

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

02.11.2000 Bulletin 2000/44

(51) Int Cl.7:

H01F 3/10, H01F 3/14,
H01F 30/10

(21) Application number:

00650039.1

(22) Date of filing:

26.04.2000

(84) Designated Contracting States: AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE Designated Extension States: AL LT LV MK RO SI	(72) Inventors: - Rinne, Karl Kinsalebeg, County Waterford (IE) - O Suilleabháin, Liam Bishopstown, Cork City (IE)
(30) Priority: 26.04.1999 IE 990349	(74) Representative: O'Connor, Donal Henry c/o Cruickshank & Co., 1 Holles Street Dublin 2 (IE)
(71) Applicant: Artesyn Technologies County Cork (IE)	

(54)

Improvements in and relating to magnetic devices

(57)

A magnetic device of separate non-interacting magnetic components housed in a housing 4. Each component has a central core 5 and a winding 2 and 3.

Each core 5 has an air gap 6. The windings 2 and 3 extend beyond the air gap 6. This gives increase reluctance confining the magnetic field in the core 5.

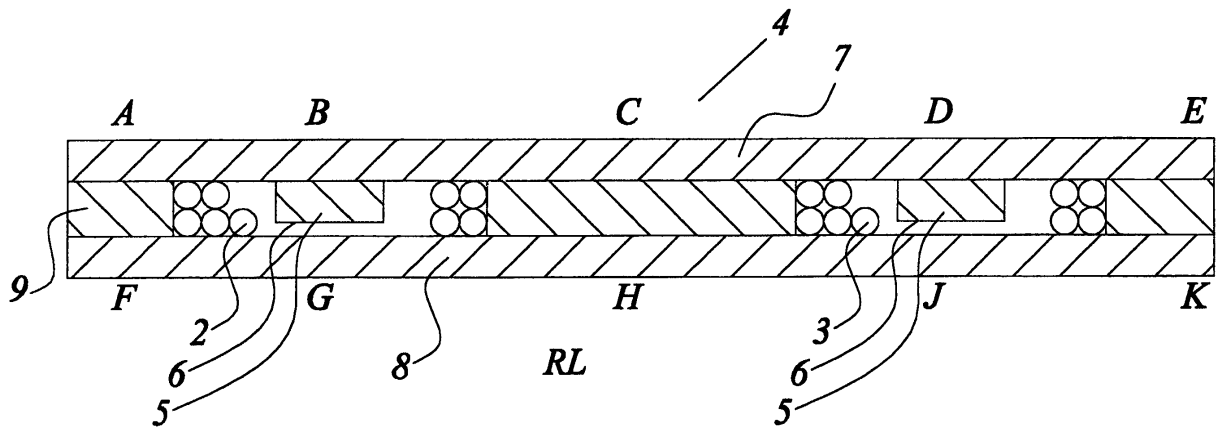


Fig. 2

Description

[0001] The present invention relates to magnetic devices.

[0002] One of the major problems in the development of smaller SMPCs is the large physical size of magnetic components. Few advances have been made in this particular area of power electronics in comparison to semiconductors where a high degree of miniaturisation and integration has been achieved. The incorporation of inductors and transformers into a single magnetic system within the SMPCs could be extremely advantageous in that it would result in converter designs of lower cost, weight and size than an SMPC including a large number of discrete magnetic components.

[0003] Thus, for example, there would be considerable advantages in combining inductors and transformers into a single physical assembly if it could be done in such a way as to provide little or no compromising conversion characteristics and as mentioned above unfortunately, with few exceptions, inductors and transformers are also major contributors to the total cost, weight and size of a converter system. Thus, in combining magnetic components into one physical assembly the added benefits are: less ferrite, less area/volume, non-coupling of magnetics on a common core while not degrading other electrical parameters including EMI (radiated), examples of which are mentioned in a book by Severns and Bloom, Chapter 12.

[0004] A major problem that arises by having the components in this configuration is the linking flux that will occur between the individual components and in any coil there will therefore be the normal flux induced within the coil which is produced by self-induction and then there will be a flux introduced into the coil by that produced by mutual induction i.e. caused by dynamic changes in the current of the remaining coils.

