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(54) Surface mount electronic component with a grooved core and a method for making

(57) A method for fabricating electronic components such as transformers and inductors having wire windings formed from a metal sheet rather than from manual winding of wire. Grooves (12 and 17) are formed in the surface of a core (11) during a molding process. The core (11) is then covered with an insulating layer and a metal film. Metal windings (13 and 18) are carved with one of several methods that rely on parallel grooves (12 and 17) to isolate and pattern each continuous winding. An additional embodiment describes the use of a second insulating layer (14) and a second metal film (16) to modify a component such that the component operates in re-entrant mode. This additional embodiment widens the operational bandwidth of any electronic component with at least two metal windings such as a transformer or coupled inductors.

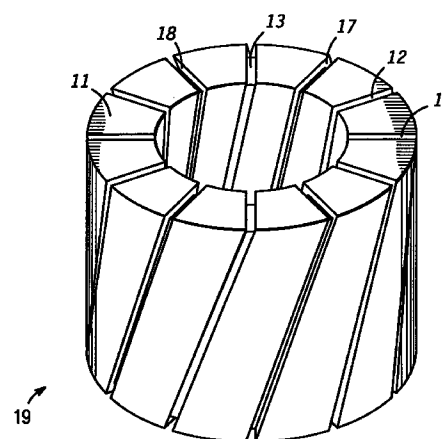


FIG. 1

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Description

Background of the Invention

This invention relates, in general, to transformers or inductors and more particularly, to surface mount components and a method for making such.

Various configurations and structures for electrical transformers and inductors are well known in the art. A basic transformer has at least two coupled wire coils around a center core. The coils are formed from wires that are insulated from both each other and from the core and are wrapped around the core a predetermined number of turns.

The increasing miniaturization of integrated circuits has made it difficult, if not impossible, to wire wrap some cores with mechanical means. To fabricate transformers and inductors on a core that is 1 mm to 10 mm in size requires the metal windings to be hand wound. This has impacted the precision of these components since a transformer's performance is directly related to the number of turns, the tightness of the turns, the spacing between each turn, and the total length of wire used. With manual labor it is difficult to replicate the accuracy that is required of these components.

Attempts to employ processing methods used to fabricate semiconductor devices using photolithography techniques are well known in the art. Planar two dimensional transformers and inductors can be made by a sequence of depositing, patterning, and etching successive layers. Unfortunately the use of photolithography techniques to pattern transformers requires that the surfaces be flat and adds tremendous expense versus the hand wound method.

Accordingly, it would therefore be highly desirable to provide a method for manufacturing electronic components for high volume production that does not require the use of manual winding of wire around a central core. It would also be advantageous to provide a method for improving the coupling between wires of an electronic component to compensate for hand wound windings and to improve the operational bandwidth of the electronic component.

Brief Description of the Drawings

FIG. 1 is an enlarged view showing a first embodiment of the current invention;
FIG. 2 is an enlarged top-down view showing an additional embodiment of the current invention; and
FIG. 3 is a side view of an embodiment of the present invention.

Detailed Description of the Drawings

Typical surface mount transformers and inductors are formed by winding wire around a core section. The size and pitch of the wire and the shape and composition of the core will determine the electrical characteris-

tics of the component. Large components are formed by using a mechanical means to wrap the wire by rotating a bobbin of wire through the center of the core. Small components that are commonly used in many surface mount applications require that the metal windings be formed by hand wrapping the wire around the core. This is not only a timely and costly procedure, but variation in the tightness of the wrap and spacing between windings is introduced into the component. These variations will limit the precision of the component manufactured.

The present invention provides embodiments that allow for the elimination of hand winding electrical components. The metal windings are carved from a sheet of metal that is formed on a core and then patterned with the use of grooves in the surface of the core. These grooves provide for a simplified manufacturing process that improves the precision of the components produced. This invention also provides embodiments for fabricating a three dimensional electronic component that operates in a re-entrant mode. By operating in a re-entrant mode, the coupling between windings is improved which reduces the number of windings required and improves the operational bandwidth of the component.

