The "PARRYPHASE" PUSH-PULL CIRCUIT

From the pen of C. Parry, the development engineer responsible for the already popular series of articles on acoustical compensation, comes this ingenious suggestion for paraphase push-pull.

AMONG the several methods developed to provide antiphase voltages for the grids of a push-pull output stage is that which is known as "paraphase." There is much to be said both for and against this method, but it is not the purpose of this article to discuss relative merits of any particular systems.

Basic Principle

Although the idea is by no means new, it is as well to discuss briefly the salient points in the light of subsequent discussion.

In Fig. 1 it will be seen that the driving voltage for V_1 is split by RR_1. The portion V9 tapped off is applied to a separate amplifying device V_2, and then applied to grid of V_3. Since a phase reversal takes place within V_2, it is obvious that push-pull action may take place if now the attenuation of the tapping for V_2—

$$\left\{ \frac{R_1}{R + R_1} \right\}$$

is made equal to the dynamic amplification of V_2—

$$\left\{ \frac{M\ RL}{RL + Rp} \right\}$$

then the voltage E_1 will equal E and true push-pull will result.

One of the disadvantages of this system is, of course, the phase shift, which occurs at low and high frequencies, and the accompanying unbalance. By using a further grid coupling network for V_1, as shown by the phantom circuit, which has a time constant equal to R_2C, the low end may be maintained, but this introduces further complications in the plate load of V4.

Some Points

The high-frequency shift may be more serious and cannot be easily eliminated. Again, in production, the resistors R and R_1 must be maintained within close limits to prevent unbalance occurring due to a change in their ratio.

It will also be realised that hum voltages in the plate circuits of V4 and V_2 will not balance, and so hum may result.

Notwithstanding these facts, if care is taken, the simple circuit shown will provide very satisfactory operation.

It will be realised that a high gain valve may be used for V4, and its characteristics will in no way upset balance conditions. Thus it is quite feasible to use any tone compensation device across the points A B.

The simplicity of the circuit has led many designers to incorporate V_2V4 in a single valve, such as the 6A6 or 6F7. This can, of course, be done quite easily, but it is important to realise that, as common currents flow in the common cathode circuit, this must be effectively by-passed, and this automatically excludes the use of feedback to the cathode circuit.

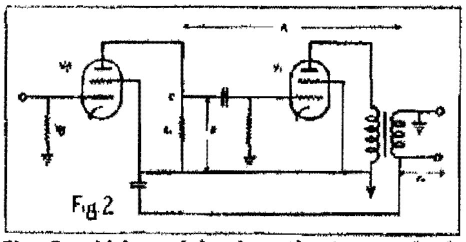

Fig. 2, which explains how the inverse feedback is applied.

So much for the paraphase principle.

Screen Feedback

As there will be many who would not care to build an amplifier using pentodes in the output without also applying some method of feedback, we will consider this in further detail.

Take the basic circuit of Fig. 2. It is impossible to feedback to the cathode, and undesirable to go to the control grid of V4. Nevertheless, overall feedback has desirable advantages.

The idea of screen injection has been discussed before, and a very effective circuit using this principle appeared in Radiotronics No. 89, 1938.

Nevertheless, feeding the inverse voltage from the primary of the output transformer seems to suffer from certain practical disadvantages. The two halves of the primary and the secondary should be tightly coupled, while unbalance seems to be further increased. Precautions are often necessary to prevent oscillation, and the home set-builder frequently finds himself in trouble.

New System

The obvious point from which any feedback voltages should be taken is the voice coil winding, since in this case it will automatically take care of transformer discrepancies. Also it is clear that the voltages fed back from this point are dependent on conditions of unbalance, but do not tend to affect unbalance in any way.

Let us therefore consider the voice coil voltages fed back to the screen of V4 by condenser C (the normal screen by-pass condenser — Fig. 2).

If Rt is the triode plate resistance formed by the screen and plate of V4, and Ut the amplification of this triode, then there is developed across RL an antiphase voltage given by —

$$Ep_1 = \frac{Eo\ Ut\ RL}{RL + Rt}$$

Now, a voltage Vg on the grid of V4 will produce a voltage across RL given by —

$$Ep = \frac{Vg\ Up\ RL}{Rp + RL}$$

where Up and Rp refer to the pentode characteristics of V4 with the screen as in Fig. 2. Now, Ep_1 will either add or subtract from Ep, depending on whether Eo is positive or negative. If the polarity of the voice coil is correctly chosen, then Eo is negative and the actual plate voltage is given by —

$$E = Ep - Ep_1$$

$$= \frac{Vg\ Up\ RL}{Rp + RL} - \frac{Eo\ Ut\ RL}{RL + Rt} \quad .. (1)$$

If A is the overall amplification from the point C to the voice coil, then, obviously Eo = AE.

