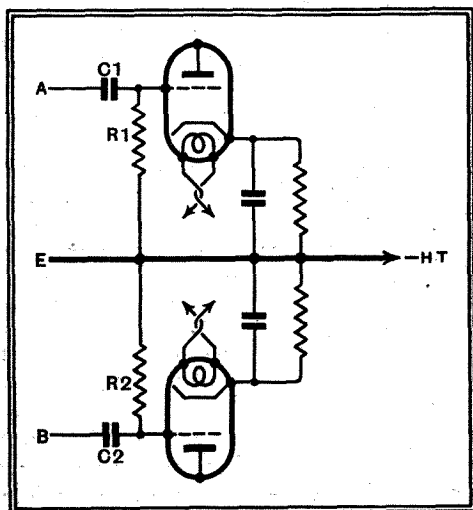


Fig. 1.—The input of a typical push-pull amplifier is shown here.

that which exists between B and E. In other words, if the point A be 1 volt positive with respect to E, the point B must be 1 volt negative also with respect to E. When neither terminal of the input need be earthed, this result can be secured very

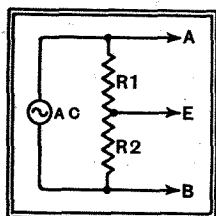


Fig. 2.—The simplest method of phase-reversal for the input consists of a centre-tapped resistance.

simply indeed. Suppose, for instance, that the amplifier of Fig. 1 is to be fed from an AC generator, which might well be a gramophone pick-up, the phase reversal can be secured by connecting two equal resistances in series across it and earthing their centre-point. This is

shown in Fig. 2 where the resistances are denoted by  $R_1$  and  $R_2$ .

The operation of a circuit of this type is very easy to understand. Assuming for the moment that the arrangement of Fig. 2 is not connected to anything else, the generator drives a current through the two resistances. As these have the same value and as there is the same current through them, the voltage drop across each is the same and is one-half the generator voltage when the generator has no internal impedance. The voltage is less when the generator impedance is appreciable, but the voltage across  $R_1$  is still equal to that across  $R_2$ . Now the question of phase arises, and is equally easy to settle. Suppose that at any instant A is 2 volts positive with respect to B. Since the voltage drop across  $R_1$  equals that across  $R_2$  it is obvious that A must be 1 volt more positive than E, and E 1 volt more posi-

tive than B. But if E is 1 volt positive with respect to B, then B must be 1 volt negative with respect to E. Hence A and B are at any instant at equal and opposite potentials with respect to E and the required phase reversal has been obtained. This holds also when another circuit is connected to that of Fig. 2, provided that the external impedance between AE has the same value and is of the same nature as that between BE.

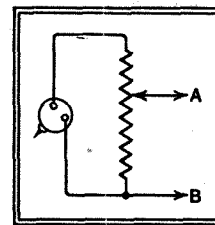


Fig. 3.—When a gramophone pick-up is used, this circuit can feed an amplifier; the input is split by  $R_1$  and  $R_2$  of Fig. 1.

It follows that an amplifier of the type of Fig. 1, which is really the input of *The Wireless World* Push-Pull Quality Amplifier,<sup>1</sup> can be fed from a gramophone pick-up by connecting it to the terminals A and B, leaving E blank, for the grid leaks  $R_1$  and  $R_2$  provide the necessary centre-tap to the input. In general, however, this method is not very satisfactory, for a pick-up having a very large output is usually needed; the Quality Amplifier, for instance, requires an input of 7 volts peak. When required, a volume control can be connected as shown in Fig. 3.

This method of phase reversal may still be used when it is desired to couple a diode detector directly to an amplifier as shown in Fig. 4. When a volume control is not wanted, it is best to split the diode

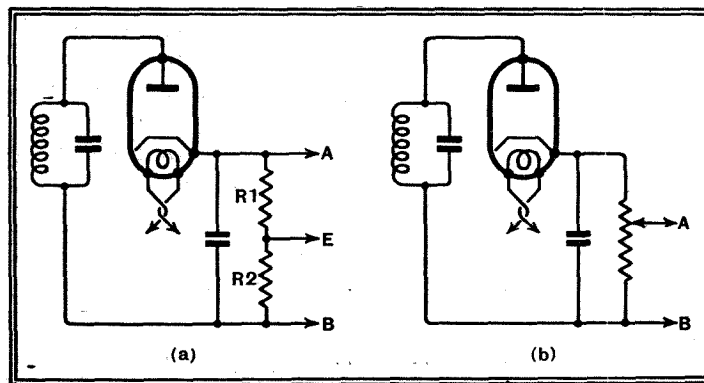


Fig. 4.—The arrangement of Fig. 2, as applied to a diode detector, is shown at (a), and at (b) the connections necessary when volume control is required.

load resistance into two equal parts,  $R_1$  and  $R_2$ , as shown at (a); no part of the circuit except the centre-tap must be earthed. If volume control be required, however, the arrangement of (b) can be

<sup>1</sup> First described May 11th and 18th, 1934, and reprinted February 22nd, 1935. These issues are now out of print, but the original articles are available in booklet form.