FIG. 1 is an enlarged view showing a first embodiment of the current invention. The details for fabricating a toroidal transformer 19 will be provided, however, the same methods can be used to form other electronic components that incorporate a core with wire wrapping such as an inductor or linear transformer. A cylindrically shaped core 11 is used to provide the structure of transformer 19. The core 11 is formed by a casting process used by those skilled in the art. The composition of core 11 will depend on the electrical characteristics of the component fabricated. For a toroidal transformer 19 the core material is an iron based magnetic material, but for other applications the core material can consist of a non-magnetic material, ceramic, or plastic.

Previously known methods for casting the core, have formed the core with smooth surfaces. The casting process involves filling a mold with the desired core material and heating the mold. Core 11 then takes the shape provided by the mold. In the present invention, two continuous grooves 12 and 17 are patterned on the surface of core 11 and delineate the two wires of toroidal transformer 19. Grooves 12 and 17 are formed from the mold used to cast core 11 and are patterned such that grooves 12 and 17 encompass core 11. Groove patterns 12 and 17 are pitched axially off the center of core 11 such that grooves 12 and 17 are essentially parallel to each other and that the pattern does not overlap onto itself. Grooves 12 and 17 have several characteristics that can be adjusted to determine the performance of toroidal transformer 19. The depth, shape, or pitch (distance between two adjacent portions of grooves 12 and 17) is predetermined based on required performance of toroidal transformer 19.

Most electronic applications require that the metal wires of the component be insulated from the core.

Electrical isolation is provided by an insulating layer formed overlying the surface of core 11 where metal windings 13 and 18 will be shaped. In the present embodiment, the entire surface of core 11 is coated with an insulating material such as paralyne. A metal film is then formed over the insulating layer by any of the techniques used by those skilled in the art. The metal film can be any conductive material depending on the electrical properties required of transformer 19. Such materials include copper, silver, aluminum, gold, tungsten, titanium-nitride, titanium-tungsten or nickel. The metal film is formed on the insulating layer both in grooves 12 and 17 and overlying the surface of core 11 between adjacent portions of the groove pattern.

In the present invention, the metal film is then selectively removed by scraping the exposed surface of core 11. Alternatively, the metal film can be removed by chemical etching, mechanical polishing, or the like. Metal windings 13 and 18 are formed by a portion of the metal film that is left remaining in grooves 12 and 17 respectively. In a second embodiment which is not shown, the grooved patterns are used as a guide to remove the metal film from grooves 12 and 17 and form metal windings 13 and 18 on the surface of core 11 which are isolated by bordering portions of the grooved patterns. Metal windings 13 and 18 replace the functionality of wires wrapped around a core in previously known methods for forming a transformer. There is no need to hand wind wire and the above mentioned embodiments can be scaled to manufacture a transformer of various sizes. Typical surface mount components used in an integrated circuit are formed on cores that have an outer diameter of 1 mm to 100 mm and an inner diameter of 0.5 mm to 98 mm. By using a mold to form grooved patterns in the core, evenly spaced windings are made with a fixed length and pitch which improves the precision of the electronic component produced. The precision is also repeatable and reproducible in a manufacturing process since this invention is not susceptible to the inconsistencies in wire spacing and tightness common with hand winding.

In a third embodiment of the present invention, which is not shown, the entire surface of core 11 need not be patterned with grooves 12 and 17. The metal windings 13 and 18 are partially or completely formed by scraping the surface of core 11 in a rifling pattern. A portion of the surface can be left smooth during the casting process and covered with the insulating layer and the metal film. The metal windings 13 and 18 are then formed by scraping the smooth surfaces with a rifling pattern such that continuous metal windings 13 and 18 are formed.

In any of the above mentioned embodiments, one or more grooves can be formed on the surface of core 11. A single groove that forms one metal winding, will form an inductor or a precision inductor. By forming multiple grooves that run essentially parallel to each other while encircling the core, various electrical components can be formed. Possible components include a toroidal

transformer 19 if at least 2 wires encircle a magnetic core, a linear transformer if at least two windings are formed around a non-magnetic core, or a plurality of coupled inductors are produced if the core is cylindrical in shape.

