

PATENT SPECIFICATION

824,647

DRAWINGS ATTACHED.

Inventors :—DONOVAN ERNEST LEA SHORTER and JAMES ROBERT CHEW.



Date of filing Complete Specification : June 12, 1956.

Application Date : June 17, 1955. No. 17619/55

Complete Specification Published : Dec. 2, 1959.

Index at Acceptance :—Class 38(2), T1A, T7C(1A : 5 : 7E).

International Classification :—H01f.

COMPLETE SPECIFICATION.

Improvements in and relating to Transformers for Use in Circuits Employing Negative Feedback.

We, THE BRITISH BROADCASTING CORPORATION, a British Body Corporate, of Broadcasting House, London, W.1, do hereby declare the invention, for which we pray that

5 a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement :—

10 The present invention relates to transformers for use in circuits employing negative feedback.

In such circuits, it is frequently required to obtain for feedback purposes a signal voltage proportional to, and in phase with, the

15 voltage appearing across a particular winding of the transformer. In many cases however, there exist between this winding and earth, direct or alternating voltages which it is desired to isolate from the feedback circuit, and to this end the feedback voltage may be

20 derived from a separate winding having no metallic connection with the main winding.

The voltage generated in a single feedback winding on a transformer will not in general

25 bear a constant amplitude and phase relationship to the voltage appearing across any of the other windings, for no two windings can embrace exactly the same flux. In particular, the feedback winding will be linked by the

30 leakage fluxes between the other windings or between different sections of the same winding. These leakage fluxes are a function of the currents flowing in the windings ; and since the voltages which they induce will not

35 bear a constant amplitude or phase relationship to the voltage across the winding from which it is desired to derive the feedback, but will vary with the impedance of the load

connected to the transformer, it is impossible to compensate for them by networks external to the transformer. 40

One known remedy for this state of affairs is to divide the feedback winding into several sections interleaved with the remainder of the windings in such a way that the effects of leakage flux in the various sections substantially cancel one another. However, where the main transformer windings are divided into many sections, the number of sections in the feedback winding must also be large. This leads to a design which is not only complicated in construction, but inefficient also, for, however little power the feedback winding may have to deliver, each section of it must, in practice, occupy an irreducible minimum amount of winding space and requires an extra layer of insulation. 45 50 55

Some of the difficulties described could be avoided by the use of an auxiliary transformer, the primary winding of which is connected across the terminals of that winding on the main transformer from which the feedback is to be derived while the secondary winding provides the required feedback signal. The auxiliary transformer would not be required to transmit much power and it might therefore appear that this component could be made quite small and cheap. However, the primary inductance would have to be high compared with that of the winding on the main transformer across which it was connected, since otherwise additional magnetising current would be drawn from the source, while the number of turns and the cross-sectional area of the core would have to be sufficient to handle the full signal voltage without iron saturation at the lower fre- 60 65 70 75

[Price 3s. 6d.]

Price 4s 6d.

quencies. In many cases, therefore, the use of a separate feedback transformer is uneconomic.

According to the present invention, there is provided an audio frequency transformer for use in a circuit employing negative feedback having main primary and secondary windings and auxiliary primary and secondary windings all arranged upon the same core, the auxiliary primary winding being connected in parallel with the main primary or secondary winding and having approximately the same number of turns as but being of substantially thinner wire than the winding with which it is in parallel, the auxiliary secondary winding being substantially more tightly coupled to the auxiliary primary winding than it is to that one of the main windings with which the auxiliary primary winding is in parallel, and the arrangement being such that when a signal voltage is applied to the main primary winding there is generated across the auxiliary secondary winding a feedback voltage which is substantially proportional to, and in phase with, the signal voltage across the said one of the main windings.

Since the auxiliary windings are not required to transmit appreciable power, a high resistance of the auxiliary primary winding is of little importance. Moreover, since the auxiliary primary winding is of relatively thin wire it occupies but little space and it can, therefore, be more tightly coupled to the auxiliary secondary winding than would be the case with thicker wire.

Where all the windings are wound on the same limb of the core, the auxiliary primary and auxiliary secondary windings are preferably located within the main primary and secondary windings. Alternatively the auxiliary primary and auxiliary secondary windings may be arranged upon a different limb of the core from the main windings. The depths of the auxiliary primary and secondary windings are made as small as possible so that the coupling between these two windings should be tight. To the same end, the auxiliary primary and auxiliary secondary windings may be sub-divided into sections interleaved with one another according to known art.

