United States Patent [19]

Fierstien et al.

[11] **3,721,932**

[45] **March 20, 1973**

[54] **BROADBAND RADIO FREQUENCY FERRITE TRANSFORMER PROVIDING CLOSE COUPLING**

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[22] Filed: **Sept. 14, 1971**

[21] Appl. No.: **180,515**

Related U.S. Application Data

[63] Continuation of Ser. No. 15,619, March 2, 1970, abandoned.

[52] **U.S. Cl.** **336/65,** 336/183, 336/205

[51] **Int. Cl.** **H01f 27/30**

[58] **Field of Search**......336/180, 182, 183, 170, 171, 336/205, 65

[56] **References Cited**

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[57] **ABSTRACT**

A broadband radio frequency transformer for use in the frequency range from 25 to 175 megahertz includes closely coupled windings on a ferrite rod providing low leakage inductance. A plurality of primary coils and a single continuous secondary coil are provided, with each primary coil bifilar wound with a portion of the secondary coil. The number of turns in the secondary coil is equal to the total number of turns in all the primary coils, or may be up to 50% greater than the total number of turns in the primary coils. The primary coils are connected in parallel to provide a step-up transformer having an impedance ratio related to the ratio of the number of turns in each primary coil to the number of turns in the secondary coil. The single coil can be used as the primary winding and the plurality of coils connected in parallel as the secondary winding for an impedance step-down transformer.

2 Claims, 4 Drawing Figures

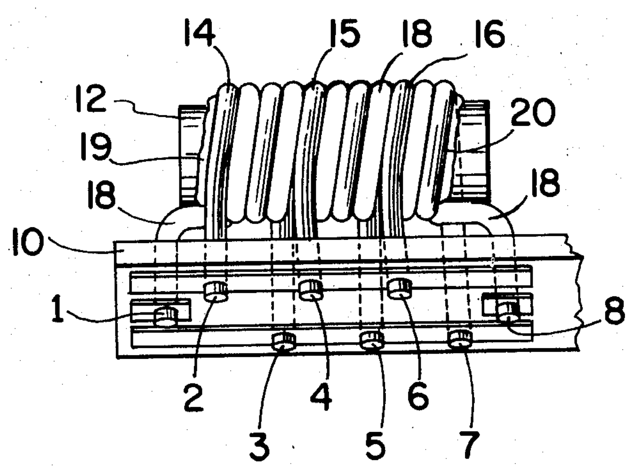


FIG. 1

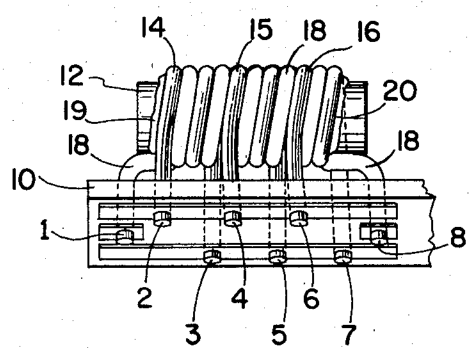


FIG. 2

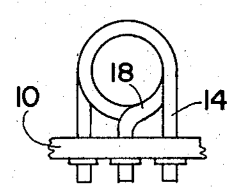


FIG. 3

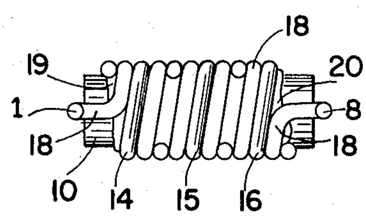
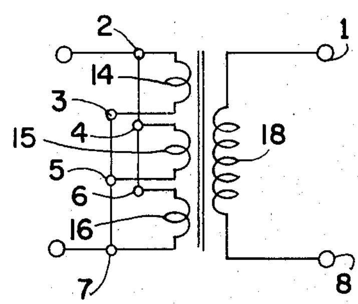


FIG. 4



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BROADBAND RADIO FREQUENCY FERRITE TRANSFORMER PROVIDING CLOSE COUPLING

This is a continuation of application Ser. No. 15,619, filed Mar. 2, 1970, now abandoned.