[0005] However, it is important to note that what is required for non-interacting separate magnetic devices which are in effect manufactured separately for each component and if they are kept sufficiently spaced apart then they will not interact with other magnetic components on a board.

[0006] It has been known to use one core for several magnetic components in a converter circuit. Elaborate design methods are used to ensure that the flux properties of the individual components are so-arranged to reproduce what is effectively the flux properties that would be produced if the components had been kept in totally separate cores. This again is not particularly advantageous as it requires considerable design care and further can be very difficult as the magnetic components are based on the assumption that linear relationships exist between flux and exciting forces of the windings. This can only occur when operation is well below the saturation limits of the magnetic material.

[0007] A further problem with the present methods of integrating magnetic elements is that it is necessary to be very careful in the specification of the performance of the magnetics for production use and in its manufacture to ensure that a consistent magnetic product which may be much more complex than a simple transformer or inductor is produced. It will be appreciated that changing any such device once in production can be much more costly than with discrete magnetic devices because of the intimate relationship that exists between the various inductances and or transformer elements in the larger composite device. Thus, these methods are not, by any means, as efficient as they should be.

[0008] U.S. Patent Specification No. 5,414,401 (Roshen et al) describes a multi-pole magnetic component which incorporates a core with air gaps which will reduce winding and core losses. However, it does not address the problems of non-interactive magnetic components. The purpose is to achieve a distributed air gap over a number of even poles. All components are interacting.

[0009] Finally as the trend towards further miniaturisation gathers increasing pace the size of these magnetic components reinforces the need for integrated magnetic elements.

[0010] The present invention is directed towards providing a magnetic device comprising a plurality of separate magnetic components which can be housed in one core without the components interacting.

Statements of Invention

[0011] According to the present invention, there is provided a magnetic device comprising a plurality of separate non-interacting magnetic components housed in the one physical structure, characterised in that each magnetic device has associated therewith a central core of any shape for windings, each central core having a reluctance higher than that of the remainder of the structure.

[0012] Ideally, there is provided a magnetic device in which the central core includes an external air gap.

[0013] Preferably, there is provided a magnetic device in which the central core includes air voids encapsulated in it.

[0014] In another embodiment, there is provided a magnetic device in which the central core incorporates non-ferromagnetic material.

[0015] Ideally, there is provided a magnetic device in which the ferromagnetic device is in the form of layers within the core.

[0016] Ideally every second magnetic pole has an air gap.

[0017] In a further embodiment, there is provided a method of producing a magnetic device characterised in that the

method of winding a coil around each core is critical to the performance of the device, in which considerable ferrite material is saved and in which the physical size of the device is reduced.

[0018] Another way of viewing the present invention is that the core housing forms alternate full or continuous cores and cores with air gaps so that the reluctance can be varied in a controlled manner. Thus, non-interactive components can be mounted effectively on the one core. Correct choice of the physical characteristics of the core housing is the key to the present invention.

[0019] It can be viewed as a series of an odd number of full poles with one reluctance and an even number of poles of higher reluctance.

[0020] Preferably one winding surrounds one pole of the core housing only.

Detailed Description of the Invention

[0021] The invention will be more clearly understood from the following description of some embodiments thereof, given by way of example only described with reference to the accompanying drawings in which:

Fig. 1 is a perspective view of a device according to the invention;

Fig. 2 is a cross-section of the device of Fig. 1;

Fig. 3 is an electrical circuit equivalent model of the device;

Fig. 4 is a similar electrical equivalent model of a more generalised construction of the device; and

Fig. 5 is a sectional view similar to Fig. 2 of an alternative construction of the device according to the invention.

[0022] Referring to Figs. 1 and 2, there is illustrated a magnetic device indicated generally by the reference numeral 1 comprising two windings or coils 2 and 3. The magnetic device 1 comprises a fabricated ferrite housing 4.

