Magnetic component

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Publication date:
2001

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 August 2001 (23.08.2001)

PCT

(10) International Publication Number
WO 01/61715 A1

(51) International Patent Classification[7]**:** **H01F 27/34**

(21) International Application Number: PCT/EP01/01501

(22) International Filing Date: 9 February 2001 (09.02.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
09/506,544 17 February 2000 (17.02.2000) US

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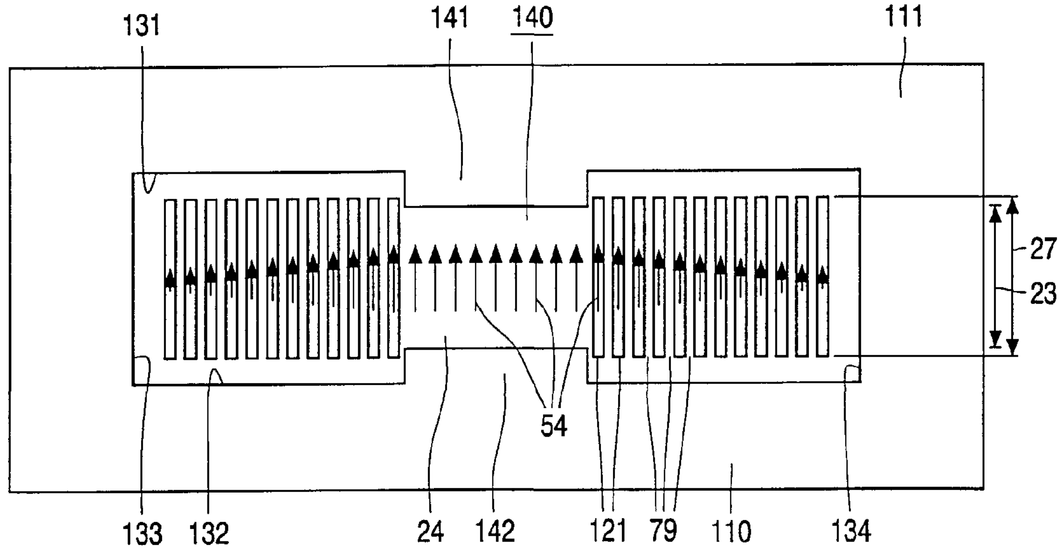
(81) Designated States *(national)***:** CN, JP.

(84) Designated States *(regional)***:** European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: MAGNETIC COMPONENT



(57) Abstract: A magnetic component has a core (100) with a cavity (105) and a winding structure (21) accommodated in the cavity (105). The winding structure (21) has a height (27) in a direction transverse to its bottom (126) and top faces (125), and is provided with a number of turns (121) which extend from the bottom (126) to the top face (125). The core (100) has a magnetic gap area (24), which has an extension that is at least 50 % of the height (27) of the winding structure. Therewith, eddy currents are substantially limited.

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Magnetic component

The invention relates to a magnetic component provided with a core and a winding structure, which core has a first and an opposite, second side face and is provided with a first cavity, which cavity extends from the first to the second side face of the core and which cavity accommodates the winding structure at least partly, a – winding window named - cross-section of which core taken substantially perpendicularly to the cavity has a first and second pair of sides, the first pair of sides separated in a height direction by a height, the second pair of sides separated in a width direction by a width,

which winding structure comprises a primary winding having a plurality of foil wound, mutually insulated turns and has a bottom and a substantially parallel top face, said faces being separated in the height direction, the turns of which winding structure substantially extend from the bottom to the top face and being wound around a central part.

The invention further relates to a consumer electronics device.

Such a magnetic component is known from WO-A 99/22565. The known component has as its central part a central portion of the core, in which a magnetic gap is provided. The magnetic gap is orientated substantially parallel to the bottom and top face of the winding structure and substantially transverse to the individual turns. As a result, the primary winding in the known component is a compact structure having a high density and mechanical rigidity. The magnetic component can be an inductor or a transformer.

In a magnetic component with a magnetic gap, an eddy current may come into existence, when the component is operated with an alternating current at a high frequency. Said eddy current give rise to substantial energy losses, and hence to a temperature rise. In the known magnetic component, the eddy current is limited, as the surfacial area of a turn parallel to the orientation of the magnetic gap is small. As said above, the magnetic gap is orientated substantially transverse to the individual turns.