**Feeding Push-Pull Amplifiers—**

used, and here the grid leaks in the amplifier are relied upon for splitting the input to the amplifier.

These precise arrangements, however, are not widely used, because some additional amplification is usually required for gramophone use and this is generally retained on radio also. One very satisfactory arrangement is shown in Fig. 5, and the method of phase reversal is basically the same as in the case of the circuits just discussed. The resistances  $R_1$  and  $R_2$  must have the same value, usually 20,000-50,000 ohms and the decoupling condenser  $C_1$  must be of large capacity, some 8 mfd. Thorough decoupling is usually necessary, and it is wise, even when  $C_1$  has a capacity of 8 mfd., to make  $R_4$  as high as 50,000 ohms. Grid bias is

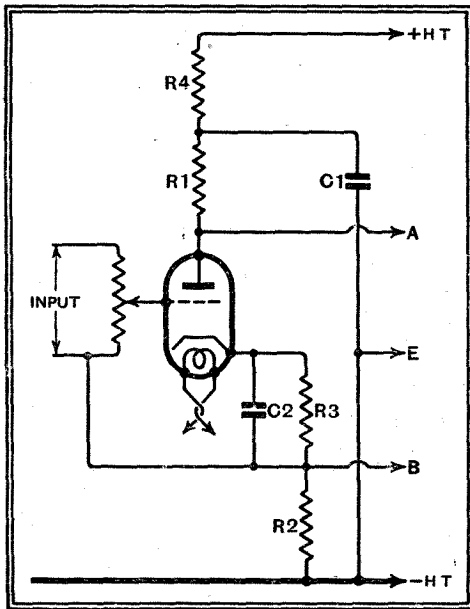


Fig. 5.—One very satisfactory method of feeding an amplifier is obtained by placing equal resistances  $R_1$  and  $R_2$  in the anode and cathode circuits of a triode.

obtained by the voltage drop across  $R_3$  and a value of 1,000-2,000 ohms is normally suitable; the by-pass condenser  $C_2$  should be large, at least 25 mfd.

This system may be used on both radio and gramophone and a gain of about 10 times from the input terminals to each half of the output, or 20 times between the input and AB may be expected when suitable components are used. The greatest disadvantage of the arrangement is that neither terminal of the input may be earthed. This does not greatly matter on gramophone, for there is rarely any difficulty in isolating each pick-up lead, but it is often inconvenient on radio. In the first place, it prohibits the use of some detector circuits, and secondly it greatly increases the difficulty of filtering the detector output properly.

There are many cases where it is essential for one terminal of the input to be earthed, and it is then usual to employ the paraphase system. There are many variants of this, but there is actually little to choose between them and one of the simplest arrangements is that of Fig. 6.

It will be seen that whereas the "B" output terminal is fed directly from the input, the "A" terminal is fed through the valve which is connected as a conventional resistance-coupled amplifier. Since there is a complete phase reversal in one stage of resistance amplification, it is clear that in this way the output terminals A and B are always at opposing potentials. In order that the magnitude of the potentials be the same, however, the gain of the stage must be unity. The valve grid, therefore, is fed with only a portion of the input from the potentiometer  $R_1$ ; in practice,  $R_1$  is adjustable and is set so that the amplifier as a whole is balanced and each output valve gives the same output. Incidentally, any of the other arrangements may be exactly balanced if desired by making the appropriate resistances adjustable.

**The Paraphase System**

Although the valve used in paraphase gives no effective amplification the phase-reversing stage as a whole gives a gain of 2 times. This is easily seen when it is remembered that the whole of the input appears between the B and E terminals, while the potential between the A and E terminals is derived through the valve. With the direct input split by a tapped resistance (Fig. 2) only one-half the input appears between each pair of output terminals.