[0023] Each coil 2 and 3 has a coupling core portion 5 having an air gap 6. Thus, this coupling core portion 5 has a reluctance considerably higher than that of its surrounding core.

[0024] The housing 4 specifically includes top, bottom and side walls 7, 8 and 9 respectively with suitable apertures 8a in the bottom wall 8 for the windings 2 and 3.

[0025] Referring now to Fig. 3 which illustrates the equivalent electric circuit, the letters A to K illustrate the various positions of flux produced by the flow of the current in the coils 2 and 3. Thus, for example, the flux will be downward from A to F and upwards from G to B in the particular example as illustrated in Fig. 3. In Fig. 3 RL represents a low resistance equivalent to a low reluctance and RH represents a high resistance due to a high reluctance.

[0026] In this particular example the reluctance paths have only been shown as having two reluctances, namely a high reluctance RH all of which are equal and a low reluctance RL. It will be appreciated that there will obviously be different reluctances in that, for example, the reluctance between C and H might be higher or lower than the reluctance between A and F.

[0027] Again with reference to Fig. 3 V1 and V2 are the voltage sources representing the windings. Presuming firstly that V2 is equal to 0, because there is no winding on the second airgap leg and using Kirchoff's voltage and current laws for analysis, we have the following:

[0028] Current equations:

$$I_1 = I_2 + I_3 \quad (A)$$

$$I_3 = I_4 + I_5 \quad (B)$$

$$I_5 = I_6 + I_7 \quad (C)$$

[0029] Note in the following theory, V represents mmf (magnetic motive force) of the windings, I represents the flux ϕ in the core and R represents the reluctance of the core section.

[0030] Assuming a relative permeability μ for the core and noting that reluctance increases with decreasing μ , the value μ is called the relative permeability of the core and is a scalar value. Therefore, it can be used with electrical

parameters in the following analysis.

[0031] Loop ABGF:

$$\begin{aligned}
 V_1 &= I_1 \cdot R_H + 3I_2 \cdot R_L \\
 &= I_1 \cdot R_L \cdot \mu + 3I_2 \cdot R_L \\
 &= (I_1 \cdot \mu + 3I_2) R_L \quad (1)
 \end{aligned}$$

[0032] Loop BCHG:

$$\begin{aligned}
 V_1 &= I_1 \cdot R_H + I_4 \cdot R_L + 2I_3 \cdot R_L \\
 &= (I_1 \cdot \mu + I_4 + 2I_3) R_L \quad (2)
 \end{aligned}$$

[0033] Loop BDJG

$$\begin{aligned}
 V_1 &= I_1 \cdot R_H + I_7 \cdot R_H + 2I_3 \cdot R_L + 2I_5 \cdot R_L \\
 &= (I_1 \cdot \mu + I_7 \cdot \mu + 2I_3 + 2I_5) R_L \quad (3)
 \end{aligned}$$

[0034] Loop BEKG:

$$\begin{aligned}
 V_1 &= I_1 \cdot R_H + 3I_6 \cdot R_L + 2I_5 \cdot R_L + 2I_3 R_L \\
 &= (I_1 \cdot \mu + 3I_6 + 2I_5 + 2I_3) R_L \quad (4)
 \end{aligned}$$

[0035] Now combining equations (2) and (3)

$$(I_1 \cdot \mu + I_4 + 2I_3) R_L = (I_1 \cdot \mu + I_7 \cdot \mu + 2I_3 + 2I_5) R_L$$

$$I_4 = I_7 \cdot \mu + 2I_5$$

$$I_7 = \frac{I_4 - 2I_5}{\mu}$$

[0036] From Equations A, B and C we have

$$\begin{aligned}
 \mu I_7 &= I_4 - 2I_5 \\
 &= (I_3 - I_5) - 2I_5 \\
 &= I_1 - I_2 - 3I_5
 \end{aligned}$$

[0037] Since I_2 will be relatively large and μ is many times greater than 1, then I_7 becomes relatively small. Thus the near sources are not interacting significantly. Obviously the same calculation can be done by now putting the voltage V_2 in and observing the effect on the current (flux) in section BG. Extrapolating further, one can see that the effect of sources further away is lower still given the extra reluctance in the magnetic path.