FIG. 2 is a top-down view of a fourth embodiment of the present invention. Previously known methods for fabricating transformers for surface mount applications have limitations on the maximum frequency bandwidth that the component will reliably operate in due to the lack of electrical coupling between the wire windings around the core. By forming a re-entrant mode surface mountable electronic component 20, the coupling between windings 13 and 18 is improved so as to electrically seem that wire windings 13 and 18 are closer to each other than they really are. The three dimensional electronic component shown in FIG. 2 has two metal windings 13 and 18 formed in grooves 12 and 17 respectively. A second insulating layer 14 is formed overlying the two metal windings 13 and 18 and is made from any insulating material used by those skilled in the art such as paralyne. A second metal film 16 is formed on insulating layer 14 such that metal film 16 overlaps at least a portion of metal winding 13 and metal winding 18. This second metal film 16 can be deposited with a vapor deposition or in the preferred embodiment, formed by electroplating. In FIG. 3 metal film 16 is shown to completely cover the outer surface of core 11. Metal film 16 can also be formed to cover a portion of the inner opening or either the top or bottom surface of core 11 as well.

The purpose of second metal film 16 is to reduce the capacitive load between metal winding 13 and metal winding 18 relative to the electrical ground voltage. By increasing the surface area second metal film 16 overlaps metal windings 13 and 18, coupling between metal windings 13 and 18 is improved. The above mentioned embodiment can be used on any electrical component that has at least two metal windings and is not limited to transformers with windings formed by grooves in the core. By incorporating second metal film 16, the operating bandwidth of an electrical component is widened. The lower limit frequency is determined by the coupling of the core material with the metal windings and the upper limit frequency is determined by the re-entrant mode coupling with second metal film 16.

FIG. 3 is a side view showing how an electronic component incorporating one or more of the above mentioned embodiments is attached to a PC board for surface mount applications. Metal windings 13 and 18 (FIG. 1) are terminated on a surface of core 11 to form the bonding pads 22 and 23 respectively. Solder or any other conductive material is formed on bonding pads 22 and 23 to provide electrical and physical contact to a PC board (not shown) in a variety of integrated circuit applications.

This invention presents several embodiments to reduce the cost of manufacturing surface mounted electronic components and that improve the precision of the

components. A method is provided for forming the metal windings of a transformer or inductor that does not require hand winding. By using grooves to pattern a metal film, the inaccuracies due to tightness of wrap, number of turns, and the pitch of the turns from hand winding can be eliminated. An additional embodiment has been presented that improves the operational bandwidth by forming a three dimensional re-entrant mode component that improves the coupling between the metal windings of an electronic component.

Claims

1. An electronic component (19) for surface mounting in an integrated circuit comprising:

a core (11) having a surface;
 at least one continuous groove pattern (12) in the surface of the core such that the core is encircled with the at least one continuous groove pattern with a predetermined distance between adjacent portions of the at least one continuous groove pattern (12);
 an insulating layer overlying the surface of the core (11); and
 at least one metal winding (18) formed on the insulating layer (14) by a metal film such that the at least one metal winding is essentially parallel to the at least one continuous groove pattern (12).

2. The electronic component (19) of claim 1 wherein the core is a magnetic core made from magnetic material.

3. The electronic component (19) of claim 1 wherein the core is made from non-magnetic material.

4. The electronic component (19) of claim 1 wherein the at least one metal winding is formed by a portion of a metal film residing in the at least one continuous groove pattern (12).

5. The electronic component of claim 1 further comprising:

a second insulating layer deposited overlying at least two metal windings; and
 a metal film formed on the second insulating layer such that the electronic component will operate in a re-entrant mode.

6. A method for electrically coupling metal windings of an electronic component (20) by forming a re-entrant mode surface mountable electronic component comprising the steps of:

providing an electronic component comprised of a plurality of metal windings (18) and having

a surface;

forming an insulating layer (14) overlying the surface of the electronic component (20); and
 forming a metal film (16) overlying the surface of the insulating layer such that a capacitive load of the plurality of metal windings (18) is reduced and operates in a re-entrant mode.

7. The method for forming a re-entrant mode surface mountable electronic component (20) of claim 6 wherein the step of providing an electronic component (20) further comprises providing an electronic component that has a core made from magnetic material.