The values of components used for the phase-reversing valve of Fig. 6 are the conventional ones for a resistance-coupled stage, but it is important that  $C_1$  and  $R_1$  be large enough to pass very low frequencies, much lower than those needed for proper bass reproduction. An examination of the circuit will show that with this arrangement there is one more coupling on one side of the amplifier than on the other. Each coupling condenser and grid leak must cause some attenuation which increases with a reduction in frequency. Although the amplifier may be perfectly balanced over the whole range of musical frequencies it cannot be balanced at very

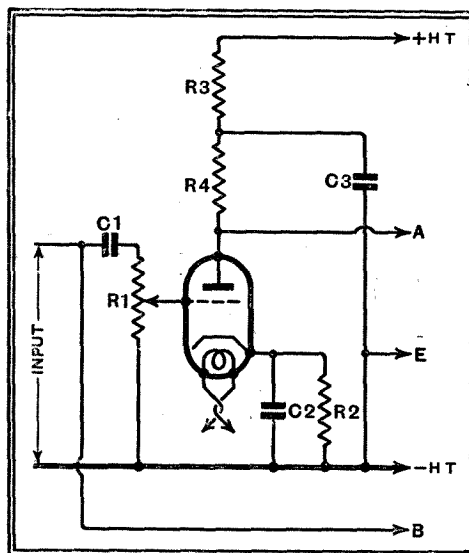


Fig. 6.—The paraphase system embodies an extra valve giving a stage gain of unity.

low frequencies, 10 c/s or lower. Now, one of the greatest advantages of push-pull is that when the amplifier is properly balanced feed-back effects through the HT supply are almost non-existent, and much difficulty in obtaining adequate decoupling of early stages is avoided.

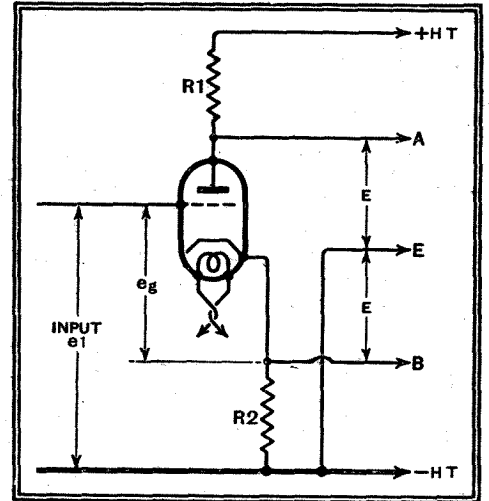


Fig. 7.—The basic connections of a new method. It is similar to the arrangement of Fig. 5, but one side of the input can be earthed.

These feed-back effects manifest themselves as motor-boating and very low frequencies are involved. Unless  $C_1$  and  $R_1$  (Fig. 6) are large enough to pass these very low frequencies with negligible attenuation, therefore, the advantage of push-pull in reducing feed-back is very largely lost. Experience shows that when  $R_1$  is 1 megohm  $C_1$  must be at least 0.1 mfd., and it is better larger.

**A New Phase-Changer**

A modification of the circuit of Fig. 5 has recently been put forward<sup>2</sup> which removes the objection of requiring an un-earthed input. The basic circuit without decoupling and biasing arrangements is shown in Fig. 7, and at first sight it would seem that the operation is the same as that of Fig. 5. It is, however, very different save in the method of phase reversal. The voltage which operates the valve is not the true input voltage  $e_i$  (Fig. 7.), but the voltage  $eg$  developed between grid and cathode, and this is less than  $e_i$  by the output voltage  $E$ , which appears across  $R_2$ . In other words, there is severe anti-phase feed-back because  $R_2$  is common to both input and output circuits. This does not cause distortion as long as  $R_2$  is not by-passed by a condenser, but any attempt to reduce the feed-back by shunting  $R_2$  by a condenser is foredoomed to failure, for it will not only affect the frequency-response characteristic but will also upset the balance between the two halves of the output.

The true input voltage to the valve  $eg = e_i - E$ , and as  $E$  is the output to one side of the push-pull amplifier,  $eg$  must be less than  $E$ . The gain of the stage, measured between the input terminals and

<sup>2</sup> Electronics, October, 1935.

**Feeding Push-Pull Amplifiers—**

one pair of output terminals (AE or BE) must be less than unity, so that the stage attenuates instead of amplifying. Actually, the "gain" closely approaches unity and is given by  $E/e_1 = \mu R_2 / R_a + 2R_2 + \mu R_2$  where  $\mu$  = valve amplification factor,  $R_a$  = valve AC resistance. The other symbols are as shown in Fig. 7,  $R_1$  being equal to  $R_2$ . Using a typical valve having a resistance of 10,000 ohms with an amplification factor of 20, it can be seen that when both  $R_1$  and  $R_2$  are 25,000 ohms the gain  $E/e_1 = 0.893$ . The total gain of  $e_1$  to the voltage between the AB output terminals is, of course, just double this, or 1.786 times, so that if the push-pull amplifier requires a total input of 7 volts peak this feeder stage needs only 3.92 volts peak or 2.78 volts RMS. The gain is, in fact, nearly 90 per cent. of that given by the paraphase system.