BACKGROUND OF THE INVENTION

Attempts have been made to provide an interstage matching network for broadband semiconductor amplifiers. Since the semiconductor devices, such as transistors, have low impedance, a transformer winding coupled thereto must likewise have low impedance for proper impedance matching. This requires a transformer with only a few turns which makes it difficult to provide close coupling. In general the impedance of a transformer winding coupled to a transistor stage should be of the order of 2 to 6 ohms. It may be desired to couple the amplifier stage to a 50 ohm line so that impedance transformation from 4 to 50 ohms may be required.

Various matching networks such as T and P*i* networks have been proposed but have been objectionable because they have had high Q. Strip lines have also been proposed, but at frequencies of 25 to 175 megahertz relatively long links are required. Prior transformers were not satisfactory because of the broadband, high power and low loss requirements and because of the range of impedances to be matched. To provide a broadband transformer it is necessary that the coupling coefficient be high, closely approaching unity and this is difficult to obtain with a large turns ratio. Further it is desired that the Q be kept quite low, less than 2 in most cases.

SUMMARY OF THE INVENTION

It is an object of the invention to provide an interstage coupling network for a broadband solid state, high frequency amplifier which provides close coupling and is of simple and inexpensive construction.

Another object of the invention is to provide a broadband coupling transformer for applications in the frequency range from 25 to 175 megahertz, which has a high coupling coefficient and a low Q to provide broadband operation, and which provides impedance matching between transistor devices and a transmission line.

A further object of the invention is to provide a broadband radio frequency transformer for use at high power, which provides the coupling coefficient required without the use of a torroid core, to thereby reduce the cost and size of the transformer.

The transformer of the invention includes primary and secondary windings wound on a ferrite rod core. One of the windings is formed by a plurality of separate coils each having the same number of turns, and the other winding is formed by a single coil having a number of turns which is either the same as the total number of turns in all the separate coils, or is greater than this total number by no more than 50 percent. For use as an impedance step-up transformer to couple a transistor amplifier to a 50 ohm line, the separate coils are connected in parallel as the primary winding and the single coil forms the secondary winding. Each separate coil is bifilar wound with a portion of the single secondary coil to provide a coefficient of coupling in the range from 0.97 to 0.98. By the use of three primary windings each having one and one-half turns and

a secondary winding having five turns, the transformer can be used for matching a push-pull transistor amplifier having an output impedance of the order of 6 ohms to an output circuit requiring an impedance of the order of 100 ohms. For use as an impedance step-down transformer, the single continuous coil can be used as the primary winding, and the parallel connected separate coils can be used as the secondary winding.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** shows the transformer of the invention mounted on a printed circuit board;

FIG. **2** is an end view of the transformer on the board as shown in FIG. **1**;

FIG. **3** is a view of the transformer from the ends of the coils; and

FIG. **4** is a schematic diagram showing the connections of the transformer windings.

DETAILED DESCRIPTION

Referring now to the drawing, in FIG. **1** there is shown the transformer of the invention mounted on a printed circuit board **10**. The transformer includes a ferrite rod core **12** with primary coils or windings **14**, **15** and **16** wound thereon in spaced axial relation, and a secondary coil or winding **18** wound on the rod and having a plurality of coil portions each of which is bifilar wound with one of the primary coils **14**, **15** and **16**. The physical arrangement of the windings is believed clear from FIGS. **1** and **3** wherein the turns of the primary coils are shaded so that they can be distinguished from the secondary coil. In FIGS. **1** and **4** conductors numbered **1** and **8** are the ends of the secondary coil, and conductors numbered **2–3**, **4–5**, and **6–7** are the ends of the primary coils.

