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(54) **Transformer and method of making a transformer**

(57) A transformer comprises circuit board having a first and a second surface. A plurality of electrically conductive paths are provided on the first and second surfaces of the circuit board, wherein some of the electrically conductive paths (20a-20f) are interconnected so as to form a primary winding of the transformer, and some of the electrically conductive paths (30a-30r) are interconnected so as to form a secondary winding of the transformer. By providing the electrically conductive paths so that they form an essentially circular pattern, the space of the PCB surfaces is utilized in an efficient way. Also, the transformer can be designed to provide impedance matching. A method of manufacturing a transformer is also disclosed.

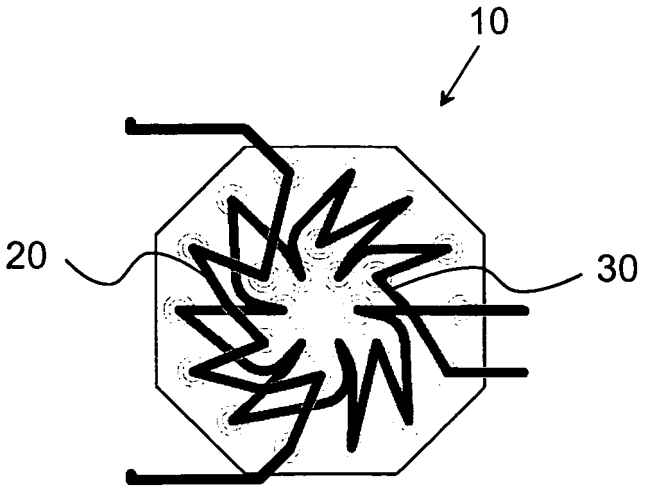


Fig. 6

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## Description

### FIELD OF INVENTION

**[0001]** The present invention relates generally to transformers and more particularly to printed transformers for radio frequency applications.

### BACKGROUND

**[0002]** Transformers are passive electrical devices that transform electric energy between a primary winding or coil and a secondary winding or coil. The input/output ratio is determined by the number of turns in the primary and secondary windings and the linked magnetic flux there through.

**[0003]** Transformers come in many different shapes and configurations. The most common type for low voltage applications has a core of ferrite material for directing the magnetic flux so as to achieve an efficient transformation of the electric energy. However, there are also so called coreless transformers, wherein air or a material of low permeability conducts the magnetic flux linking the primary and secondary windings.

**[0004]** Fig. 1 shows a prior art example of a transformer implemented on a two-layer printed circuit board (PCB). Straight electrically conductive paths on the upper and lower surfaces of the PCB are interconnected by means of through plated via holes so as to form primary and secondary winding of essentially rectangular cross-sectional shape.

**[0005]** A drawback of this prior art design is the inefficient utilization of the available space on the PCB.

**[0006]** US patent application 2005/0212642 A1 discloses a toroid transformer formed on a ceramic substrate.

### SUMMARY OF THE INVENTION

**[0007]** An object of the present invention is to provide a printed transformer, which makes efficient use of available space on a printed circuit board.

**[0008]** Another object is to provide a transformer providing for impedance matching.

**[0009]** The invention is based on the realization that by providing the electrically conductive paths on two surfaces of a printed circuit board in the shape of essentially a circle, a transformer using a minimum of available space is obtained.

**[0010]** According to the invention a transformer is provided comprising: a circuit board having a first and a second surface, a plurality of electrically conductive paths provided on the first and second surfaces of the circuit board, wherein some of the electrically conductive paths are interconnected so as to form a primary winding of the transformer, and some of the electrically conductive paths are interconnected so as to form a secondary winding of the transformer, the transformer being characterized in that the electrically conductive paths form an essentially circular pattern.

**[0011]** There is also provided a method of manufacturing a transformer comprising the following steps: providing a pattern of electrically conductive paths on a first surface of a circuit board, providing a pattern of electrically conductive paths on a second surface of the circuit board opposite to the first surface, interconnecting some of the electrically conductive paths so as to form a primary winding of the transformer, and interconnecting some of the electrically conductive paths so as to form a secondary winding of the transformer, the method being characterized in that the patterns of electrically conductive paths are essentially circular.