The precise arrangement of Fig. 7 can rarely be used, because the grid cannot normally be returned to the earth line. The steady anode current passing through  $R_2$  makes the cathode considerably positive with respect to the earth line—if the anode current be 1 mA. and  $R_2$  be 25,000 ohms, the cathode is 25 volts above earth. If the grid were returned to the earth line it would be negative with respect to cathode by the drop across  $R_2$ —with the figures just mentioned it would be negative by 25 volts—which is usually far too great a bias.

**Practical Circuit Values**

There are several ways in which the circuit can be modified to obtain the correct grid bias, and one of the simplest is shown in Fig. 8. It will be seen that a bias resistance of 1,000-2,000 ohms,  $R_2$ , with a by-pass condenser  $C_2$  of at least 25 mfd., is introduced in the cathode circuit. The grid is returned to the negative side of this through the grid leak  $R_1$ , so that the bias on the valve is merely the voltage drop across  $R_2$ . If these modifications are not to upset the operation of the circuit it is necessary for the reactance of  $C_2$  to be small compared with  $R_2$  at the lowest frequency, and  $R_1$  must be very large compared with  $R_3$ . In the anode circuit the reactance of  $C_3$  at the lowest frequency should be small in comparison with  $R_4$ , but this depends to some extent upon the value of  $R_5$ . In practice, satisfactory values for the components are:  $C_1 = 0.1$  mfd.,  $C_2 = 50$  mfd.,  $C_3 = 8$  mfd.,  $R_1 = 2$  megohms,  $R_2 = 2,000$  ohms,  $R_3 = R_4 = 25,000$  ohms,  $R_5 = 50,000$  ohms. The valve selected does not greatly influence the results, and the MH4 and MHL4 classes are entirely suitable. The HT supply can be from 200 volts to 300 volts without necessitating any change in the values of the components.

Perhaps one of the greatest advantages of this system of feeding a push-pull amplifier is the way in which a tone control can be devised. If both  $R_3$  and  $R_4$  be shunted by condensers of suitable value—0.002 mfd. to 0.01 mfd.—the higher audible frequencies are greatly attenuated,

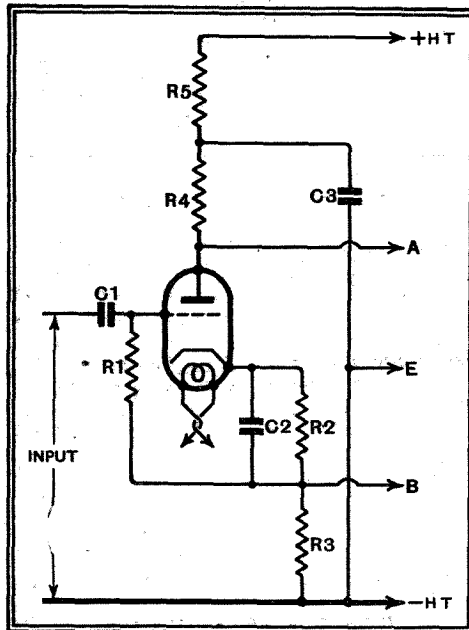
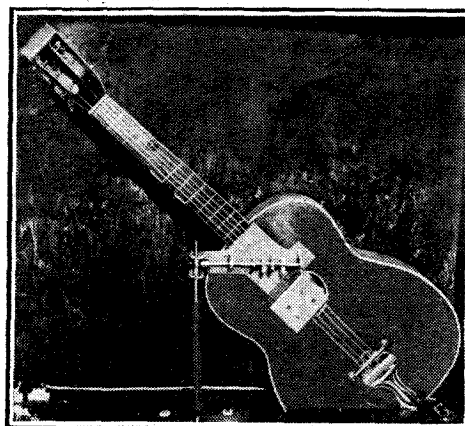


Fig. 8.—In practice, the new system is arranged in the manner shown in this diagram.

as one would expect. If only  $R_3$  be shunted, however, the total output of the push-pull amplifier is increased at high frequencies! What happens is this. When  $R_3$  and  $R_4$  are both shunted the amplification of the valve falls at high frequencies owing to the by-pass effect of the condensers; the feed-back to the grid circuit is reduced, however, so that the effect of the by-pass condensers is not as great as with an ordinary circuit. Now when only  $R_3$  is shunted the voltage developed by the signal between cathode and earth is reduced at high frequencies, the feed-back is less, and a larger proportion of the input is effective in operating the valve. In other words, the effect of shunting the resistance  $R_3$  by a condenser is to increase the voltage between grid and cathode at high frequencies. Consequently a larger voltage is developed across  $R_4$ . It can thus be seen that at high frequencies the voltage at the AE terminals rises, while that at the BE terminals falls. The rise at the one pair, however, is greater than the fall at the other, so that there is a gain in the total output.



