STIR IN HI-FI CIRCLES

Distortion Standards Upset by Triodes with Feedback

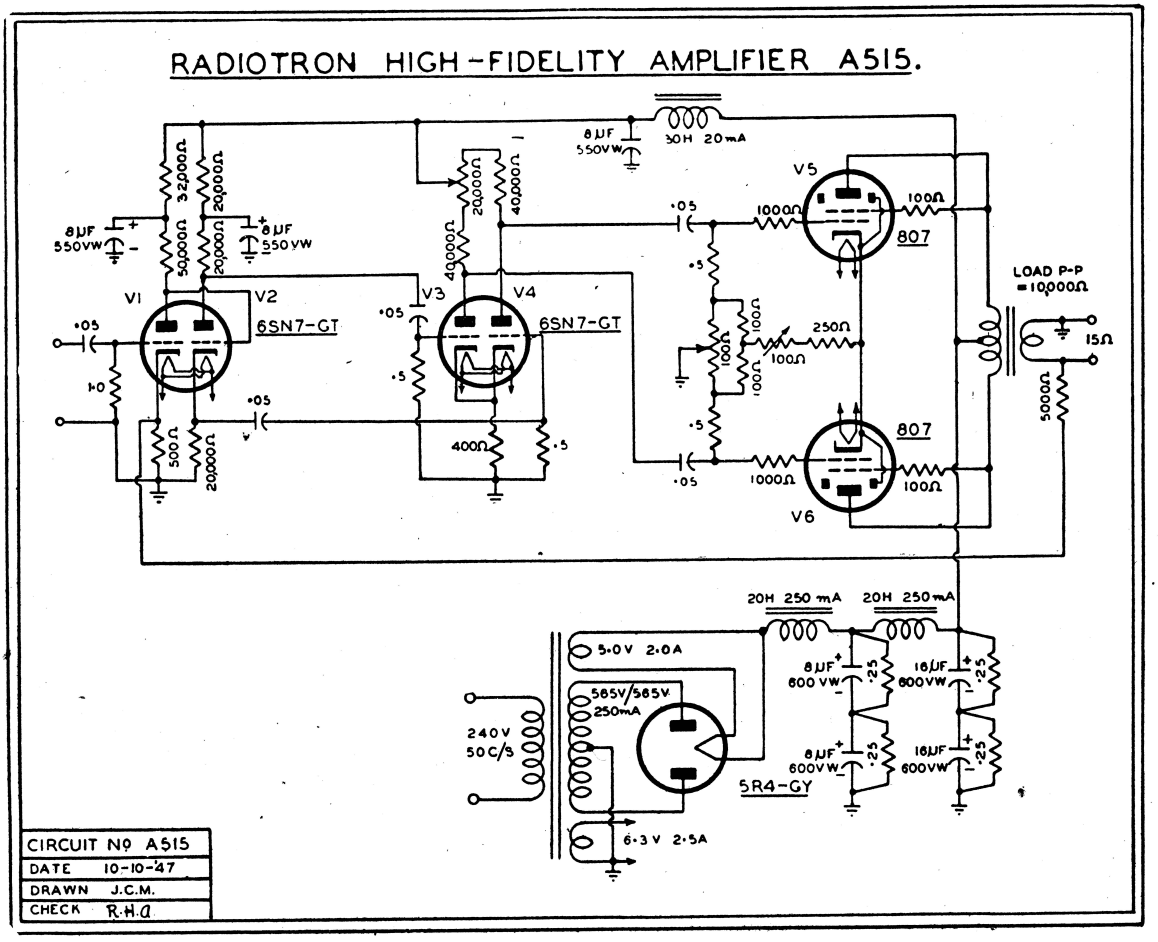
A MINOR sensation has happened in amplifier circles since the news has got around that the use of inverse feedback with triode amplifiers gives a reduction in distortion which is noticeable to the ear in spite of previous acceptance of a fable that distortion from 2 to 5 per cent could not be distinguished by the human ear.

The reason for all the hubbub can be traced back to the circuit which we published in our August, 1947, issue, having reprinted same as an item of interest from the English "Wireless World" of April and May, 1947. Designed by a Mr. D. T. N. Williamson, late of the Marconi-Osram valve factory, this circuit was presented as featuring low distortion, but since it is so easy to get amplifiers with low distortion this circuit did not arouse any terrific amount of enthusiasm until one or two of our deepest-dyed quality enthusiasts actually built it up and got to work on it. Then the startling fact was revealed that in spite of all tales which have been current to the contrary, the human ear can tell the difference when distortion is reduced from 2 or 3 per cent. to less than a quarter of a per cent. Possibly phase shift has something to do with it, too, for this amplifier has a feedkack circuit which means that trouble is encountered if the phase shift is not held to a minimum. Having taken trouble in the design to minimise phase shift in order to get the feedback circuit working properly, the nett result of the low harmonic distortion, wide frequency range and small phase shift is something which is appreciated as soon as it is heard.