**[0012]** By providing the paths in an essentially circular pattern, the space on the PCB is utilized in an efficient way.

**[0013]** In a preferred embodiment, at least parts of the paths are curved. The transformer can thereby be adapted for individual application and also be used for impedance matching, for example.

**[0014]** The transformer is preferably used for RF applications and particularly for applications in the FM radio frequency range, wherein the characteristics is the most suitable.

**[0015]** Further preferred embodiments are defined by the dependent claims.

### BRIEF DESCRIPTION OF DRAWINGS

**[0016]** The invention is now described, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 shows a prior art printed transformer,

Fig. 2 shows a printed transformer according to the invention,

Fig. 3 is a diagram showing the overall layout of a receiver system with the transformer interconnecting input to output of an amplifier,

Figs. 4 and 5 show printed electrically conductive paths on first and second surfaces, respectively, of a PCB, and

Fig. 6 shows the combined patterns of the electrically conductive paths shown in Figs. 4 and 5.

### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

**[0017]** In the following a detailed description of preferred embodiment of a transformer according to the present invention will be given.

**[0018]** Fig. 1 has been covered in the background section of the description and will not be described further

herein.

**[0019]** Fig. 2 shows a first or upper surface of a PCB. The PCB has a number of electrically conductive paths extending generally radially outwards from a virtual center point. A similar pattern (not shown) is provided on a second or lower surface of the PCB. The paths end at through plated via holes, which electrically interconnect the paths on the two surfaces of the PCB, thereby forming a primary and a secondary winding of a transformer. This will be explained in detail below with reference to Figs. 4-6.

**[0020]** The PCB is preferably an epoxy laminate, such as a glass reinforced epoxy laminate sold under the trademark FR4.

**[0021]** Fig. 3 is a diagram of a receiver system showing the transformer interconnecting input to output of an amplifier. The transformer has at least two functions in this system. Firstly, it transforms the signals received by the antenna element and amplified by amplifier core to suitable levels to the input of amplifier. RF parameters like amplification, i.e., gain, and intermodulation behavior can thereby be set up in appropriate manner. It is because the receiver circuit requires signals within predetermined ranges in order to process them correctly. Secondly, the transformer acts as an impedance matching means between the output of the antenna element and the input of the receiver circuit.

**[0022]** In a preferred embodiment, the antenna is an FM antenna and thus the receiver circuit is an FM receiver circuit. This means that the signals received by the antenna element are 88-108 MHz in Europe or between 76-110 MHz in the USA.

**[0023]** The configuration of a preferred embodiment of the transformer according to the invention will now be described in detail with reference to Figs. 4-6. In Fig. 4, the first or upper surface or side of an octagonal PCB 10 is shown. Twelve electrically conductive paths are provided between respective through plated via holes shown as concentric circles in Figs. 4-6. These paths form part of the primary and secondary windings 20 and 30, respectively, see Fig. 6. More particularly, the dark paths 20a, 20c, and 20e form part of the primary winding while the light gray paths 30a, 30c, 30e, 30g, 30i, 30k, 30m, 30o, and 30q form part of the secondary winding. Connection leads 22a, 22b are attached for the primary winding and connection leads 32a, 32b are attached for the secondary winding.

**[0024]** Turning now to Fig. 5, twelve electrically conductive paths on the second or lower surface of the PCB 10. These paths are shown in the same plan view as the ones in Fig. 4, meaning that these paths are shown from the first side of the PCB with the PCB cut away. It is realized that the paths on the second surface of the PCB form the remaining parts of the first and second windings. Thus, the dark paths 20b, 20d, 20f form the remaining part of the primary winding while the light gray paths 30b, 30d, 30f, 30h, 30j, 301, 30n, 30p form the remaining part of the secondary winding.

**[0025]** The layout of the complete primary and secondary winding is shown in Fig. 6. The primary winding comprises six paths, together forming three turns, while the secondary winding comprises 18 paths, together forming nine turns, resulting in a transformer ratio of 1:3.

**[0026]** Most of the paths are slightly bent or curved, maximizing the available PCB surface. By individual design of each loop, a desired impedance matching is also achieved.