8. The method for forming a re-entrant mode surface mountable electronic component (20) of claim 6 wherein the step of providing an electronic component (20) further comprises providing an electronic component (20) that has a core made from non-magnetic material.

9. The method for forming a re-entrant mode surface mountable electronic component (20) of claim 6 wherein the step of providing an electronic component (20) further comprises providing an electronic component (20) with a plurality of metal windings (18) formed such that the electronic component operates as a toroidal transformer.

10. The method for forming a re-entrant mode surface mountable electronic component (20) of claim 6 further comprising of providing an electronic component with a core made of a non-magnetic material, and forming the plurality of metal windings (18) such that the electronic component operates as a linear transformer.

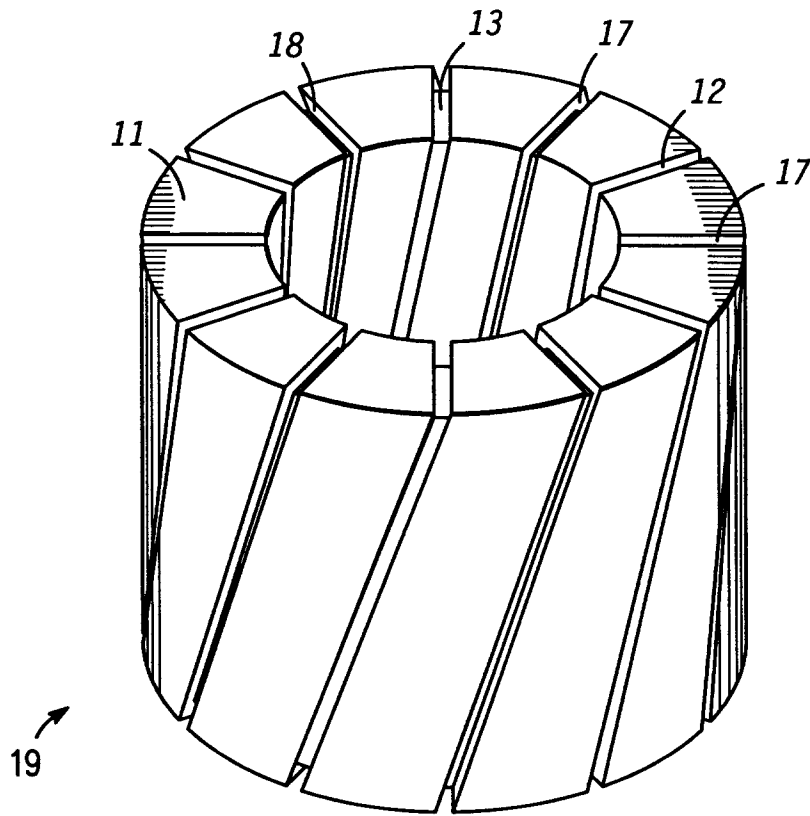


FIG. 1

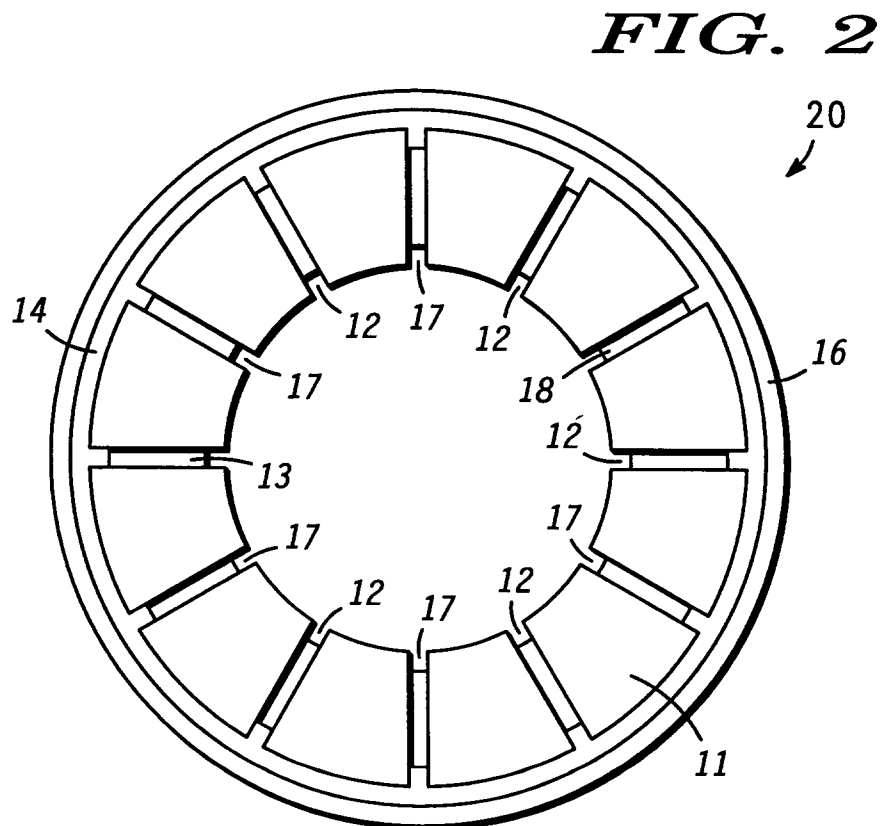


FIG. 2

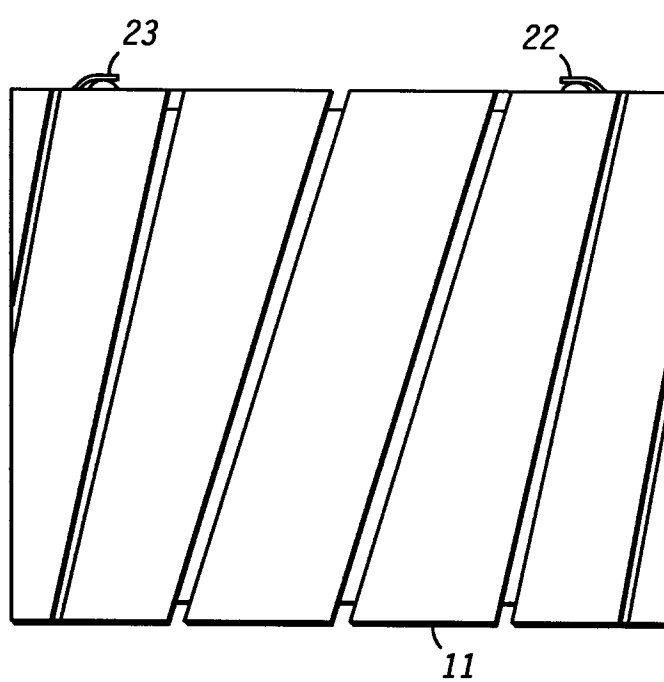


FIG. 3



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EUROPEAN SEARCH REPORT