O.P.T. Important

Essential for the proper operation of the amplifier is an efficient output transformer with low leakage inductance and high primary inductance. On account of the in-

(**Continued on next page**)



Modified "Williamson" circuit as published in "Radiotronics."

(Continued)

terest aroused by the circuit the Red Line people went into production with a special output transformer to suit this type of circuit. Known in the Red Line brand as type AF10, this transformer is a massive job, weighing 7 lbs. and listing at £6. With a frequency response of within .2 db. from 20 to 30,000 cycles per second this output transformer is the last word in such things.

Radiotron Effort.

The original English amplifier circuit used English valves of types KT66 and L63, and when reprinting the article we took the chance and mentioned that, although not identical, it appeared that the local 807 and 6J7G types could be used as substitutes. So much interest has been shown in the circuit, however, that the wide-awake Radiotron Applications Laboratory got on to the job and made tests on the 807 to prove its suitability for operation under the conditions imposed in the English circuit, viz., about 400 volts on both plate and screen. Working on the amplifier seems to have aroused keen enthusiasm in Messrs. Langford-Smith and Aston of the Radiotron organisation and so they have redesigned the circuit to suit local conditions and available valve types. the circuit being published recently in "Radiotronics."

Our local engineers have introduced one or two interesting modifications, the most noticeable being the use of the twin triode type 6SN7GT, thereby making two valves do the work of four in the original circuit.

The Radiotron engineers are not given to the making of rash statements, and therefore it is a powerful testimonial to the performance of the amplifier when they put it down in black and white that this amplifier "is by far the best which we have ever tested." Summing up, they state, "It not only gives extraordinary linearity and lack of harmonic or intermodulation distortion, but is comparatively simple, and involves no special problems except the choice of output trans-transformer."

Working from the English circuit, a Belgian engineer has developed another circuit embodying triodes with inverse feedback. Watch for it in next month's issue.

Reflections

Those who have kept in close touch with progress in amplifier circuit design find it a little hard to understand one or two points about the latest circuit. In the first place, why have the main features of the amplifier been so consistently passed over in days gone by? For example, the circuit uses a direct-coupled phase-splitter of the type first published by us in our May, 1940, issue. We battled for this cuircuit for several years, featuring it in such circuits as the "Super Seven" in June, 1941, but nobody seemed over-impressed with the claims made for the low phase-shift in this method of obtaining push-pull operation. Then the matter of applying inverse feedback to triodes is not entirely new, having been featured, for example, in an amplifier which we detailed in our issue of April, 1942. This amplifier used 2A3 triodes in push-pull with inverse feedback, with resistance-coupled push-pull driver stage, using the 6N7. Incidentally it mentioned in this article that the 2A3 type triode output valves were being operated with 400 volts on the plates, apparently without ill effect.

Mention of which leads us to the next reflection: why use the big beam power valves and then tie the plates, screens and other internal elements together to form a triode when there are so many perfectly good triodes available as such. Here in Australia the low price of the surplus munitions type 807 valves means that they are cheaper than the triodes, but this is hardly likely to have been a consideration for Williamson when he was working out the original English circuit.

Some Other News

There are other things which are causing added interest in high-fidelity circles. One of these is the announcement that J. H. Magrath & Co. recently landed a small shipment of English "Connoisseur" pick-ups which are of the miniature moving iron high-fidelity type of a kind which has not been prominent in Australia in the past. A short time ago news was received from Mr. Rom Errmann of the Lintas Advertising Agency in London that these English "Connoisseur" pick-ups were the answer. Mr. Errmann was a prominent member of the Sydney Recorded Music Society in the good old days of about 1934 when he was associated with Gordon & Gotch in Sydney. Knowing that Mr. Errmann would not say such things unless the pick-up was something out of the ordinary, steps were taken to get a small shipment through, just a dozen, and reserved for "Radio World" enthusiasts, as mentioned in our query columns in the November issue. There was a scramble for these samples, and they have proved so successful that arrangements are now in hand for their importation in quantity. Unfortunately we were a little astray in our initial announcement of these pick-ups, as we said that they did not require a pre-amplifier. Whilst this may be strictly correct, it gives the wrong impression as a tone-correction pre-amplifier stage is necessary. The output from the pick-up, after being stepped up in the input transformer is about .7 of a volt, but this is flat, and is not boosted on the lows as is necessary to compensate for recording technique. However, the pre-amplifier is a comparatively simple one and should not be allowed to frighten anyone.