**[0027]** A method of manufacturing the above described transformer will now be described. It essentially comprises the steps conventionally used for creating a PCB provided with electrically conductive paths. Thus, a PCB laminate, such as an FR4 laminate, is provided with through holes in positions corresponding to the via holes used for interconnecting the paths on the two sides of the PCB. Then, the paths are applied by means of conventional process for manufacturing printed circuit boards. Also, the through plating is applied in the via holes. Finally, the connecting leads are soldered to the primary and secondary windings for connection to the antenna element and the receiver circuit, respectively.

**[0028]** A preferred embodiment of a transformer according to the present invention has been described. A person skilled in the art realizes that this could be varied within the scope of the appended claims. Thus, a two layer PCB has been described with the electrically conducive paths provided on the two surfaces thereof. It will be appreciated that multi layer PCBs with more than two layers can be used as well.

**[0029]** One example of a pattern forming the primary and secondary winding has been shown. However, the pattern of the inventive transformer can be designed for each and every application, making it extremely useful, particularly in combination with the simple manufacturing thereof.

**[0030]** The inventive transformer has been described in an antenna system comprising an antenna element, an amplifier core element and a RF receiver circuit. It will be appreciated that this transformer can find application in other systems as well, such as RF-coupler, combiner and splitter, and is thus not limited to the described application.

## Claims

**1.** A transformer comprising:

- a circuit board (10) having a first and a second surface,
- a plurality of electrically conductive paths provided on the first and second surfaces of the circuit board, wherein some of the electrically conductive paths (20a-20f) are interconnected so as to form a primary winding of the transformer, and some of the electrically conductive paths (30a-30r) are interconnected so as to form a sec-

ondary winding of the transformer,

**characterized in that**

- the electrically conductive paths form an essentially circular pattern.

**2.** The transformer according to claim 1, wherein at least part of the paths are curved.

**3.** The transformer according to claim 1 or 2, wherein the circuit board is an epoxy laminate.

**4.** The transformer according to claim 3, wherein the circuit board is a glass reinforced epoxy laminate.

**5.** The transformer according to any of claims 1-4, wherein the transformer is arranged to transform radio frequency signals.

**6.** The transformer according to claim 5, wherein the radio frequency signals are in the frequency range of 76 - 110 MHz.

**7.** The transformer according to any of claims 1-6, wherein the paths on the first and second surfaces are interconnected by through plated via holes.

**8.** A receiver system, comprising an antenna element, a receiver, and a transformer interconnecting an output of the antenna element and an input of the receiver circuit,
**characterized in that**
the transformer is a transformer according to claim 1.

**9.** The receiver system according to claim 8, wherein the primary and secondary windings of the transformer are designed for impedance matching.

**10.** A method of manufacturing a transformer, the method comprising the following steps:

- providing a pattern of electrically conductive paths on a first surface of a circuit board (10),
- providing a pattern of electrically conductive paths on a second surface of the circuit board opposite to the first surface,
- interconnecting some of the electrically conductive paths (20a-20f) so as to form a primary winding of the transformer, and
- interconnecting some of the electrically conductive paths (30a-30r) so as to form a secondary winding of the transformer,

**characterized in that**

- the patterns of electrically conductive paths are essentially circular.

Fig. 1 (Prior art)