It is however a disadvantage of the known magnetic component that the eddy current increases relatively much above a frequency of about 100 kHz, as can be seen in Figure 3 of the above mentioned patent application.

It is therefore an object of the present invention to provide a magnetic component of the kind described in the opening paragraph, in which the eddy current at frequencies above 100 kHz are limited compared to the known magnetic component.

This object is achieved in that the central part comprises a magnetic gap area, which extends in the height direction and has an extension of at least 50% of the height. A magnetic gap in general permits the magnetic field to be confined and concentrated in its small volume, which is very advantageous for storage of energy. The use of magnetic components is based on their capability to store energy, and, in particular in the case of transformers, to transfer energy. In many applications it is beneficial to transfer a part of the energy and to store the remainder. Energy is stored in a magnetic field generated by a current through the primary winding.

In the known magnetic component the confinement of the magnetic field in the magnetic gap coincides with a deformation of the magnetic field. This deformation consists in a change in the direction of the magnetic field; without a gap, the direction is parallel to the turns; with a gap, the direction is not parallel anymore in areas near to the winding turns. These neighboring areas lie between of the gap and the bottom and top face of the winding structure. As a consequence, eddy currents come into existence at high frequencies.

In the magnetic component of the present invention, the neighboring areas lie at a short distance to the top and the bottom face of the winding structure. As a consequence, the main deviation of the magnetic field from the direction parallel to the winding turns takes place above the top face, and under the bottom face of the winding structure. However, above the top face and under the bottom face, there are no turns present. Hence, eddy currents will be further limited.

The magnetic component of the present invention does fulfil further conditions, such as a sufficient energy storage. In fact, in comparison with the known magnetic component, in the component of the invention has the height of the winding structure is decreased, instead of that the gap area has been enlarged. Typical heights are in the order of 1 to 10 mm.

The magnetic gap area in the magnetic component of the invention can be free of magnetic material. This has the advantage of a simple construction. Preferably, in combination with this the extension of the magnetic gap area is 80 to 100 % of the height.

To fine-tune the properties of the magnetic component, the gap area can be filled with a low permeability potting material, such as any of the existing low permeability ferrite materials. Such a low permeability material enables the setting of the desired inductance during assembly, provides electrical isolation, increases creepage distances and provides a high thermal conductivity. The low permeability composite material is in effect a combination of a polymer material and a magnetic material, that is fine-grained by preference. The material may be produced in any shape or form through the use of plastic extrusion and molding techniques. Through variation of the amount of composite material in the magnetic gap area the inductance of the component can be set. So far, these magnetic composite materials have been used mainly for Electromagnetic-interference (EMI) shielding applications. See, for example, the materials described in U.S. patent No. 5,714,102 and the Tokin Flex-Suppressor and Epcom/Siemens-Matsushita products, e.g. C302, C303, currently available on the market. Preferred examples of such magnetic composite materials are nanocrystalline Fe polymer composite and amorphous Co-polymer composite.

In an advantageous embodiment, the magnetic gap area comprises a multilayered structure, which comprises alternatingly a first layer of magnetic material and a second layer of non-magnetic material, which layers are substantially parallel with the bottom face of the winding structure. In this embodiment the magnetic gap area is constituted by a distributed gap. In an example of the multilayered structure the first layer is a ferrite plate, which is embedded in a polymer or other non-magnetic electrically insulating material acting as the second layer. In another example of the structure is the first layer comprises a low permeability polymer magnetic composite material. Such a material can be made easily in a permeability range of 1 to 30, which fits the use in the magnetic gap very well. To achieve optimal results the first layer should have a thickness close to that of the magnetic particle diameter. The second layer can have a thickness equal to the particle diameter or larger. The multilayered structure can be inserted in the winding structure after pressing the stack of layers into a disk.

The magnetic component of the invention can be an inductor. In a favorable embodiment, however, the winding structure comprises a secondary winding, which is insulated from the primary winding, which primary and secondary winding are each provided with a multiple output. In this case the magnetic component is a transformer. The windings have a foil thickness in the range of 0.5 μm to 500 μm, and can be made of any conductive material, such as copper, silver or a conductive organic material, or an organic material filled with conductive particles. Due to the multiple output the primary and secondary winding can each be incorporated in a circuit. The outputs are preferably led out of the magnetic component at a side where there is no obstruction by outer core legs.

