

METHOD OF IMPROVING THE POWER OF A FERRITE BEAD IN
BEARING ELECTRIC CURRENT. METHOD OF FABRICATING
FERRITE BEADS. AND THE RELATED PRODUCTS

BACKGROUND OF THE INVENTION

The present invention relates to ferrite beads for use in EMI filters and video apparatus. and more specifically the invention relates to a method of improving the power of a ferrite bead in bearing larger electric current.

In digitized electronic products, high frequency noises from DC power supply lines and signal lines may cause an electromagnetic interference. A variety of EMI filters have been disclosed for protection against such an electromagnetic interference. However, EMI filters for use in DC power supply lines and EMI filters for use in signal lines have different properties. An EMI filter for use in a DC power supply line must be capable of bearing much volume of electric current. Because a DC power supply line provides the necessary working energy of the whole circuit, much volume of electric current passes through a DC power supply line than a signal

1-100000

line. However, because a chip inductor is small, it can only bear a limited volume of electric current. Therefore, technical improvement is needed so that a chip type inductor can bear a relatively higher volume of electric current. For example, in order to improve the maximum current bearing capability of a chip type ferrite bead, improvement must be made to prevent the ferrite bead from overheat or dropping of effective inductance. On this side, RDC (DC resistance value) is the main factor which affects the capability of the ferrite bead in bearing electric current. The DC resistance value of a ferrite bead directly determines the volume of heat energy produced during its operation. If a ferrite bead produces an excessive high volume of heat energy during its operation, the ferrite bead will be unable to function well. Basically, the smaller the DC resistance value, the higher the capability of bearing electric current.

Currently, a chip type ferrite bead is made by: preparing a Ni-Cu-Zn material sheet, then arranging metal wires on the Ni-Cu-Zn material sheet, and then covering a plurality of material

sheets on the Ni-Cu-Zn material sheet. and then processing the material sheets in a laminated structure by a heat press. and then cutting the laminated structure into laminated pieces, permitting them to be sintered into laminated chip type ferrite beads.

US Pat. No. 3,765,082 entitled "METHOD OF MAKING AN INDUCTOR CHIP" and US Pat. No. 5,515,022 entitled "MULTILAYERED INDUCTOR" teach different ferrite beads fabrication methods. According to US Pat. No. 3,765,082. a monolithic inductor chip (ferrite bead) is formed by providing a plurality of ferrite wafers each having a conductive element silk screened on its top surface. An end portion of each element passes through a hole in the wafer to a point on the bottom of the wafer. The various wafers are stacked in such a manner, that the end portion on the bottom of one wafer electrically connects to the initial point of the element on the top of the next successive wafer so that the stacked wafers define an inductive coil. According to US Pat. No. 5,515,022, a multilayer inductor is fabricated by sandwiching a first magnetic material sheet

between a second magnetic material sheet and a third magnetic material sheet and integrating the three layers. The first magnetic material sheet and the second magnetic material sheet have a respective spiral conductor pattern formed by screen-printing. These two methods still cannot improve the capability of a ferrite bead in bearing electric current. In order to improve the capability of bearing electric current, the most commonly used methods are to increase the width and thickness of conductors, or to use electrode paste (conductive material) of high metal concentration or low resistance for printing internal conductors. However, due to the limitation of current screen printing techniques, it is not easy to increase the thickness of the internal conductors of a ferrite bead. If to improve the capability of bearing electric current by changing the composition of the electrode paste (conductive material), material cost will be relatively increased. If the best conductive material, higher metal content in the paste is used for making the conductors, it gives little improvement in reducing the DC resistance, however it greatly increases the cost. Furthermore, if all technical problems are overcome, it is still

difficult to increase the width and length of the conductors in the limited area of a ferrite bead.

Further, different silk screens may be designed for printing different lengths of conductors in ferrite beads, so as to provide different impedance. However, preparing a different silk screen in order to achieve a different impedance, greatly increases the manufacturing cost of ferrite beads.

SUMMARY OF THE INVENTION

The present invention has been accomplished under the circumstances in view. It is one object of the present invention to provide a method of improving the capability of a ferrite bead in bearing electric current. This object is achieved by integrating a plurality of conductors in a ferrite bead, permitting the conductors to be connected in parallel between two end electrodes. The conductors can be respectively arranged in straight line or a curved line. This arrangement greatly reduces the DC resistance of the ferrite bead, therefore the ferrite bead produces low heat when a big volume of electric current passes.

It is another object of the present invention to provide ferrite bead made according to the aforesaid method. A ferrite bead made according to the aforesaid method comprises a plurality of conductors connected in parallel. The design of the parallel conductors in the ferrite bead greatly reduces the DC resistance of the ferrite bead, therefore the ferrite bead produces little heat when a big volume of electric current passes.