The invention will be described by way of example with reference to the drawing accompanying the Provisional Specification in which Fig. 1 is a diagrammatic sectional view of a transformer according to the invention and Fig. 2 is a circuit diagram of a push-pull transformer according to the invention suitable for use as the output transformer of an audio-frequency amplifier designed to give 25 watts output from a pair of pentodes connected in push-pull and working in class AB₁ with 25 dB. of negative feedback. It is assumed that it is required to provide a feedback voltage proportional to and in phase

with the signal voltage across the main primary winding of the transformer.

Referring to Fig. 1, a laminated iron core 10 has the windings carried on a spool 11 divided into two equal halves by a partition 12. Nearest the central limb 13 of the core is an auxiliary secondary winding consisting of the sections FS₁ and FS₂ connected in series. Over this is wound the auxiliary primary winding in two sections FP₁ and FP₂ connected in series. The main primary and secondary windings P and SE respectively are wound in a number of interleaved sections, all the sections of the main primary windings P being connected in series.

As shown in Fig. 2, the main primary winding has terminals T₁ and T₂ across which is connected the auxiliary primary winding FP₁, FP₂. The terminal T₅ is strapped to the terminal T₆ and the terminal T₇ is strapped to the terminal T₈. The main output terminals are T₃ and T₄ and the output terminals from the auxiliary secondary winding, for feedback, are T₉ and T₁₀. The core in this example is of 0.015" thick Radiometal laminations, ISCC size 442A stacked to a depth of 2" and interleaved in groups of four.

The winding of the transformer of Fig. 2, using insulated wire sold under the Registered Trade Mark "Lewmex," or equivalent enamelled wire, may be carried out as follows, in the order named :—

In one half of the spool :

- FS₁ : 25 turns 36 S.W.G. in one layer spaced to fill the width of one half of the spool. 100
- FP₁ : 1000 turns 46 S.W.G. in reverse sense to FS₁, layer wound, 200 turns per layer, interleaved with 1 mil. varnished paper. 105
- P₁ : 125 turns 32 S.W.G., in the same sense as FS₁, layer wound. 110
- P₂ : 125 turns 32 S.W.G. in the opposite sense to FS₁, layer wound. 110
- SE₁ : 67 turns 20 S.W.G., in the same sense as FS₁, layer wound with 17 turns per layer for the first three layers and 16 turns on the final layer. 115
- P₃ : 250 turns 32 S.W.G., in the same sense as FS₁, layer wound. 115
- P₄ : 250 turns 32 S.W.G., in the opposite sense to FS₁, layer wound. 115
- SE₂ : 67 turns of 20 S.W.G., in the same sense as FS₁, layer wound as SE₁. 120
- P₅ : 125 turns 32 S.W.G., in the same sense as FS₁, layer wound. 120
- P₆ : 125 turns 32 S.W.G., in the opposite sense to FS₁, layer wound. 125

In the other half of the spool FS₂ is as FS₁ and in the same sense. Then follow FP₂, P₇, P₈, SE₃, P₉, P₁₀, SE₄, P₁₁ and P₁₂, which are

wound in the same way, and in the opposite sense to FP₁, P₁, P₂, SE₁, P₃, P₄, SE₂, P₅ and P₆ respectively.

5 Two layers of 5 mil. empire tape are provided between all sections, and one layer of this tape is provided overall. In Fig. 2 the start and finish of windings are represented by S and F respectively. The impedance ratio is 3000 : 12 ohms. With the strap
10 between T₇ and T₈ removed, with T₃ strapped to T₈ to constitute one output terminal and T₄ strapped to T₇ to constitute the other output terminal, the impedance ratio is 3000 ohms : 3 ohms.

15 WHAT WE CLAIM IS :—

1. An audio frequency transformer for use in a circuit employing negative feedback having main primary and secondary windings and auxiliary primary and secondary windings all arranged upon the same core, the
20 auxiliary primary winding being connected in parallel with the main primary or secondary winding and having approximately the same number of turns as but being of substantially thinner wire than the winding with which it
25 is in parallel, the auxiliary secondary winding

being substantially more tightly coupled to the auxiliary primary winding than it is to that one of the main windings with which the auxiliary primary winding is in parallel, and the arrangement being such that when a
30 signal voltage is applied to the main primary winding there is generated across the auxiliary secondary winding a feedback voltage which is substantially proportional to, and in phase
35 with, the signal voltage across the said one of the main windings.