Latest news from England is that the crystal pick-up people are recognising the threat of the high-fidelity types of moving iron and moving coil pick-ups and are taking the necessary steps to uphold their claims that crystal pick-ups are best. It seems that the competition between the types will result in improvements.

English Speakers.

English manufacturers have long claimed that their loudspeakers have good high-note response and several brands of high fidelity speakers have been available on the English market. A few of these have trickled through to the Australian market, some undoubtedly good speakers, others not

Fig. 7.44 is the circuit of such an amplifier using push-pull triodes, with extraordinarily low distortion. It is based on the design of Williamson (Refs. F4, F5, F6). The first triode (V_1) is direct-coupled to the grid of a phase splitter (V_2) which in turn is r.c. coupled to push-pull triodes (V_3 and V_4) and thence to the output stage. No by-pass condensers are used and the only reactances to cause phase shift at low frequencies are the two grid coupling condensers. The circuit has a number of refinements which are described in the references.

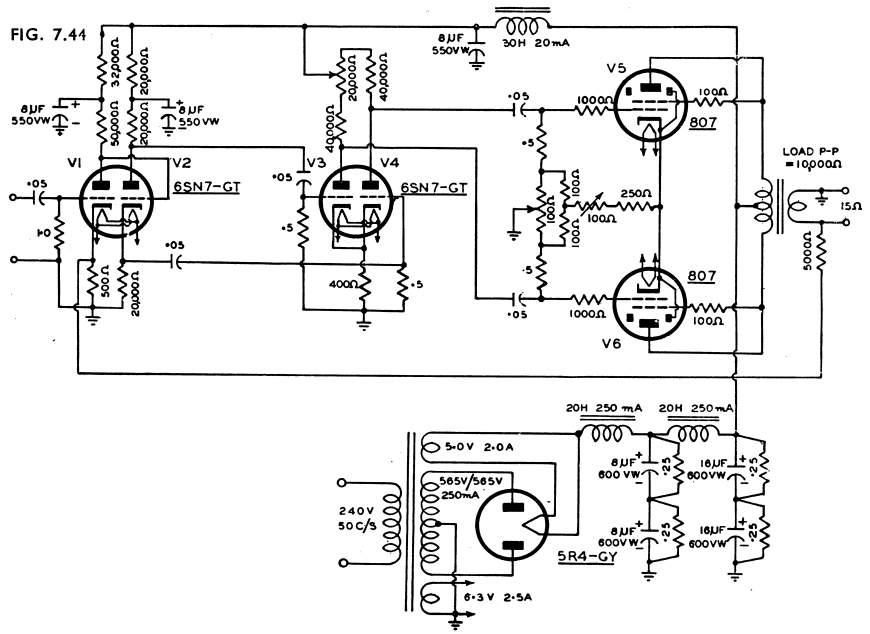


Fig. 7.44. Amplifier employing voltage feedback from the secondary of the output transformer, with push-pull triodes. The amplifier is virtually distortionless up to an output of 11 *watts, and has a smooth overload up to* 16 *watts.*

The original version used type L63 valves in place of each half of the 6SN7-GT, and type KT66 as triodes in the output stage. The circuit shown (A515) gives almost identical results, but type 807 valves are used in place of type KT66.

The specifications laid down by Williamson for the **output transformer** are as follows :

Primary load impedance	10 000 ohms, centre-tapped
Primary inductance	100 henrys, min.
Leakage inductance, series (whole prim. to whole sec.)	30 millihenrys, max.
Primary resistance	250 ohms, approx.

Commercial transformers wound to the original winding data supplied by Williamson perform quite satisfactorily, although some difficulty may be experienced where the winding structure differs from that recommended. This is brought about by the increase in interwinding capacitances which may result.

Several manufacturers have recently marketed some wide range output transformers which are a considerable improvement on that specified above.

In one particular transformer, the Partridge CFB, the series leakage inductance, the winding resistances and weight have been reduced by a third, but the power handling capabilities have been increased four times. The core distortion at a level

of 16 watts has been reduced ten times and the important leakage inductance existing between the halves of the primary has been decreased thirty times.

These improvements mean that this transformer, when used in the original Williamson circuit, will give a greater stability margin or alternatively will permit the use of a greater amount of feedback.

Distortion will be appreciably reduced in any amplifier by the use of a well designed transformer of such a type.

Distortion with amplifier A515

Power Output	H_2	H_3	H_4	H_5	Total r.m.s.
11 watts	0.01	0.04	0.01	0.015	0.045%
14 watts	0.075	0.35	0.01	0.26	0.44%
16 watts	0.04	0.92	0.11	0.45	(overload)

The smooth overload is a particularly valuable feature.

Intermodulation distortion

Conditions of test—input frequencies 60 c/s and 2000 c/s ; higher frequency 12 db lower than 60 c/s level.