Preferably, the primary and secondary winding are mutually insulated through a first isolation having a first creep distance. The insulation can be made of insulating materials, which are known to the person skilled in the art. Preferably, a polymeric insulating material is used, such as polyethyleneterephtalate (PET). Preferred thicknesses are 1 μm to 100 μm; the preferred height is 0.1 mm to 30 mm; this is further dependent on the safety regulations proposed by the laws in different countries.

The windings comprise turns that are mutually insulated. However, it is further advantageous to provide a second insulation between the primary winding present at the outside of the winding structure and the core. It is further dependent on the application whether this primary winding is part of the primary circuit or the secondary circuit. The magnetic component of the invention can be incorporated in a in a fly-back topology, but also and preferably in a resonant circuit.

The invention further relates to a consumer electronics device, which comprises the magnetic component of the invention. Due to its miniaturized shape and its good behavior at high frequencies the magnetic component is very suitable for use in consumer electronics devices, such as mobile phones, portable computers, electronic lamp ballasts, etcetera.

These and other aspects of the magnetic component of the invention will be further explained with reference to the figures, wherein like elements are designated by identical reference numerals, in which figures:

Fig. 1 shows a perspective view of the magnetic component;

Fig. 2 shows a perspective view of the magnetic component, of which the top part of the core has been left away for clarity;

Fig. 3 shows a diagrammatical cross-section of the magnetic component, taken along the lines V-V as indicated in Fig. 1 and 2;

Fig. 4 is a pictorial illustration of a core and a winding arrangement of magnetic of the prior art;

Fig. 5 is a pictorial illustration of a core and winding arrangement of the present invention;

Fig. 6 is a graphical illustration of a winding dissipation function of magnetic components with various gap configurations plotted on dissipation losses versus operating frequency graph;

Fig. 7 is a graphical illustration of a magnetic component in association with a graph of a magnetic field distribution; and

Fig. 8 is a diagrammatical cross-section of the magnetic component on a cooling body.

Fig. 1 shows a perspective view of the magnetic component of the invention 22. The magnetic component has a core 100 with a first side face 101 and an opposite, second side face 102. The core 100 has a bottom portion 110 and a top portion 111, in between of which there is a first cavity 105, extending from the first side face 101 to the second side face 102. The first cavity 102 accommodates a winding structure 21.

Fig. 2 shows the magnetic component 22 of Fig. 1a. However, the top portion 111 of the core 100 has been left out. Besides the bottom portion 110 the core 100 comprises upstanding portions 112, 113. The winding structure 21 is oval-shaped and comprises turns 121 of a primary winding 78, which turns 121 are mutually insulated by an isolation 79. The winding structure 21 has a height 27, between its top face 125 and its bottom face 126. The turns are being wound around a central part 140

Fig. 3 shows a diagrammatical cross-section along the lines V-V as indicated in Fig. 1 and 2. This cross-section is the winding window 130. It has a first and second pair of sides. The sides 131, 132 of the first pair are separated in a height direction H. The sides 133, 134 of the second pair are separated in a width direction. In the central part 140 there are provided two portions 141, 142 of the core 100. In between of the central portions 141, 142 there is the magnetic gap area 24. This magnetic gap area 24 has an extension 23, which is at least 50 % of the height 27, in this case approximately 85%.

Fig. 4 shows a magnetic component 200 according to the prior art. There are two different areas of losses 38,40 in the foils close to the magnetic gap area 224, which has an extension 223 of less than 50% of the height 27. In the areas 38 on the top and on the bottom a gap related distortion of the magnetic field, indicated in magnitude and direction by the arrows occurs. Therefore the magnetic field is in these areas 38, 40 not parallel to the gap 224, creating considerable eddy currents and dissipation losses due to local field enhancement. The distortion of the magnetic field can lead to considerable eddy currents, as there is a build-up of the magnetic field towards the central part 240, as is indicated by the size of the arrows 12. Due to field fringing the magnetic field is not parallel to the foil turns in the areas 38 and 40 near the gap 224, where the field is the highest. This leads to additional losses as indicated in area 40.