CRACOW'S NEW INTERVAL SIGNAL is produced by a real guitar played by an automatic hand, which can be seen in the picture just above the small microphone. The only disadvantage in the arrangement is that the guitar must be tuned daily.

A very useful accentuation of the upper register can be obtained in this way, but it is, of course, accompanied by a loss of balance in the push-pull amplifier, for at high frequencies one-half of the chain does most of the work. This does not always matter, however, for two reasons—first, the signal amplitudes at high frequencies are usually small, and secondly, the harmonics introduced by any non-linearity are likely to be above audibility. Considering this point first, if the method be used to accentuate frequencies above 5,000 c/s only, there will be no lack of balance at lower frequencies, and all the advantages of push-pull will be obtained for such frequencies. Now if the lack of balance at higher frequencies does introduce harmonic distortion, it is unlikely to be present on any frequency lower than 7,000 c/s, for if the amplifier be balanced at 5,000 c/s the lack of balance between 5,000 c/s and 7,000 c/s will be quite small. The second harmonic of 7,000 c/s is 14,000 c/s, which is getting near the upper limit of audibility. It is fairly certain that such a frequency could not be heard unless it were of considerable intensity, and in any case it is unlikely to be reproduced by any but the very best loud speaker. The other point which helps to make the lack of balance unlikely to result in distortion is that the amplitudes at frequencies over 5,000 c/s are normally quite small compared with those at low frequencies. The large amplitudes occur at low frequencies, and it is at these frequencies that the amplifier must be balanced if distortion is to be avoided.

It can thus be seen that this method of tone control, although at first sight inadmissible, is actually quite permissible, and a useful increase in the high-frequency response to compensate for sideband cutting or other deficiencies can be obtained very simply and without reducing the gain of the amplifier. This last is the most important point, for most other effective methods of tone-correction only give a relative increase in the high-frequency response, and it is actually obtained by reducing the amplification at low and medium frequencies. This is undoubtedly rather wasteful.

**THE RADIO INDUSTRY**

AN arrangement has been concluded whereby Baird "Televisors" are to be manufactured and distributed by Bush Radio, Ltd. Television courses for Bush agents' service engineers will commence in February, and will be conducted by Baird Television, Ltd.

W. Bryan Savage, Ltd., have again moved to a larger factory; the new address is: Westmoreland Road, Stanmore, Middx. Telephone number: Colindale 7131.

Wireless exhibits on the T.M.C.-Harwell stand at the British Industries Fair at Birmingham (No. Cb.821-720), will comprise condensers of all types, together with the new T.M.C.-Hydra Interference Suppressor Units.

The Newcastle branch office of Siemens' Electric Lamps and Supplies, Ltd., has been transferred to Siemens' House, Carlisle Square, Newcastle-on-Tyne. Telephone number: Newcastle 20641.

# CURRENT TOPICS

## Events of the Week in Brief Review

### Moscow Television

TELEvised scenes from the life of Lenin were broadcast in Moscow on January 21st on the eleventh anniversary of his death.

### Direct Television in Germany

DIRECT television of the Winter Olympic Games at Garmisch is to be carried out daily from the Witzleben broadcasting tower in Berlin.

### Radio Weeks

THE Radio Manufacturers' Association is to consider the inauguration of a "radio week" in the early spring. Another project is a "radio progress week" at the beginning of October to emphasise the latest technical improvements in radio sets.

### New Zealand Amateurs' "Mourning Whistle"

ALL transmitting members of the Radio Society of Great Britain closed down for the whole of Sunday, January 26th, as a mark of respect for King George.

Nearly 200 New Zealand amateur transmitters sent out a continuous whistle on the 80-metre wavelength for three minutes on the "day of mourning," January 28th.

### "Apex" Waves

ULTRA-SHORT-WAVE experimental transmitters now being licensed in America are known as "apex" stations because their aerials must be located at high points. Besieged by applications for ultra-short-wave licences, the Federal Communications Commission is understood to be reserving the "apex" group of waves for visual broadcasting. Half the applicants for "apex" permits are newspapers.