We can thus substitute in (1) and

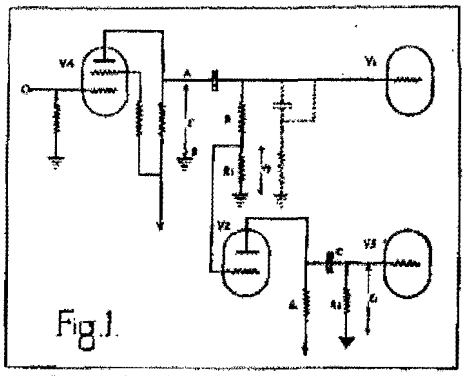

Fig. 1, showing how the out-of-phase signals are derived.

find the ratio of the gains with and without feedback; that is —

$$E = \left\{ \frac{Vg\ Up\ RL}{Rp + RL} \right\} \left\{ \frac{1}{1 + \dfrac{AUtRL}{RL + Rt}} \right\}$$

with feedback.

Without feedback, the voltage across RL is, of course, unaffected

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by Eo and equals the first bracketed term of the above equation.

Then the ratio of gain without feedback to gain with feedback is —

$$\frac{E_1}{E} = \frac{1}{\dfrac{1}{1 + \dfrac{AUtRL}{RL + Rt}}} = \frac{RL + Rt + AUtRt}{RL + Rt} = \frac{RL + Rt\ (1 + AUt)}{RL + Rt} \quad \ldots\ldots (3)$$

This factor therefore represents the amount by which the gain is reduced when this particular feedback is applied.

It may be shown that a gain reduction of about 2.5, for 6V6G valves, will give performance approximately equal to triode operation.

Substituting known values in the above equation gives us a figure somewhat in excess of this, so that we may consider the system quite satisfactory.

Effects of Feedback

It is a point to note that the feedback is not adjustable and in fact no attempt has been made to achieve this. In the light of the circuit considered this has been regarded as relatively unimportant. The constants of the final amplifier have been so chosen as to give a slight high-frequency droop. This, together with the adequate control of resonances by the feedback, provides a highly-satisfactory tonal response.

Referring again to the equation developed, some interesting conclusions may be drawn (these remarks apply in general to all feedback systems). It will be realised that the gain reduction is almost proportional to A. Thus any change in the amplification of V_1, due to load changes and so on, are almost perfectly taken up within V4.

Loss Within Feedback Path

Assuming that the feedback remains negative, it is very important to realise that, while the amplification of the system drops by the above factor, this also represents the maximum "lift" which it can bring about at any frequency for which A is less than at the calculated frequency.

More explicitly, if, by some means or other, we introduce a loss between C and the voice coil which is greater than this factor, the output which otherwise would be fairly constant at all frequencies must drop.

Thus it is quite feasible to put small condensers within the feedback path to cut down high-frequency response provided the feedback remains negative. This is simple in this circuit, because the feedback path is quite linear and does not introduce undesirable phase shifts itself. Further, the shift which occurs in the transformer at high frequencies is taken by, or over-ridden by the shift produced by any such condensers. In general, however, it is not really necessary to do this. Where proper variable acoustic compensation is required, the designer is advised in this instance to provide this before V4 and not attempt it after.

The decrease is gain of V4 is quite permissible as it is quite high, and an extra stage would be all that would be required for microphone work.

It remains now merely to put both principles discussed together and the resultant circuit is in Fig. 3.

Applying the 6J8

In searching for a suitable valve to use for V4 and V_2 (Fig. 1), attention turned to the very popular 6J8. It was felt that the oscillator section would be suitable for paraphase operation, the pentode section for amplification and inverse feedback. Some doubts existed in regard to coupling between the two sections, as it was thought at first that this might exist sufficiently to upset the paraphase action. However, in practice the valve worked quite efficiently. The early assumption, too, that separate bias would be necessary for both pentode and triode sections was justified in initial experiments. However, by correctly proportioning the resistors in each of the elements, a compromise was found which allowed both sections to operate at an optimum point, so a single cathode resistor and bypass sufficed. Under the operating conditions shown sufficient drive for the 6V6 grids is easily developed without overloading any part of the 6J8, so the output stage may be properly driven without fear of distortion.