Fig. 5 shows a diagrammatical cross-section of the magnetic component 22 of the invention, e.g. the winding window 130. In this component 22, the gap area 24 has an extension 23 which is 100% of the height 27 of the winding structure 21. Also in this component 22 there is a build-up of the magnetic field towards the central part 140. However, the field lines in areas 38,40 near to the central part 140 are parallel to the field within this part 140. In this embodiment the gap 24 is filled with a multilayer structure 60 of first layers 61 of magnetic material and second layers 62 of electrically insulating material.

Fig. 6 shows a graph of a winding dissipation where dissipation losses D are plotted against operation frequency f. Curve 10 represents dissipation losses D as operation-frequency f is increased by the magnetic component 200 of the prior art as shown in Fig. 4. Curve 12 represents dissipation losses as frequency is increased, by the magnetic component 22 of the invention as shown in Fig. 5. The winding losses are calculated for an element of the core 100, which element is a layer oriented parallelly to the winding window 130 with a thickness of 0.5 mm. The calculation is done with the method of finite elements. The result is shown in Watts as a function of the frequency of the alternating current.

Fig. 7 is a graphical illustration of a magnetic component 32 in association with a graph of the magnetic field distribution. The magnetic component shown relates to a transformer 32. Arrows in Fig. 7 indicate the direction of the magnetic field (H).

Fig. 7a shows a cross-section of the magnetic component 32 along the winding window. The magnetic component 32 comprises a core 100 without a core leg, so that the gap area 23 has an extension which is equal to the height of the winding structure. The winding structure comprises a primary winding 78 and a secondary winding 80. Both windings are built up of - not shown - mutually insulated turns extending from the bottom to the top face of the winding structure. These reference numbers, although not indicated in Fig. 7b, 7c and 7d for reasons of clarity, will be used in the figure description of the Figures 7b, 7c and 7d.

Fig. 7b shows a graph 70 of the direction of the magnetic field in the magnetic component 32 for a fully loaded and effectively shorted secondary winding 80 in a secondary circuit The magnetic field builds up in the primary winding 78 from a point p5, reaching its maximum at point p6. The maximum build up of the magnetic field is maintained between the primary 78 and secondary winding 80 between point p6 and point p7. The magnetic field decreases between the points p7 and p8 in the secondary winding 80. This behavior of the magnetic field in the transformer is called the leakage flux. Under these conditions, the leakage flux is parallel to the foils of the magnetic component 32.

For a practical transformer 32, there will always be a small fraction of the total leakage flux that is not coupled to the secondary winding 80. This leakage flux may circle in the core 100 in a manner shown in Figure 7c and indicated by arrows. Under no load conditions, i.e. the secondary winding is open, the magnetic component or the transformer 32 behaves essentially as if it were an inductor. The primary winding 78 generates a magnetic field and the energy is stored in the magnetic gap area 24. The area 24 is located between points p4 and p5, in the center part 140 of the core 100. This gap area 24 has an extension 23 which is essentially equal to the height 27 of the winding structure 21. As shown in Fig. 6, the magnetic field is parallel to the foils of the turns 121 under these conditions.

In the intermediate case, shown in Fig. 7d, part of the magnetic field 46 builds up in the primary winding 78. This build-up is transferred to the secondary winding 80 partly, and part of it is stored. As with the previous example, the magnetic field will remain parallel to the turns 121 under all conditions.

The transformer 32 performs preferably in a 300 to 500 kHz resonant power supply in comparison to a conventional wire wound transformer in terms of size and eddy current losses. The primary winding 78 has forty-three turns 121; the secondary winding 80 has a comparable number of turns 121. Both windings are provided with multiple outputs, and are wound with a total thickness per winding 78, 80 of 20 μm. The thickness of the individual turns 121 is 0.4 μm, including the insulation. The height of the winding structure 21 is 5mm. The isolation between the turns 121 consists of polyethylene terephtalate, having a thickness of 8 μm and a height of 6 mm. In order to meet safety requirements regarding mains, isolation between primary and secondary windings 78,80 and the core 100, and between the windings 78, 80, the primary and secondary windings 78,80 are encapsulated by polyimide, thus providing a creep distance of 2.3 mm. This distance can be adapted to provide an amount of leakage desired and typically seals the surface area in between of the primary and secondary winding 78, 80. The transformer has a leakage inductance of 26 μH and a primary inductance of 61 μH.