2. A transformer according to Claim 1, wherein all the said windings are wound upon the same limb of the core. 40

3. A transformer according to Claim 2, wherein the auxiliary primary and secondary windings are located within the main primary and secondary windings. 45

4. A transformer substantially as hereinbefore described with reference to the drawings accompanying the Provisional Specification. 45

REDDIE & GROSE,
Agents for the Applicants,
6 Bream's Buildings,
London, E.C.4.

PROVISIONAL SPECIFICATION.

Improvements in and relating to Transformers for Use in Circuits Employing Negative Feedback.

50 We, THE BRITISH BROADCASTING CORPORATION, a British Body Corporate, of Broadcasting House, London, W.1, do hereby declare this invention to be described in the following statement :—

55 The present invention relates to transformers for use in circuits employing negative feedback.

In such circuits, it is frequently required to obtain for feedback purposes a signal voltage proportional to, and in phase with, the voltage appearing across a particular
60 winding of the transformer. In many cases however, there exist between this winding and earth, direct or alternating voltages which it is desired to isolate from the feedback circuit, and to this end the feedback voltage may be
65 derived from a separate winding having no metallic connection with the main winding.

The voltage generated in a single feedback winding on a transformer will not in general
70 bear a constant amplitude and phase relationship to the voltage appearing across any of the other windings, for no two windings can embrace exactly the same flux. In particular, the feedback winding will be linked by the
75 leakage fluxes between the other windings or between different sections of the same winding. These leakage fluxes are a function of the currents flowing in the windings; and

since the voltages which they induce will not bear a constant amplitude or phase relationship to the voltage across the winding from which it is desired to derive the feedback, but will vary with the impedance of the load connected to the transformer, it is impossible to compensate for them by networks external to
85 the transformer.

One known remedy for this state of affairs is to divide the feedback winding into several sections interleaved with the remainder of the windings in such a way that the effects of leakage flux in the various sections substantially cancel one another. However, where the main transformer windings are divided into many sections, the number of sections in the feedback winding must also be large. This leads to a design which is not only complicated in construction, but inefficient also, for, however little power the feedback winding may have to deliver, each section of it must, in practice, occupy an irreducible
90 minimum amount of winding space and requires an extra layer of insulation. 95

Some of the difficulties described could be avoided by the use of an auxiliary transformer, the primary winding of which is connected across the terminals of that winding on the main transformer from which the feedback is to be derived while the secondary
105

winding provides the required feedback signal. The auxiliary transformer would not be required to transmit much power and it might therefore appear that this component could be made quite small and cheap. However, the primary inductance would have to be high compared with that of the winding on the main transformer across which it was connected, since otherwise additional magnetizing current would be drawn from the source, while the number of turns and the cross-sectional area of the core would have to be sufficient to handle the full signal voltage without iron saturation at the lower frequencies. In many cases, therefore, the use of a separate feedback transformer is uneconomic.

According to the present invention, there is provided a transformer for use in a circuit employing negative feedback having main primary and secondary windings and auxiliary primary and secondary windings for deriving, for feedback purposes, a signal voltage substantially proportional to, and in phase with, a signal voltage across one of the main windings, the auxiliary windings being upon the same core as the said one main winding and the auxiliary primary winding being connected in parallel with the main winding.

The auxiliary primary winding must have the same number of turns in series as the main winding which is in parallel with it but may be of finer wire. Since the auxiliary windings are not required to transmit appreciable power, a high resistance of the auxiliary primary winding is of little importance.

The auxiliary secondary winding is preferably within the main primary and secondary windings. The depth of the auxiliary primary winding is made as small as possible so that its coupling with the auxiliary secondary winding should be tight, and to the same end, the auxiliary primary and secondary windings may be subdivided into sections interleaved with one another according to known art. The auxiliary primary and secondary windings may be arranged upon a different limb of the core from the main windings.

The invention will be described by way of example with reference to the accompanying drawing in which Fig. 1 is a diagrammatic sectional view of a transformer according to the invention and Fig. 2 is a circuit diagram of a push-pull transformer according to the invention suitable for use as the output transformer of an audio-frequency amplifier designed to give 25 watts output from a pair of pentodes connected in push-pull and working in class AB₁ with 25 dB. of negative feedback. It is assumed that it is required to provide a feedback voltage proportional to and in phase with the signal voltage across

the main primary winding of the transformer.

Referring to Fig. 1, a laminated iron core 10 has the windings carried on a spool 11 divided into two equal halves by a partition 12. Nearest the central limb 13 of the core is an auxiliary secondary winding consisting of the sections FS₁ and FS₂, connected in series. Over this is wound the auxiliary primary winding in two sections FP₁ and FP₂, connected in series. The main primary and secondary windings P and SE respectively are wound in a number of interleaved sections, all the sections of each of these windings being connected in series.