Paraphased Feedback

The advantage of the feedback chosen is further apparent, as any discrepancies occurring within the 6J8 are within the feedback path and so are diminished. The term "paraphased feedback" will also now be self-explanatory, since the feedback voltage is in effect applied in the correct phase relation to both 6V6G grids. As with other feedback systems working from the voice coil, the correct polarity of this must be observed or oscillation will result. In view of the feedback applied, the time constant of C_2R_6 (Fig. 3) is quite adequate even on low frequencies, and the response in this region is exceptionally good.

In Practice

In practice the optimum ratio of R R_1 (Fig. 1) is determined roughly by calculation and finely by adjustment. Thus in our particular case the values chosen were proved experimentally to give proper balance at mid-frequencies.

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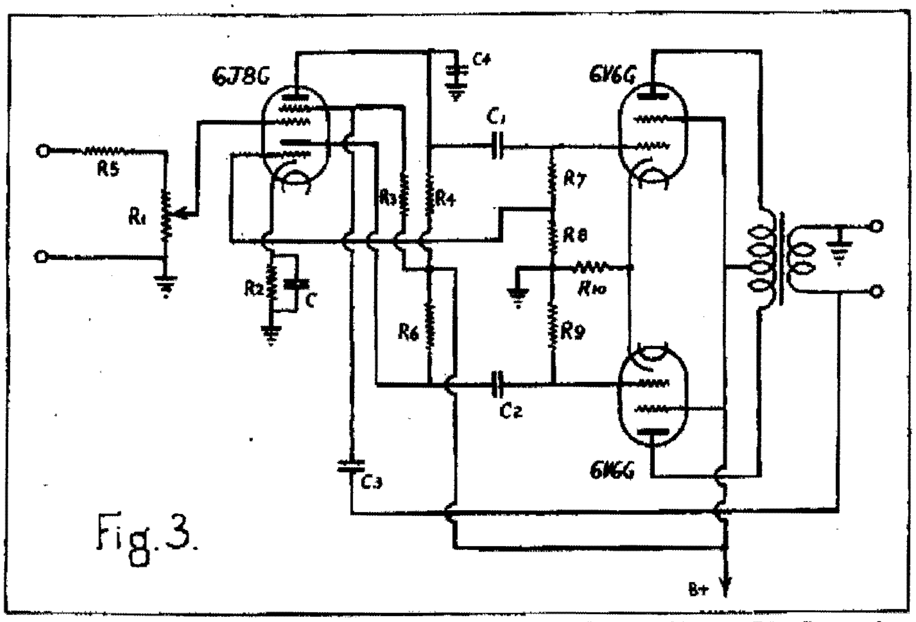

Circuit diagram of the amplifier. Suggested component values would be:—R1, .5 megohms; R2, 1,500 ohms; R3, 1 megohm; R4, .5 megohm; R5, see text; R6, .25 megohm; R7, .5 megohm; R8, 65,000 ohms; R9, .5 megohms; R10, 160 ohms; C, 25 mfds.; C1, .02 mfds.; C2, .05 mfds.; C3, .5 mfd.; C4, optional, over .0005 mfds.; T, output transformer, centre-tapped with 10,000 ohms plate-to-plate load.

SYSTEMATIC SERVICING

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Test No. 6 includes a complete line-up of the receiver. An all-wave signal generator is necessary for this test, preferably one with its output calibrated in microvolts so that the actual sensitivity of a receiver may be measured and passed as normal for a receiver of the type. Alignment should be perfect, and if the dial is frequency calibrated, the stations should come in on the correct readings.

When sensitivity and calibration are finished, the receiver should be passed to Test No. 7.

Test No. 7 is for the purpose of checking. The receiver should be checked for tonal quality, sensitivity, selectivity, dial calibration, speaker rattles, and for a slipping dial, as well as for other loose parts about the chassis. When passed as O.K. it should be replaced in the cabinet, checked again for dial position and loose knobs, and the cabinet polished.

Test No. 8 is merely running the receiver for a period of time — preferably as long as possible, on a line voltage slightly higher than that to which it is accustomed. Country areas, particularly, have high line voltages, and this test is really more of a check on all the parts, to make sure that none will break down. The writer uses a transformer having a 230v. primary and tapped secondary up to 270v.