It is still another object of the present invention to provide a method of controlling the impedance of a ferrite bead. The impedance of a ferrite bead made according to the present invention can be properly controlled by changing the pitch of the conductors. The pitch of the conductors can be adjusted by changing the thickness of the substrate between the conductors, or adjusting the printing locations of the conductors in the silk screen.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a sectional view showing the structure of a ferrite bead according to the

present invention:

Fig. 2 is an exploded view of a ferrite bead according to a first embodiment of the present invention;

Fig. 3 is an exploded view of a ferrite bead according to a second embodiment of the present invention;

Fig. 4 is an exploded view of a ferrite bead according to a third embodiment of the present invention;

Fig. 5 is an exploded view of a ferrite bead according to a fourth embodiment of the present invention; and

Fig. 6 is a sectional view of a ferrite bead according to a fifth embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to Figure 1, the ferrite, referenced by 1, is comprised of a bottom ferrite substrate 10, a top ferrite substrate 12, an intermediate ferrite substrate 11 sandwiched between the bottom ferrite substrate 10 and the top ferrite substrate 12. two end electrodes 14 fastened to the ferrite substrates 10, 11 and 12 at

two opposite ends, and a plurality of conductors 13 integrated in between the ferrite substrates 10, 11 and 12 and each having two opposite free ends respectively connected to the end electrodes 14. Because the conductors 13 are connected in parallel, the resistance of the ferrite bead 1 is low, and the ferrite bead 1 produces low heat ($H=I^2 R$) when huge current passes. Therefore, the design of the present invention can effectively bear much volume of electric current without causing much heat. In the aforesaid structure, two conductors 13 are linearly integrated in between the ferrite substrates 10, 11 and 12, and connected in parallel.

Figure 2 shows a ferrite bead according to a first embodiment of the present invention. According to this embodiment, the ferrite bead 1a comprises three conductors 13a connected in parallel and arranged in a curved manner. This arrangement greatly reduces the DC resistance (RDC) of the ferrite bead 1a, therefore the ferrite bead 1a produces low heat when electric currents passes.

Figure 3 shows a ferrite bead according

to a second embodiment of the present invention. According to this alternate form, the ferrite bead 1b comprises a bottom ferrite substrate 10b, a top ferrite substrate 12b, and two conductors 13b integrated in between the bottom ferrite substrate 10b and the top ferrite substrate 12b and linearly connected in parallel.

Figure 4 shows a ferrite bead according to a third embodiment of the present invention, in which the ferrite bead 1c comprises a bottom ferrite substrate 10c, a top ferrite substrate 12c, and two conductors 13c integrated in between the bottom ferrite substrate 10c and the top ferrite substrate 12c and curvally connected in parallel. The curved arrangement of the conductors 13c greatly increase the impedance of the ferrite bead 1c. When the conductors 13c are connected in parallel, the RDC is greatly reduced.

Figure 5 shows a ferrite bead according to a fourth embodiment of the present invention, in which the ferrite bead 1d comprises a bottom ferrite substrate 10d, a top ferrite substrate 12d, and three conductors 13d integrated in between the

bottom ferrite substrate 10d and the top ferrite substrate 12d and connected in parallel.

The aforesaid ferrite beads 1, 1a, 1b, 1c, 1d are made by one of the following two methods. The first method comprises the steps of:

i) preparing a bottom ferrite substrate 10, 10a:

ii) printing a conductor 13, 13a on the bottom ferrite substrate 10, 10a, permitting two opposite free ends of the conductor 13, 13a to be extended to both ends of the bottom ferrite substrate 10, 10a:

iii) covering an intermediate ferrite substrate 11, 11a on the bottom ferrite substrate 10, 10a over the conductor 13, 13a:

iv) printing a conductor 13, 13a on the top side of the intermediate ferrite substrate 11, 11a, permitting two opposite free ends of the conductor 13, 13a to be extended to both ends of the intermediate ferrite substrate 11, 11a:

v) repeating the steps iii) and iv) subject to the capacity of the ferrite bead to be finished:

vi) covering a top ferrite substrate 12,

12a over the intermediate ferrite substrate 11.
11a: and

vii) fastening two end electrodes 14 to the substrates 10. 10a. 11. 11a. 12. 12a. permitting the free ends of the conductors 13. 13a to be respectively connected to the end electrodes 14.

The second method comprises the steps of:

i) preparing a bottom ferrite substrate 10b. 10c. 10d:

ii) printing on the bottom ferrite substrate 10b. 10c. 10d a plurality of conductors 13b. 13c. 13d. permitting two opposite free ends of each conductor to be extended to both ends of the bottom ferrite substrate 10b, 10c, 10d:

iii) covering a top ferrite substrate 12b. 12c, 12d on the bottom ferrite substrate 10b. 10c, 10d over the conductors 13b. 13c. 13d; and

iv) fastening two end electrodes 14 to the ferrite substrates 10b, 10c, 10d, 12b. 12c, 12d at two opposite ends. permitting the free ends of the conductors 13b. 13c. 13d to be respectively connected to the end electrodes 14.