[0038] The important thing to appreciate is it can be seen the nearer sources are not interacting significantly. Obviously the further away the sources are the less interaction.

[0039] Referring now briefly to Fig. 4 it will be appreciated that there can be any number of inductors. While the calculation has only been done for inductors, it can be equally well done for transformers.

[0040] This analysis was greatly simplified by assuming all low (high) reluctance paths on the core are equal. This is not necessary for the invention but is merely a convenience for the purposes of this specification.

[0041] Referring to Fig. 5 there is illustrated an alternative construction in which there is provided a magnetic device indicated generally by the reference numeral 10 having three coils 12, 13 and 14 mounted within a housing 15 having a central coupling core portion 16 including a plurality of holes 17 drilled adjacent the coils 12, 13 and 14 respectively. This portion of the core will therefore have much greater reluctance than the rest of the core.

[0042] The high reluctance path inhibits mutual coupling between the magnetic components by preventing the flux produced by any one component linking the structures that need to be isolated from it. Essentially any number of magnetic components can be placed on a common ferrite block of arbitrary shape in such a way that they interact to a very small extent. Essentially therefore the components can be considered to act independently of each other and thus all design and other considerations are simply carried out.

[0043] The present invention is based on a relatively simple concept that flux from any mmf sources will flow through the path of least reluctance. The amount of flux flowing in a section of ferrite may be reduced by increasing the reluctance of that particular section. This property is used in the invention in order to suppress the amount of mutual coupling in the system. For example when the high reluctant paths are placed as indicated it can be seen from the theoretical analysis given above that the flux linking any of the magnetic components is to all intents and purposes, its own self-linkage. Thus, the components are not in any way affected by the flux induced by the other components.

[0044] It will be appreciated that any method of increasing the reluctance of the relevant core sections may be used including airgaps, insulator layers, half gaps, step gaps, drilling holes in the ferrite or any other method of increasing the reluctance of that portion of the circuit.

[0045] The construction need not have a high reluctance path for each of the magnetic components but can support a situation in which several components may couple due to a low reluctance centre path while those which must remain independent have the high reluctance path described in Figure 4.

[0046] The low reluctance paths at the outside of the device allow for flux containment or noise reduction and this is beneficial in reducing EMI. This construction is, therefore, superior to one in which the coils are wound on the outer core legs of, say, a planar E core. In that case the coupling would also be low but the stray fields produced may cause interference problems in the application. In fact, the EMI performance is not degraded with respect to separate inductor formations since the outer core legs are closed in this construction.

[0047] However, the invention is not confined to cases where the outer core legs have a low reluctance since in some situations, the EMI generated may not be critical to design performance.

[0048] The construction can be employed for wire wound magnetics, planar magnetics or any other technology that may be utilised to form the coils and ferrite.

[0049] The construction is not limited to a 2D expansion as implied in Figure 2 but can be expanded upwards in a skyscraper effect if required. In fact, as long as the high reluctance paths are placed correctly there is no limit to the stacking or spreading potential of the structure.

[0050] This is a very space and material efficient design suitable for miniaturisation of cost-effective planar magnetic components. In fact, the more components on the ferrite, the larger the saving over using separate components. Planar components can therefore be made, potentially, to be comparable to, or better than, conventional wire wound magnetics in terms of board area used. The design also saves ferrite volume, which is important in a cost critical design.

[0051] The construction is thus independent of the shape or construction of the core or indeed the material used. It is the choice of different reluctance paths which is essential.

[0052] In the specification the terms "comprise, comprises, comprised and comprising" or any variation thereof and the terms "include, includes, included and including" or any variation thereof are considered to be totally interchangeable and they should all be afforded the widest possible interpretation and vice versa.

[0053] The invention is not limited to the embodiment hereinbefore described, but may be varied in both construction and detail within the scope of the claims.