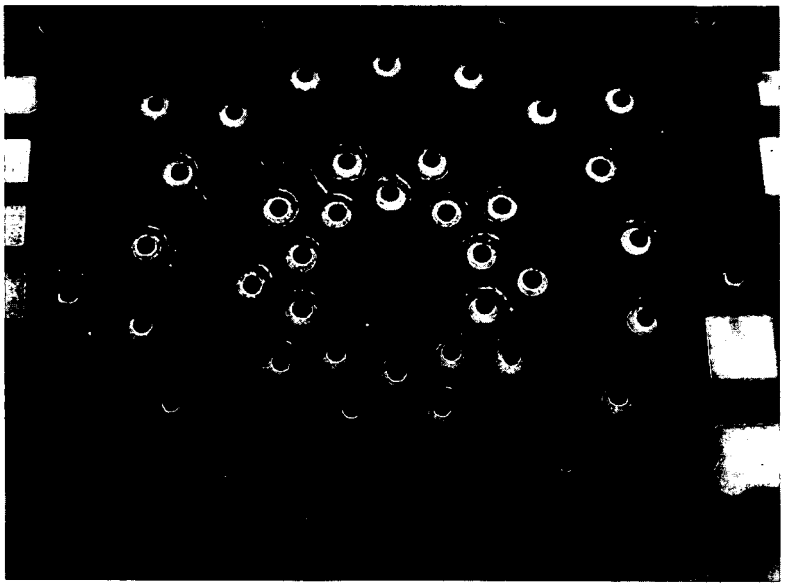

Fig. 2

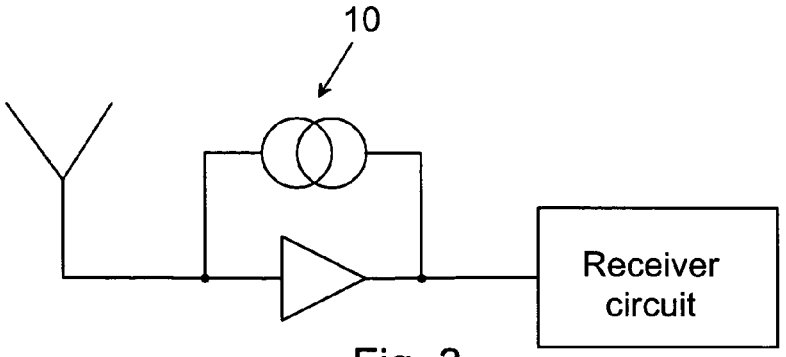


Fig. 3

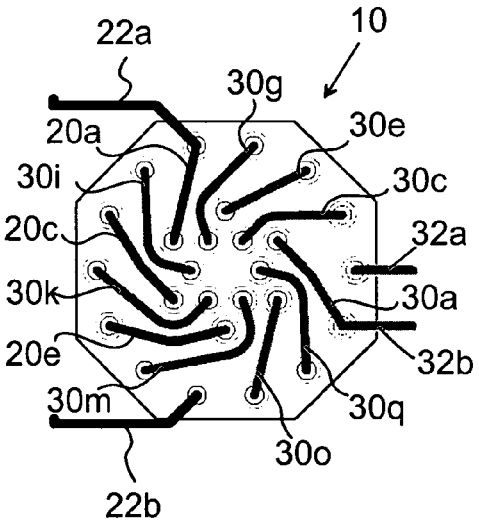


Fig. 4

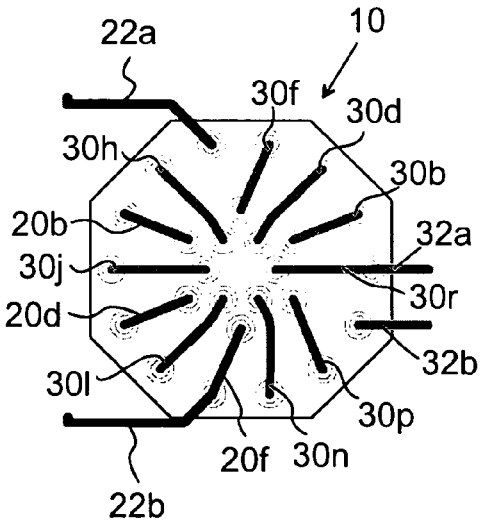


Fig. 5

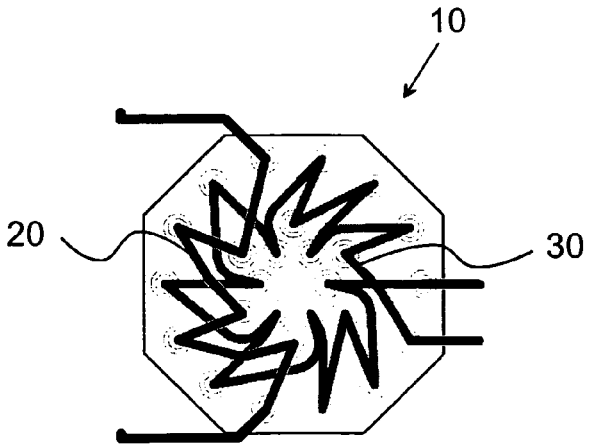


Fig. 6

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Application Number
EP 06 44 5068

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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| Munich | 8 May 2007 | VAN DEN BERG, G |

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| Place of search | Date of completion of the search | Examiner |
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