Application Number
EP 96 10 8606

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US-A-3 319 207 (DAVIS) 9 May 1967 * column 1, line 64 - line 70 * * column 3, line 67 - column 4, line 8 * * column 4, line 53 - line 74; figures 1,3,4 *	1-4	H01F17/06 H01F27/36
X	--- PATENT ABSTRACTS OF JAPAN vol. 007, no. 170 (E-189), 27 July 1983 & JP-A-58 078402 (YAGI ANTENNA KK), 12 May 1983, * abstract *	1,2,4	
A	--- GB-A-1 243 495 (INTERNATIONAL STANDARD ELECTRIC CORPORATION) 18 August 1971 * page 1, line 39 - line 70; figures *	5-7,10	
A	--- US-A-4 748 430 (GUAIS NOEL) 31 May 1988 * column 2, line 20 - line 57; figures *	5,6,8	
A	--- DE-A-24 24 715 (MESSERSCHMITT BOELKOW BLOHM) 4 December 1975 * page 4, line 4 - line -; figure *	5-7	TECHNICAL FIELDS SEARCHED (Int.Cl.6)
A	--- ELEKTOR ELECTRONICS, vol. 20, no. 219, 1 February 1994, pages 52-58, XP000430260 CARR J J: "BUILDING YOUR OWN TOROID CORE INDUCTORS AND RF TRANSFORMERS" -----		H01F
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 11 September 1996	Examiner Marti Almeda, R
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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