Fig. 8 is a diagrammatical cross-section of the magnetic component 22 that is present on a cooling body 300. During operation the magnetic component 22, especially if embodied as transformer, gives rise to dissipation of energy, which has to be removed from the magnetic component 22.

As there is a temperature gradient between the magnetic component 22 and the cooling body 300, dissipated energy in the form of heat will flow to the cooling body 300. As the turns 121 are oriented transversely to the cooling body, the conduction of heat is good. The top portion 111 of the core 100 is in contact with air. Between this top portion 111 and the air there is a temperature gradient as well, which is however less steep; not only is the difference in temperature smaller, but the heated air not removed in an active way either. To improve the heat dissipation the central portion 140 of the core 100, which is by preference free of any core leg, can be filled with an electrically insulating material having a relatively high heat conduction coefficient. Example of these are not-ionic, not metallic crystalline material. This allows heat in the top portion 111 of the core 100 to be dissipated to the cooling body via the central portion 140.

CLAIMS:

1. A magnetic component(22, 32) provided with a core (100) and a winding structure (21), which core (100)has a first (100) and an opposite, second side face (102) and is provided with a first cavity (105), which cavity (105) extends from the first (101) to the second side face (102) of the core (100) and which cavity (105) accommodates the winding structure (21) at least partly, a – winding window (130) named - cross-section of which core (100) taken substantially perpendicularly to the cavity (105) has a first (131, 132) and second pair (133, 134) of sides, the first pair of sides (131, 132) separated in a height direction by a height (27) second pair of sides (133, 134) separated in a width direction by a width, which winding structure (21) comprises a primary winding (78) having a plurality of foil wound, mutually insulated turns (121), which winding structure (21) further has a bottom (126) and a substantially parallel top face (125), said faces (125, 126) being separated in the height direction, the turns (121) of which winding structure (21) substantially extend from the bottom (126)to the top face (125) and being wound around a central part (140), characterized in that the central part (140) comprises a magnetic gap area (24), which extends in the height direction and has an extension of at least 50% of the height (27).

2. A magnetic component (22, 23) as claimed in Claim 1, characterized in that the magnetic gap area (24) has an extension (23) of 80 to 100% of the height (27).

3. A magnetic component (22, 32) as claimed in Claim 2, characterized in that the magnetic gap area (24) has an extension (23) of substantially 100% of the height (27), such that the magnetic component (22, 32) is present without a core leg.

4. A magnetic component as claimed in Claim 1, 2 or 3, characterized in that the magnetic gap area (24) is free of magnetic material.

5. A magnetic component as claimed in Claim 1, 2 or 3,

characterized in that the magnetic gap area (24) comprises a multilayered structure (60), which comprises alternatingly a first layer (61) of magnetic material and a second layer (62) of non-magnetic material, which layers (61, 62) are substantially parallel with the bottom (126) face of the winding structure (21).

6. A magnetic component (32) as claimed in any of the claims 1-5, characterized in that the winding structure(21) comprises a secondary winding (80), having a plurality of foil wound, mutually insulated turns (121), which secondary winding (80) is insulated from the primary winding (78), which primary and secondary winding (80) are each provided with a multiple output.

7. A magnetic component (32) as claimed in claim 6, characterized in that the primary (78) and the secondary winding (80) are mutually insulated through a first isolation having a first creep distance.

8. A magnetic component (32) as claimed in claim 6 or 7, characterized in that a second isolation is present between the primary winding (78) and the core (100).