The various tests are summarised in concise form below:—

(1) Service call. Check valves, aerial, arrester, power line and flex, knobs and dial.
(2) Remove from cabinet and clean out dust. Check valves carefully; inspect power transformer and rectifier.
(3) Check all condensers and resistors with condenser analyser and ohmmeter. Check condensers for capacity and leakage. Check volume and tone controls.
(4) Check all voltages and currents with multi-range meter.
(5) Loudspeaker test; check for rattles, and test field and matching transformer. Inspect voice coil leads for breaks.
(6) Complete line up and sensitivity check with signal generator.
(7) Check tone quality, sensitivity, selectivity, dial calibration, speaker for rattles, dial and knobs. Replace in cabinet and polish.
(8) Check on slightly higher line voltage.

The receiver is now checked in almost every possible way. The chassis has been cleaned, the cabinet polished, all defective parts replaced, and the set re-aligned perfectly. In fact, the radio should be as good as the day it came out of the factory.

It is as well to clean and polish the cabinet of every set. Remember that the owner cannot see what has been done inside, and that outside appearance always counts for a great deal.

Common Service Troubles

It is now proposed to consider some of the more common troubles encountered in radio service, and to discuss briefly the likely causes of such troubles. The conditions for discussion are listed below.

(1) No signal.
(2) No signal on shortwave bands.
(3) Intermittent signals — signals cut out.
(4) Weak signals.
(5) Fading.
(6) Distortion.
(7) Hum.
(8) Noise.
(9) Oscillation or instability.

(1) No signal. This is doubtless the easiest fault to rectify, since it is definite. Valves may light up, but cease to function; they should be tested for emission as well as for element shorts. If there is no H.T. voltage, look for a shorted filter condenser, shorted plate or H.T. by-pass, open choke or speaker field, open in "B" circuit or an open coupling condenser.

The speaker transformer may be open and in the case of a pentode power valve, this fault can be recognised by the elements of the valve becoming very hot and glowing brightly. The connection to the speaker voice coil may have broken, or the voice coil itself may be open.

(2) No signal on shortwave bands. This fault is generally caused by a faulty contact in the wave-change switch. Clean the contacts with carbon tetrachloride, but do not apply any grease. The oscillator may be faulty and fail to oscillate at the higher frequencies. The set may be out of alignment on the short waves.

(3) Intermittent signals. This fault may be caused by a valve. Run the receiver until the valves get hot, tune in a programme, then tap all the valves with a pencil. A valve may be gassy and operate for a few minutes, then cut out. A slightly gassy valve may test all right in a valve checker, yet cause cut-out and fading if used in oscillator or a.v.c. circuits.

There may be an intermittent break in the speaker field or speaker transformer. The speaker voice coil leads may be partially broken. There may be a resin joint in the wiring. Dirt or metal flakes may be present in the plates of the gang condenser. Volume control or wave-change switch may be faulty. Coupling condenser may be opening intermittently.

(4) Weak signals. Valves may be old or faulty in other respects. Secondary of R.F. or I.F. transformers may be open. Voltages may be low, due to leaky filter or by-pass condenser. Coupling condenser may be partially open. May be a short in the speaker field. Receiver may be out of alignment. Aerial primary may be open. Volume control may be open. Bios resistor may be open or up in value. Coils may be damp; bake them out and impregnate.

(5) Fading. Fading is generally a hard fault to find unless it is caused by valves, which should be tested thoroughly. Leaky a.v.c. by-pass con-

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The balance is thus maintained within the required limits of 3%.

The use of feedback has the important advantage of overcoming those earlier defects mentioned, since unbalance is more or less "swamped," and the ratio of R R_1 is not so critical.

The feedback path also has the economical advantage of requiring no extra parts.

Final Points to Note

A good clean 6-8 watts can be obtained with very low harmonic content, and the frequency response without any alterations provides really delightful listening. For those who care to load up Piezo electric pick-ups, there is quite adequate gain to put series resistors up to several megs. in position R5 and so obtain full advantage of the response of this type of reproducer.

In some cases a slight additional filtering may be necessary for the 6J8 as shown by the dotted lines, but where the usual well-filtered supply is used this will hardly be necessary.

In conclusion we feel that the cheapness and simplicity of this circuit with the very effective and rather novel feedback make it well worth the building, while the tonal response and transient reproduction are really remarkable.