### Radio Prison

A STRANGE fate awaits the Norwegian wireless station at Udlanhaug, which closed down on Saturday last. The premises are being purchased by the Stavanger City Council for conversion into a prison. Broadcast listeners in the district who have been troubled by the Udlanhaug spark transmitter hope that the station *personnel* will be retained after the change.

### Broadcasts for Bedridden

THE Ravag station in Vienna is to inaugurate a weekly hour for invalid listeners.

### How France Listens

REGISTERED radio sets in France now number 2,625,677. Nearly half of these are in the Paris region.

### 40 Years On

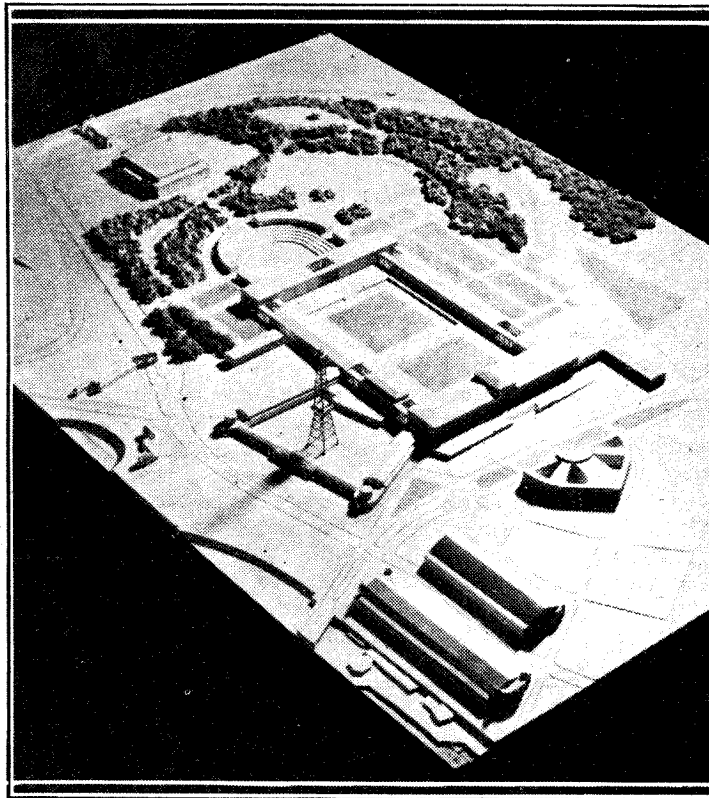
SUNDAY last, February 2nd, was the fortieth anniversary of Marchese Marconi's first arrival in England with the crude apparatus which was so soon to startle the British Post Office with its feats of communication without wires.

Marconi's initial demonstration was before Sir William

Is it possible that our American colleagues have deprived themselves of proprietary rights in the word "amateur" through reverting to the porcine appellation "ham"? British amateurs, with a few notable exceptions, have been content to be known as amateurs, leaving the terminology of the meat industry to those who feel better for it.

### Cycle-Radio

CAR radio is common enough among the police forces of Great Britain, but cycle radio is



SHOW FORECAST.—Already the Berlin Radio Exhibition for 1936 is planned in detail, as this architect's model indicates. The main exhibition building is in the centre. Note the famous Radio Tower and, to the right, the semi-circular "Broadcasting House" from which programmes will be relayed.

Preece, Chief Electrical Engineer of the Post Office, in July, 1896.

### Are "Hams" Amateurs?

STRONG protests against the use of the term "amateur" by U.S. broadcasting tyros are being made by the American Radio Relay League, which contends that a radio amateur is "a person interested in radio technique solely with a personal aim and without pecuniary interest." In a special statement the League urges "the puzzled broadcast listener to do his best to get his definitions straight and try not to confuse the gulping crooner with the amateur expert next door."

more of a novelty. Indeed, Liverpool Police Force are believed to be the first to adopt it. Many of their officers on cycle patrol carry midget receivers to keep them in touch with headquarters. A wavelength of about 148 metres is used.

### Set Making in Palestine

HAS the British radio trade missed an opportunity? It is recorded that 75 per cent. of the radio receivers now in demand in Palestine following the opening of the Jerusalem transmitter are being supplied by a new radio firm working at high pressure in Tel-Aviv.

### Recording Demonstrations

A RECORD made on the spot will be reproduced at the meeting of the Golders Green and Hendon Radio Society on Wednesday next, February 12th, when Mr. A. L. Royer will lecture on "Home Recording" at the Hampstead Art Galleries, 343, Finchley Road. The meeting opens at 8.15 p.m.