9. A consumer electronics device comprising the magnetic component (22, 32) according any of the preceding Claims.

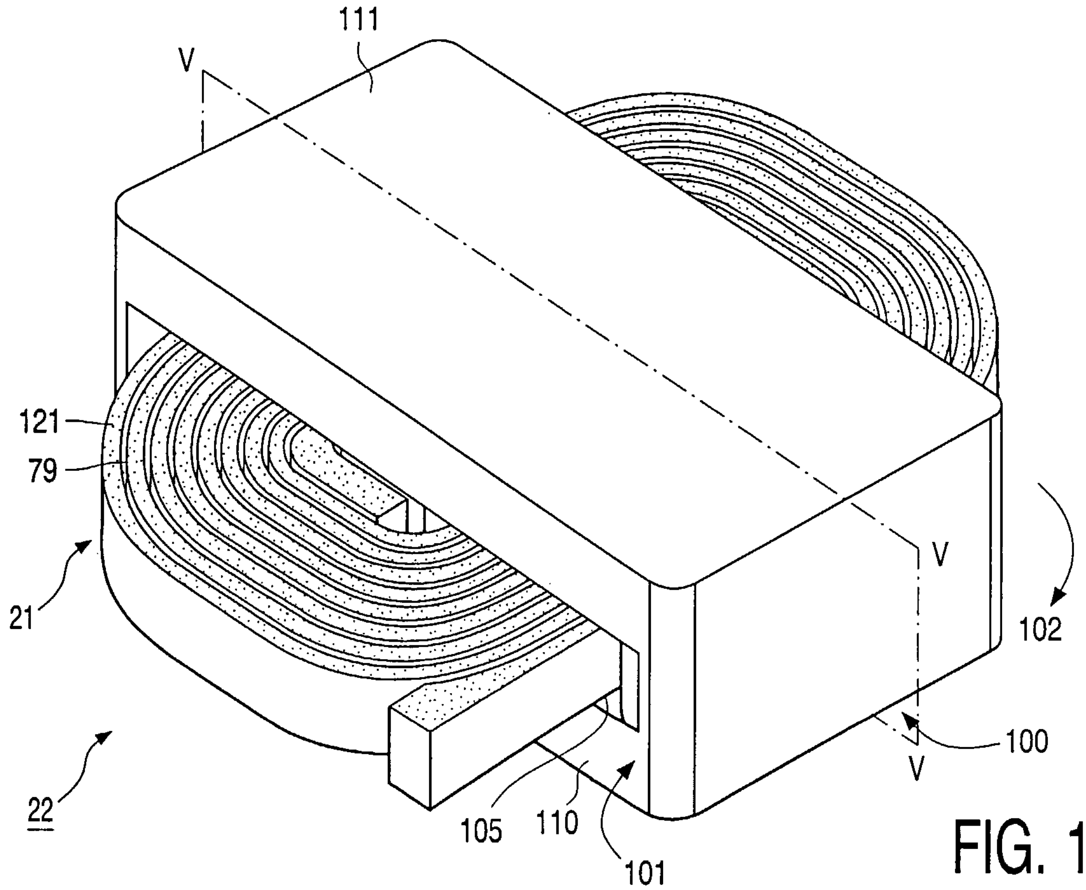
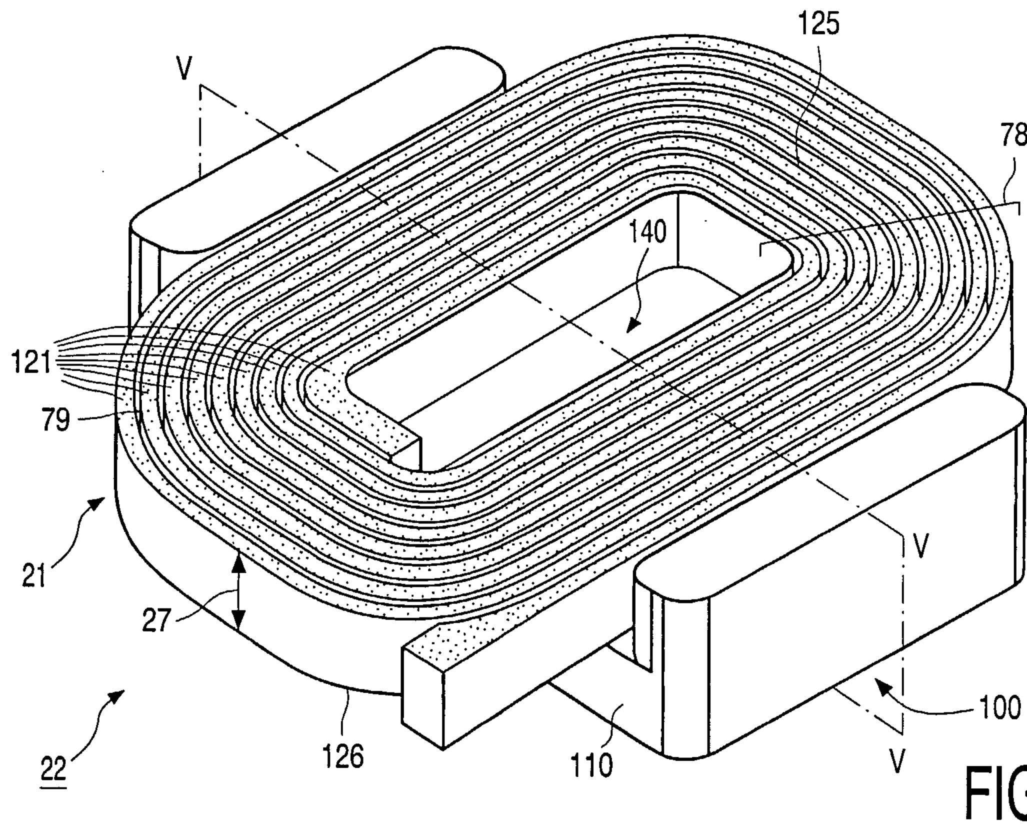