In the aforesaid production procedures.

the ferrite substrates 10, 11, 12 can be made from Ni-Cu-Zn-Ferrite, Ni-Zn-Ferrite, Cu-Zn-Ferrite, or Mg-Cu-Zn-Ferrite. The conductors 13 can be made from Au, Ag, Cu, Mo, or any of a variety of precious metal.

Further, the impedance of the ferrite bead 1, 1a, 1b, 1c, 1d can be properly controlled by changing the pitch between the conductors 13. As illustrated in Figure 6, the thickness of the intermediate ferrite substrate 11e of the ferrite bead 1e is properly design, so that the pitch between ferrite bead 1e between the conductors 13e is controlled. The relationship between the impedance of the ferrite bead 1e and the pitch of the conductors 13e is shown by the following equation:

$$Z = Cl \left[\log_e \frac{2l}{d} - \log_e k - 1 + \frac{d}{l} - \frac{1}{4} \frac{d^2}{l^2} \right]$$

in which:

C: coefficient of material, which is affected by the material, for example, the value of C is approximately equal to $2 \text{ to } 6 \times 10^7$ when

Fe-Ni-Cu-Zn Ferrite is used for making the ferrite substrates:

l: length of the conductors 13e:

d: pitch of the conductors 13e:

K: coefficient of shape determined subject to the shape of the ferrite bead, and affected by the conductor width/conductor pitch and conductor thickness/conductor width, for example. if conductor width/conductor pitch=0.1 and conductor thickness/conductor width=0.1, the value of K is 1.0008. therefore the impedance of the ferrite bead 1e is known when the pitch of the conductors 13e is designed. In a 2.0x1.2x0.9mm dual-conductor ferrite bead. if the conductor pitch is 90 μ m, the impedance will be about 14 Ω ; if the conductor pitch is 200 μ m, the impedance will be about 10 Ω . Therefore, the impedance of the ferrite bead can be properly controlled by changing the conductor pitch.

As indicated above, the ferrite bead fabrication method and the method of changing the impedance of a ferrite bead according to the present invention, greatly improve the capability of a ferrite bead in bearing electric current.



I claim:

1. A method of improving the power of a ferrite bead in bearing electric current, comprising the step of integrating a plurality of conductors in a ferrite bead, permitting the conductors to be connected in parallel.

2. The method of claim 1 wherein said conductors are made on a substrate by printing.

3. The method of claim 1 wherein said conductors are respectively printed on a plurality of substrates arranged in a stack, and having two opposite ends respectively connected to two opposite end electrodes at two opposite ends of the ferrite bead.

4. The method of claim 3 wherein said conductors are respectively printed on said substrates by a same printing screen.

5. A ferrite bead comprising two electrodes at two opposite ends thereof, and a plurality of conductors integrated on the inside and connected in parallel, each of said conductors



having two opposite free ends respectively connected to said end electrodes.

6. The ferrite bead of claim 5 wherein said conductors are made on a substrate inside the ferrite bead.

7. The ferrite bead of claim 5 wherein said conductors are respectively made on a plurality of substrates arranged in a stack inside the ferrite bead.

8. A method of controlling the impedance of a ferrite bead having a plurality of conductors arranged in parallel on the inside, by controlling the pitch between said conductors.

9. The method of claim 8 wherein the pitch of said conductors is controlled by changing the thickness of substrates, which are arranged in a stack inside the ferrite bead.

10. The method of claim 8 wherein the pitch of said conductors is controlled subject to the printing screen used for printing said



conductors.

11. A ferrite bead fabrication method comprising the steps of:

- i) preparing a bottom ferrite substrate:
- ii) printing a first conductor on said bottom ferrite substrate, permitting two opposite free ends of said first conductor to be extended to both ends of said bottom ferrite substrate:
- iii) covering at least one intermediate ferrite substrate on said bottom ferrite substrate over said first conductor:
- iv) printing a second conductor on each of said at least one intermediate ferrite substrate at one side opposite to said first conductor, permitting two opposite free ends of said second conductor to be extended to both ends of the respective intermediate ferrite substrate:
- vi) covering a top ferrite substrate over said at least one intermediate ferrite substrate: and
- vii) fastening two end electrodes to said bottom ferrite substrate, said top ferrite substrate and said at least one intermediate ferrite substrate, permitting the free ends of said



first conductor and the second conductor of each of said at least one intermediate ferrite substrate to be respectively connected to said end electrodes.

12. A ferrite bead fabrication method comprising the steps of:

i) preparing a bottom ferrite substrate:

ii) printing on said bottom ferrite substrate a plurality of conductors, permitting two opposite free ends of each of said conductors to be respectively extended to both ends of said bottom ferrite substrate:

iii) covering a top ferrite substrate on said bottom ferrite substrate over said conductors;

iv) fastening two end electrodes to said bottom ferrite substrate and said top ferrite substrate at two opposite ends, permitting the free ends of said conductors to be respectively connected to said end electrodes.