FIG. **4** is a schematic diagram of the transformer of the invention and shows the conductors numbered in the same manner as in FIG. **1**. It will be seen that each of the primary coils makes only one complete turn around the core with the ends extending in the same direction to facilitate insertion through openings in a printed circuit board. Each primary winding, therefore, has about one and a half turns. The secondary coil **18** is bifilar wound with the three primary coils **14**, **15** and **16** as shown in FIGS. **1** and **3**. This provides very close coupling between the primary coils and portions of the secondary coil, providing a coupling coefficient in the range of 0.97 and 0.98. It has been found that the turns ratio must be held small; in the range from 1:1 to 1:1.5, in order to maintain this high coefficient of coupling. This means that the number of turns in the secondary coil cannot be substantially greater than the sum of the number of turns in all of the primary coils.

In the example illustrated in FIG. **4**, each primary coil has one and one-half turns so that the three coils have a total of four and one-half turns. The secondary coil has five turns, so it has slightly more turns than the total number in all the primary coils. It is apparent that one-half turn could be added to the secondary coil at each end thereof which would be closely coupled to the primary coils **14** and **16**. Accordingly, the turns ratio could be somewhat increased without a significant loss in the coefficient of coupling.

The number of turns in the coils of the primary winding must be kept low to provide the desired impedance for matching to transistor amplifiers. In a radio transmitter using the transformers described, the impedance of the primary winding of the transformer is of the order of 2 to 6 ohms and the secondary impedance is of the order of 100 ohms. This permits the use of two transformers at the outputs of the two push-pull amplifiers to connect the same in parallel to a 50 ohm transmission line.

The transformer is constructed to have very low leakage and low loss. To accomplish this the ferrite core is made of a nickel-zinc type ferrite having low loss in the frequency range from 25 to 175 megahertz. Such a ferrite is commercially available from the Indiana General Corporation, Keasbey, New Jersey, type Q–2 ferrite being suitable for use at frequencies from 25 to 50 megahertz and type Q–3 ferrite being suitable for use at frequencies from 50 to 200 megahertz. The windings are made of heavy copper conductors having dual polyester coatings to provide the high power output required with minimum loss. As shown by FIGS. **1** and **3** epoxy is applied to the end turns of the windings on the core to hold the windings in position on the ferrite rod core. This is shown at **19** and **20** in FIGS. **1** and **3**.

Although a transformer has been described having a first winding with three separate coils, transformers in accordance with the invention have been constructed with other numbers of coils, specifically with **2**, **4** and **5** coils. In these transformers the second winding has a single continuous coil with portions bifilar wound with the separate coils of the first winding. The number of turns in the second winding can be slightly more than the total number of turns of the coils of the first winding, but to maintain close coupling can not be more than about 50 percent greater. The transformer can be used as either a step-up or a step-down transformer by using the first winding as either the primary winding or the secondary winding of the transformer.

The transformer described has been found to provide effective interstage coupling over a wide frequency band so that variable tuning is not required. The transformer provides impedance matching and at the same time close coupling between the coupled stages.

We claim:

1. A broadband, closely coupled transformer for use on a printed circuit board at frequencies in the range from 25 to 175 megahertz including in combination, a ferrite rod core formed of nickel-zinc ferrite material and having low loss, first and second winding means on said ferrite rod core, means securing said winding means to said core, said first winding means including a plurality of separate coils wound on said rod core and positioned axially therealong, said second winding means including a single continuous coil wound on said rod core having a plurality of coil portions corresponding in number to the number of separate coils of said first winding means, each of said coil portions of said second winding means being wound in a bifilar relation with one of said coils of said first winding means, said continuous coil of said second winding means having a number of turns in the range from the same number of turns as the total number of turns in all said coils of said first winding means to a number 50 percent greater than the total number of turns of all said coils of said first winding means, said plurality of coils of said first winding means and said continuous coil of said second winding means all having coil ends extending in the same direction for insertion through openings in the printed circuit board for mounting the transformer on the printed circuit board, and conductor means on the printed circuit board for connecting said coils of said first winding means in parallel.

2. A transformer in accordance with claim **1** wherein said first winding means is the primary winding of said transformer and includes three separate coils each having a number of turns in the range from one to two turns, and wherein said second winding means is the secondary winding of the transformer and has a number of turns in the range from three to four times the number of turns in each of said coils of said first winding means.

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