111
V
V
121
79
21
22
102
100
V
105
110
101

FIG. 1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78
V
140
121
79
21
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100
V
V

FIG. 2

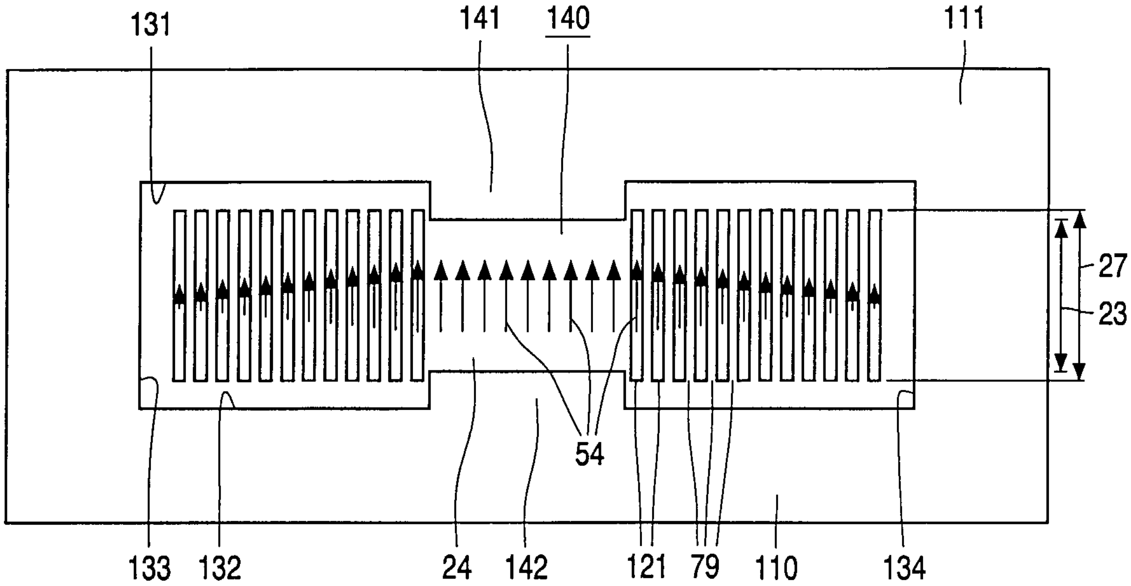
131
141
140
111
27
23
54
133
132
24
142
121
79
110
134