### For Surrey Transmitters

A NEW British transmitting pentode will be demonstrated by Mr. B. G. Wardman (G5GQ) at a meeting of the Surrey Radio Contact Club on February 11th at the Railway Bell Hotel, West Croydon Station. *Wireless World* readers wishing to attend are asked to communicate with the hon. sec., Mr. E. C. Taylor, 35, Grant Road, Addiscombe.

### Overdrafts Not Allowed

ITALIAN listeners are now provided with "cheque books" for the payment of their radio licence fees. When paying the tax for a particular year the subscriber fills up one of the forms, detaches it and hands it in, together with the licence money, at any post office.

### Mandel Remains

MEN may come and men may go, but, like Tennyson's brook, M. Mandel, French Postmaster-General, goes on for ever. The recent change of Ministry has left the radio-minded P.M.G. at his post; in fact, his disappearance, according to our Paris correspondent, is regarded as unthinkable.

### The Policeman's Lot

THE week's best story comes from Moscow, where, it is stated, policemen undergoing the rigours of point duty in cold weather are to be provided with thick coats having wire netting stitched into the lining. "This wire net," writes our informant, "will be radio-electrically heated by neighbouring broadcasting stations."

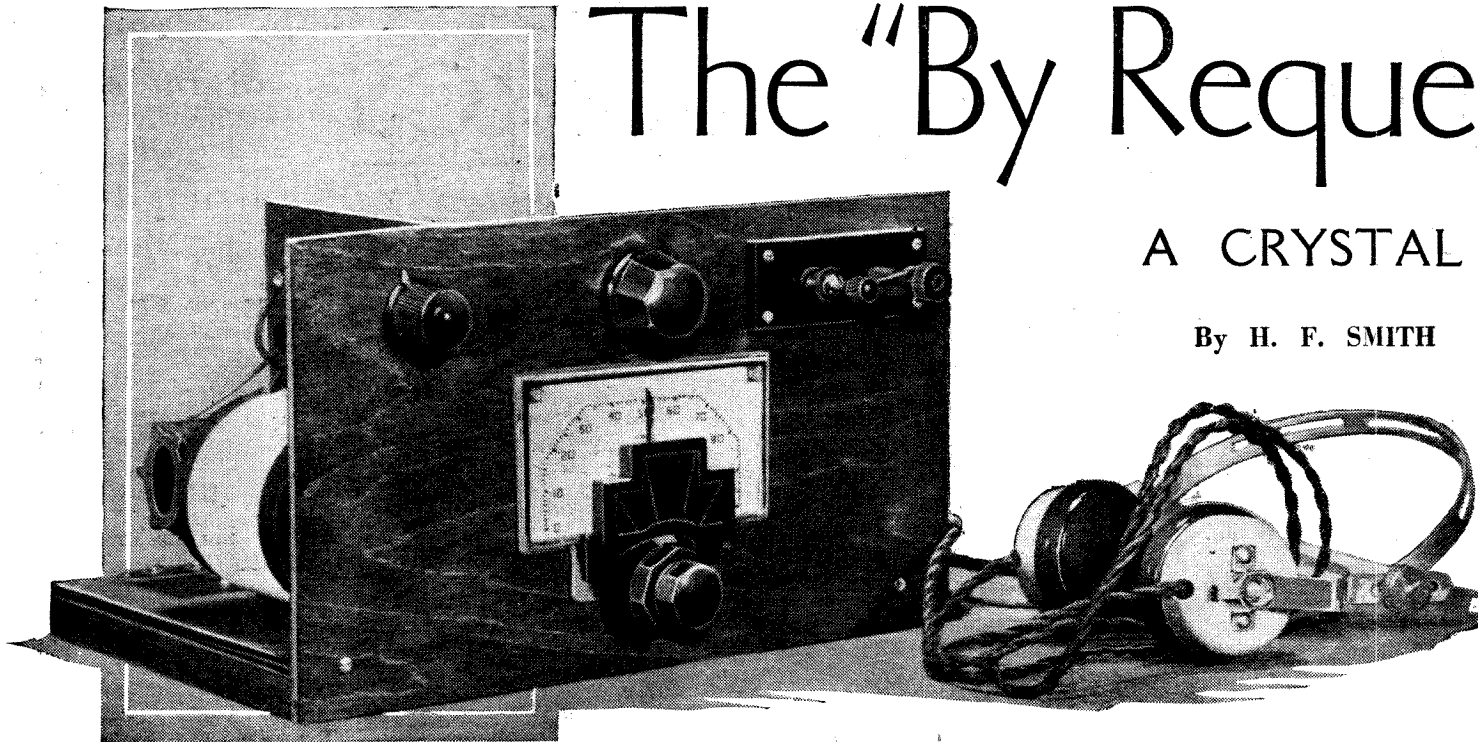
### Shut the Door

ROCHDALE radio dealers must keep the door closed when operating a loud speaker in the shop. This new by-law was given publicity last week when a local dealer was summoned for operating a shop loud speaker in such a manner as to cause annoyance to the public. He pleaded that the door was left only slightly ajar and the magistrates dismissed the case on payment of costs.