As shown in Fig. 2, the main primary winding has terminals T₁ and T₂ across which is connected the auxiliary primary winding FP₁, FP₂. The terminals T₅ and T₆ and T₇ and T₈ are strapped together. The main output terminals are T₃ and T₄ and the output terminals from the auxiliary secondary winding, for feedback, are T₉ and T₁₀. The core in this example is of 0.015" thick Radio-metal laminations, ISCC size 442A stacked to a depth of 2" and interleaved in groups of four.

The winding of the transformer of Fig. 2, using insulated wire known by the proprietary name "Lewmex," or equivalent enamelled wire, may be carried out as follows, in the order named:—

In one half of the spool:

- FS₁: 25 turns 36 S.W.G. in one layer spaced to fill the width of one half of the spool. 100
- FP₁: 1000 turns 46 S.W.G. in reverse sense to FS₁, layer wound, 200 turns per layer, interleaved with 1 mil. varnished paper.
- P₁: 125 turns 32 S.W.G., in the same sense as FS₁, layer wound. 105
- P₂: 125 turns 32 S.W.G., in the opposite sense to FS₁, layer wound.
- SE₁: 67 turns 20 S.W.G. in the same sense as FS₁, layer wound with 17 turns per layer for the first three layers and 16 turns on the final layer. 110
- P₃: 250 turns 32 S.W.G., in the same sense as FS₁, layer wound. 115
- P₄: 250 turns 32 S.W.G., in the opposite sense to FS₁, layer wound.
- SE₂: 67 turns of 20 S.W.G., in the same sense as FS₁, layer wound as SE₁.
- P₅: 125 turns 32 S.W.G., in the same sense as FS₁, layer wound. 120
- P₆: 125 turns 32 S.W.G., in the opposite sense to FS₁, layer wound.

In the other half of the spool FS₂ is as FS₁ and in the same sense. Then follow FP₂, P₇, P₈, SE₃, P₉, P₁₀, SE₄, P₁₁ and P₁₂, which are wound in the same way, and in the opposite

sense to $FP_1, P_1, P_2, SE_1, P_3, P_4, SE_2, P_5$ and P_6 respectively.

5 Two layers of 5 mil. empire tape are provided between all sections, and one layer of this tape is provided overall. In Fig. 2 the start and finish of windings are represented by S and F respectively. The impedance ratio is 3000:12 ohms. With the strap between T_7 and T_8 removed, with T_3 strapped

to T_8 to constitute one output terminal and T_4 strapped to T_7 to constitute the other output terminal, the impedance ratio is 3000 ohms : 3 ohms. 10

REDDIE & GROSE,
Agents for the Applicants,
6 Bream's Buildings,
London, E.C.4.

Abingdon : Printed for Her Majesty's Stationery Office, by Burgess & Son (Abingdon), Ltd.—1959.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2,
from which copies may be obtained.

Fig. 1.

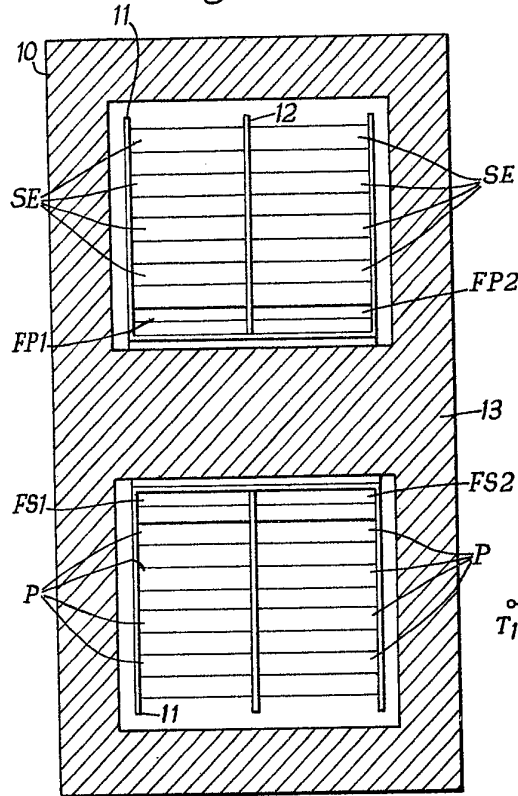


Fig. 2.