Claims

1. A magnetic device comprising a plurality of separate non-interacting magnetic components housed in the one core housing each magnetic component having a central core (5) and a winding (2,3) thereon characterised in that each core (5) includes an air gap (6) to increase the reluctance thereof.

2. A magnetic device as claimed in claim 1 in which the core (5) is cantilevered at one end to the housing and the winding projects beyond the free end of the core.

3. A magnetic device (10) as claimed in claim 1 in which each core forms part of a continuous core (16).

4. A magnetic device as claimed in any preceding claim in which the core incorporates non-magnetic material forming the air gaps.

5. A magnetic device as claimed in any preceding claim in which the core (16) includes voids (17) therein to form air gaps.

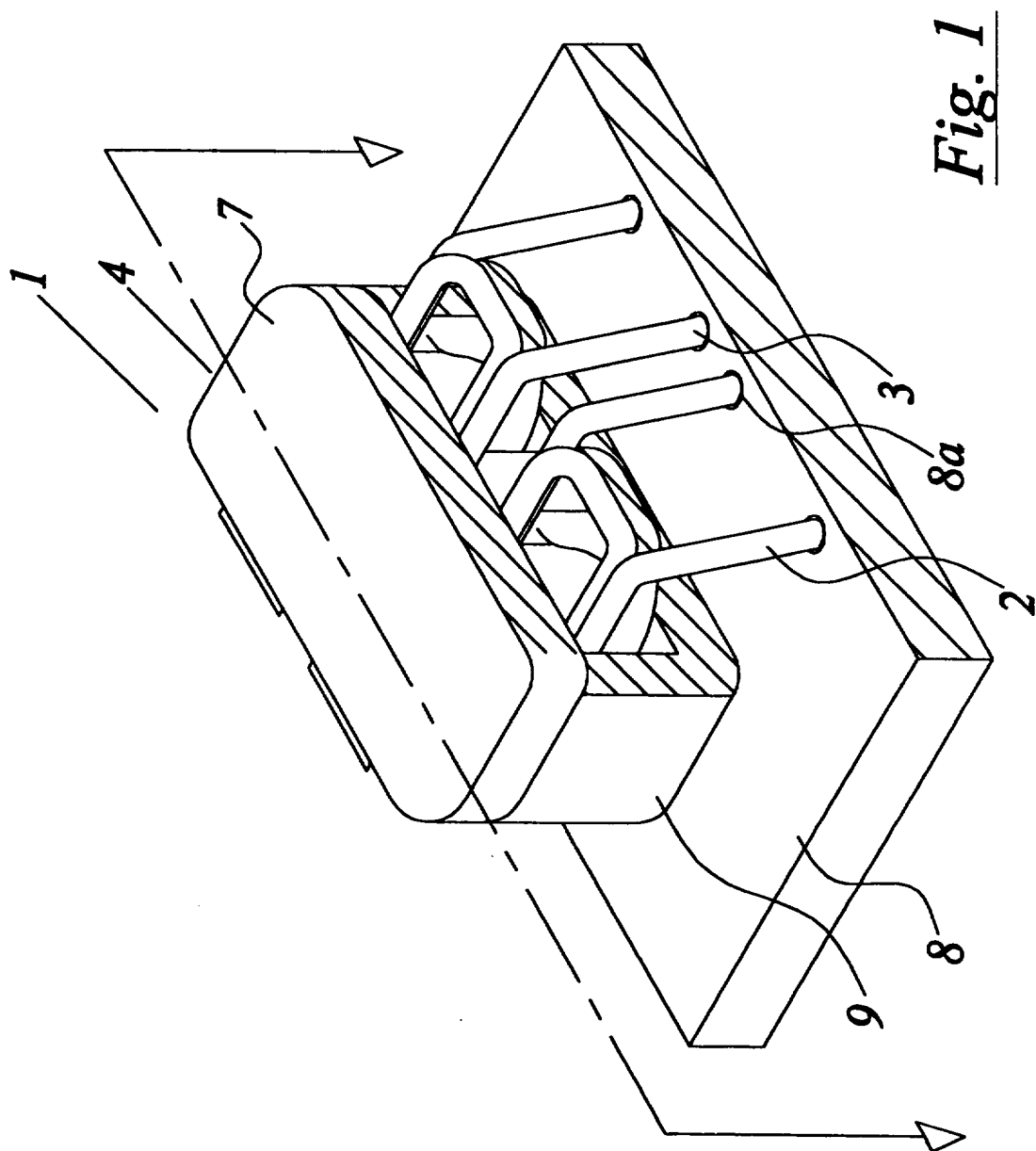
6. A magnetic device as claimed in any preceding claim in which the housing (4) at least where it contacts the cores is of a ferromagnetic material.