# The "By Request"

## A CRYSTAL SET

By H. F. SMITH



*MANY readers have expressed a desire for the publication of constructional details of an up-to-date crystal set, for use either as a "stand-by" in the event of a breakdown, or for headphone-listening in normal circumstances. The receiver described below is interesting in that it shows how far comparatively recent developments may be applied to one of the earliest types of receiver.*

WHEN the popularity of the crystal set began to wane, some ten years ago, none of our modern conveniences such as ganged tuning and waveband switching had found their way into receivers generally. In planning a modern crystal set the first task is clearly to work these features into its design, and, even more important, to provide enough selectivity for conditions as they exist to-day.

The fate of the crude crystal set, as we knew it originally, was finally sealed when the twin-station "Regional" system of broadcasting came into being some six years ago. Its selectivity was insufficient to separate a pair of local stations. The only practicable way of overcoming this weakness lies in the use of a pair of tuned circuits, and this plan is adopted in the present set.

But this, in itself, is hardly enough. It is also necessary to reduce damping due to the crystal, and at the same time to see that in all the various transferences of energy from circuit to circuit there is as little wastage of power as possible. This question of matching input impedance to output impedance is much more important than in a valve set, since we have no local source of energy to call upon.

Matching is most important of all in the case of the crystal coupling, and the matter is closely analogous to the problem of obtaining the maximum

power output from, say, a dry battery. To do so, it is necessary that the resistance of the external load should be equal to the internal resistance of the battery; anything more or less will be responsible for a falling-off in power. With the help of Ohm's Law, this may easily be verified by working out an example.

Without stretching the analogy too far, we may consider that the crystal detector represents the external load, and the tuned circuit (source of energy) which feeds

tuning coil, across a part only of the tuned circuit—in effect, an auto-transformer. Unfortunately, the matter can hardly be carried to its logical conclusion, as the impedances to be matched are not constant, and so a compromise must be struck in practice. But the arrangement advocated is demonstrably superior, both from the aspects of selectivity and output, to the crude arrangements with which we used to content ourselves.

The circuit adopted, then, is that shown in Fig. 1. Aerial coupling to the primary circuit comprising L1, L2, and C1 is changed over by the wave-range switch S1; coupling to the secondary circuit L3, L4, C2 is controlled by means of the small condenser C3. As the various switches are linked, the crystal connection is appropriately changed over to a centre tapping on L3 or L4, depending on whether the medium or long waveband is in use. The gang condenser (C1, C2) embodies built-in trimmers, that in parallel with C1 being controllable through an external knob; need for accurate matching of coils is thus avoided.

Construction is greatly facilitated by the adoption of the capacity-coupled two-circuit tuner, which does not require complicated mechanism for variation of inter-circuit coupling. The system works out quite happily in practice, and simple screening afforded by a single vertically mounted sheet of aluminium is sufficient

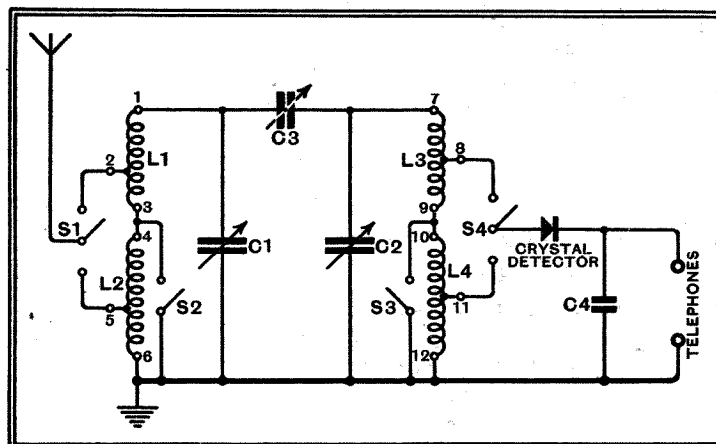


Fig. 1.—Complete circuit diagram. All the wave-change switches are mechanically linked, and operated by a single knob.

it represents the battery. At first sight it might appear that maximum power would be obtained by connecting the crystal across the whole of the tuned circuit, but the relative impedances of the two are actually such that a stepdown transformer is required. The crystal is therefore connected to a tapping on the