Power output (r.m.s.)*	4	6	8	10	12 watts
Equivalent power**	5.9	8.8	11.8	14.7	17.6 watts
Intermodulation	0.17	0.27	0.72	3.7	8.8%

*r.m.s. sum of two output frequencies

**r.m.s. sum $\times$ 25/17 to give the single frequency power having the same peak voltage swing (see Chapter 14 Sect. 3).

An American version of this amplifier is given in Ref. F8.

Note :

In the circuit of Fig. 7.44, a capacitance may be inserted in series with the 5 000 ohm resistor in the feedback circuit to provide bass boosting for equalizing purposes in record reproduction ; see Chapter 15 Sect. 9(ii)B.

A modification of this circuit, which provides for bass boosting, is given in Fig. 15.58A.

A new version of the Williamson amplifier, together with pre-amplifier and tone control (Ref. F9) is given in Figs. 17.35B,C,D,E,F,G.

(C) **Bridge circuits**

Amplifiers can be designed with bridge circuits in both input and output circuits, which prevent any modification of the input and output impedances and which also eliminate any phase shift round the feedback loop caused by reactances introduced through the input or output circuits (Refs. A1, A2, A11).

(viii) Cathode-coupled phase inverters and amplifiers

(A) **Cathode coupled phase inverters**

The fundamental circuit is Fig. 7.45 and requires two triode units with both cathodes linked, a common cathode resistor R_k and separate plate resistors R_{L1} and R_{L2}. Three tappings are required on the battery or potential divider across the B supply. The input voltage is applied between the two grids (Ref. G1).

If both V_1 and V_2 have identical characteristics and $R_{L1} = R_{L2} = R_L$, it may be shown (Ref. C7) that

$$E_{AB} = \mu E_s R_L/(R_L + r_p) \tag{43}$$

where E_s = signal input voltage applied between the two grids
and E_{AB} = signal output voltage between points A and B.

Similarly, where E_A and E_B are the voltages from these points to earth,

$$E_A = \tfrac{1}{2}\left(\frac{\mu E_s R_L}{R_L + r_p}\right)\left(1 + \frac{R_L + r_p}{R_L + r_p + 2(\mu + 1)R_k}\right) \tag{44}$$

and $$E_B = -\tfrac{1}{2}\left(\frac{\mu E_s R_L}{R_L + r_p}\right)\left(1 - \frac{R_L + r_p}{R_L + r_p + 2(\mu + 1)R_k}\right) \tag{45}$$

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EQUIPMENT

for

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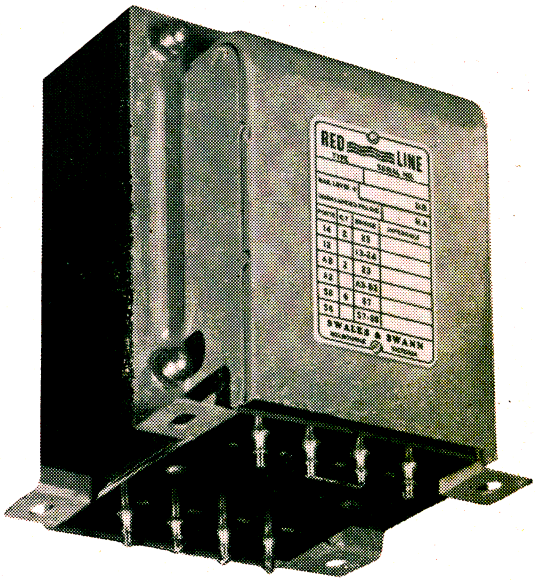
OUTPUT TRANSFORMER



TYPE No. AF10
Weight 7 lbs. Price £6

Primary Impedance, 10,000 ohms 807 (T) P.P.
Secondary Impedance 500 ohms ★ 34db.

Frequency Response: Linear within 0.2 db.
20 cps. to 30,000 cps.

Primary Inductances (at low ac flux) not less than 125 Henries

Leakage Inductance: 17 Millihenries.

Insertion Loss: 0.4 Decibels.

This transformer may be used to obtain a gain reduction of up to 25 db. across 4 Stages in a suitable negative feedback circuit★

★ *To Voice Coil if required.*

POWER TRANSFORMER

10v 210v 230v 250v 50 cps.
Sec H.T. 500/500v at 175 ma.
5v. 3a. 6.3v; 2a 6.3v. 3a. .... Type 17503 £3 12 6

FILTER CHOKE

12 Henries, 175 mA .... Type 201515 £1 11 0

SMOOTHING CHOKE

25 Henries, 60 mA .... Type 50825 £1 7 0

★ *as described by Mr. D. T. N. Williamson in "Wireless World," April and May, 1947*

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