7. A magnetic device as claimed in any preceding claim comprising:

an enclosed housing of ferromagnetic material having bottom (7), top (8) and side walls (9) at least a pair of side by side upstanding spaced apart cores (5) on the top wall (7), the free end of the core (5) being spaced apart from the bottom wall (8);

a separate winding (2, 3) for each core (5) extending from adjacent the bottom (8) and top (7) walls; and

at least one aperture (8a) in the housing (4) the windings (2,3).



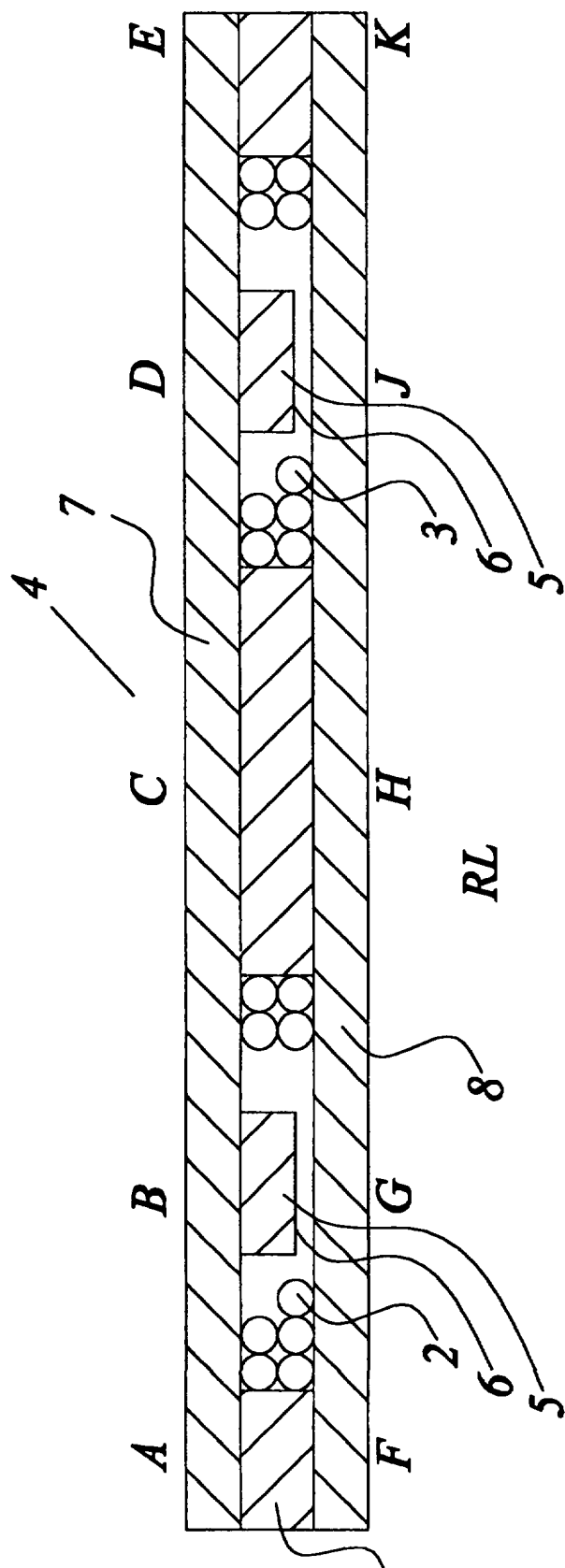


Fig. 2

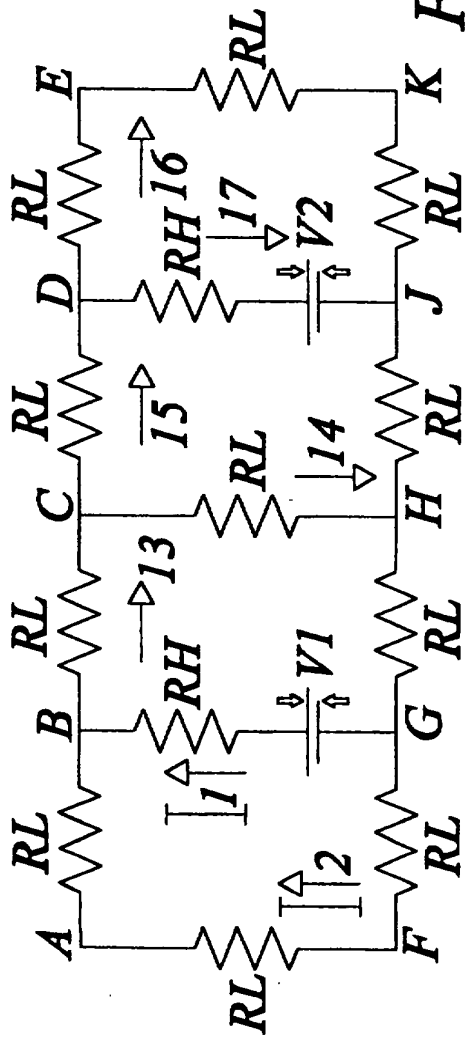


Fig. 3

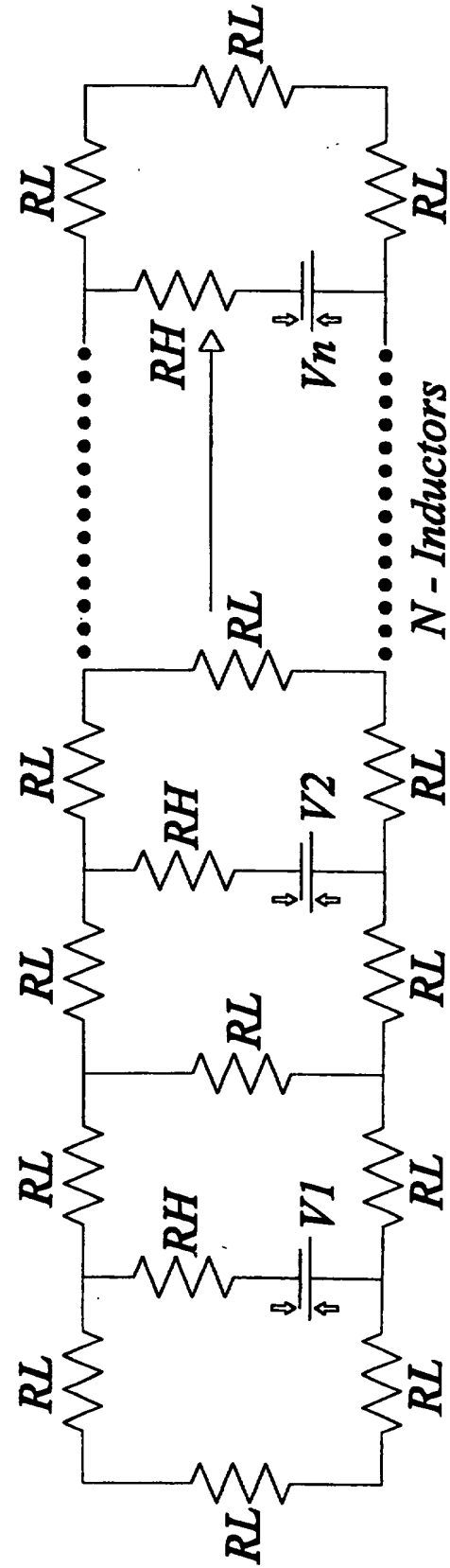


Fig. 4

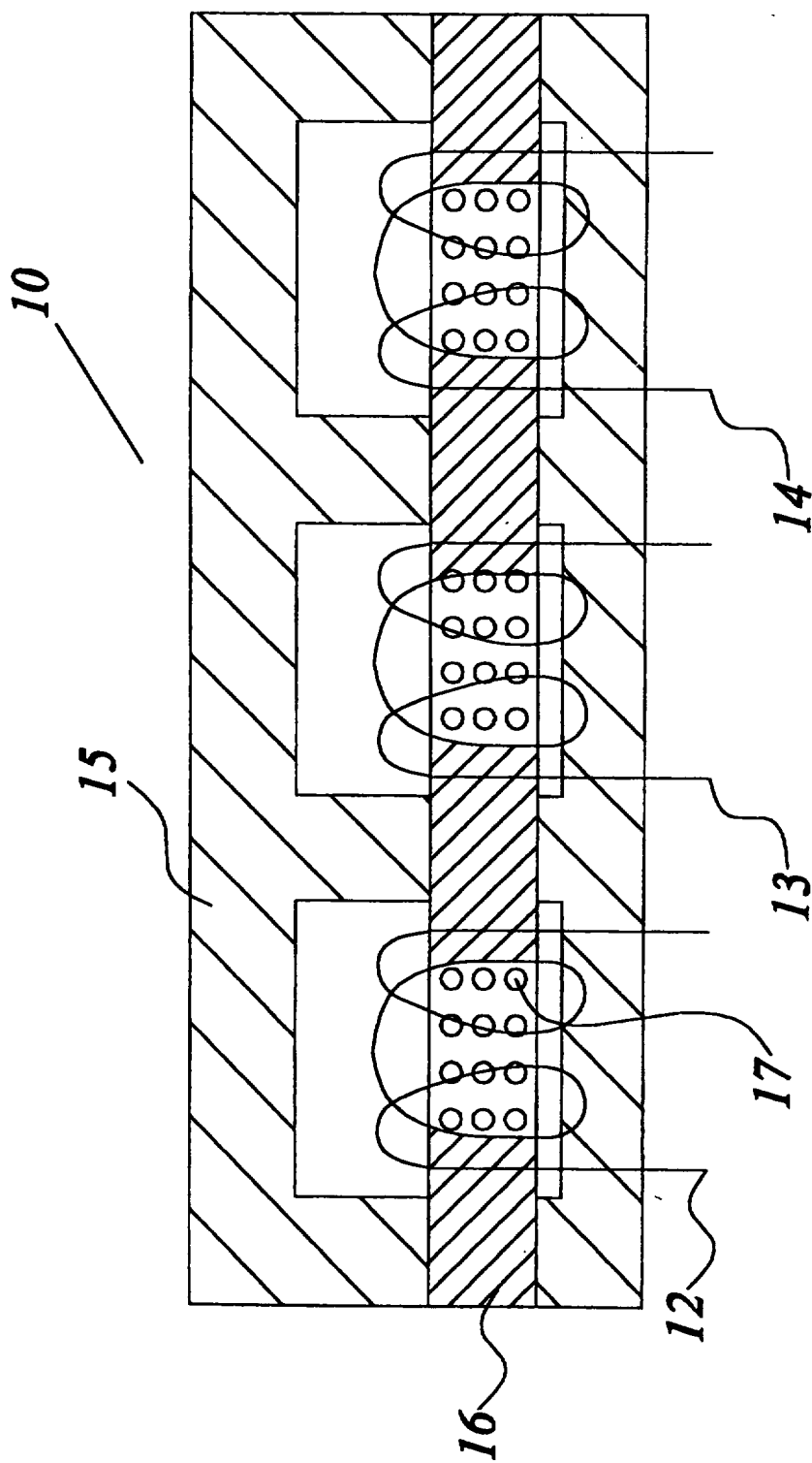


Fig. 5