FIG. 3

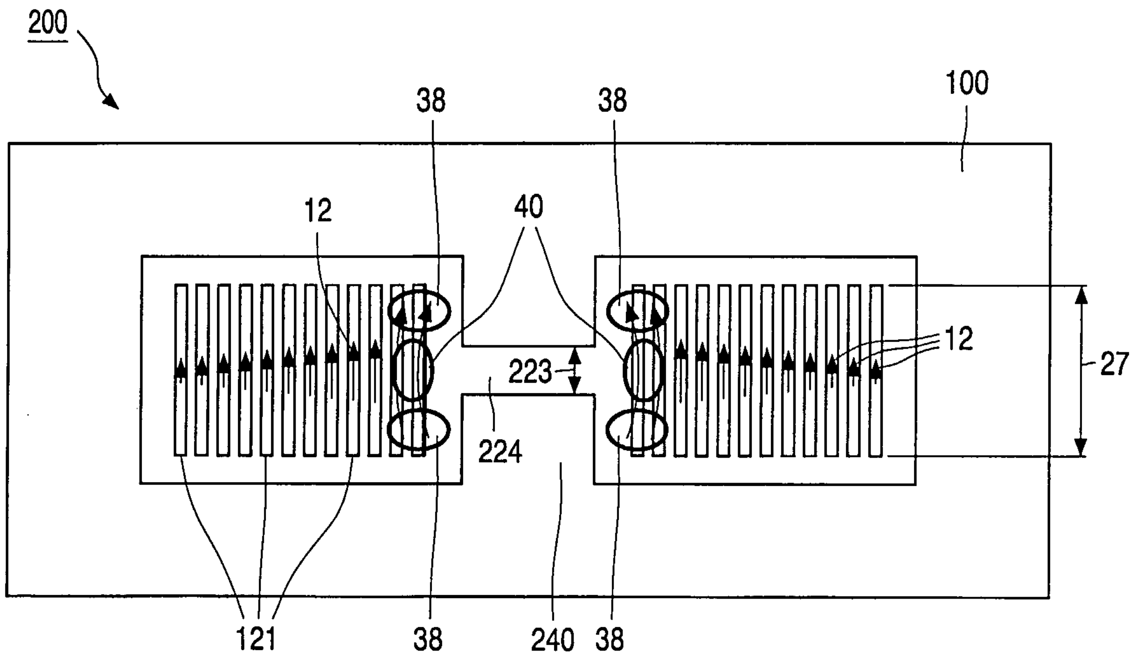
200
100
38
38
12
40
12
223
27
224
121
38
240
38

FIG. 4

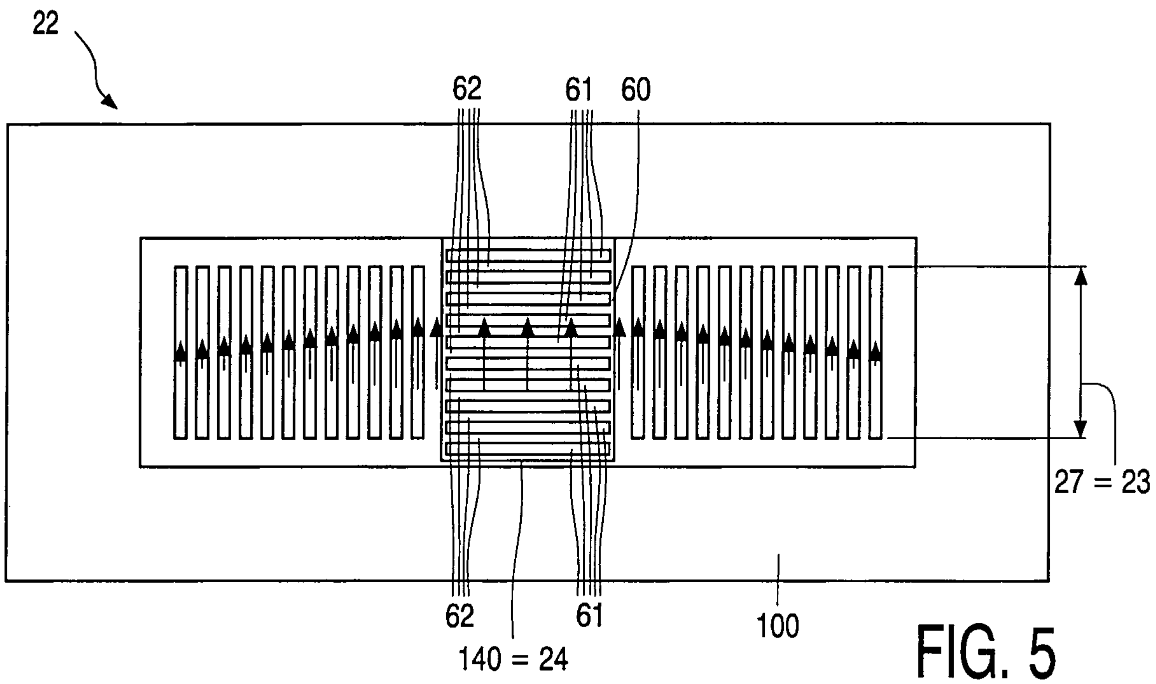
22
62
61
60
27 = 23
62
61
140 = 24
100

FIG. 5

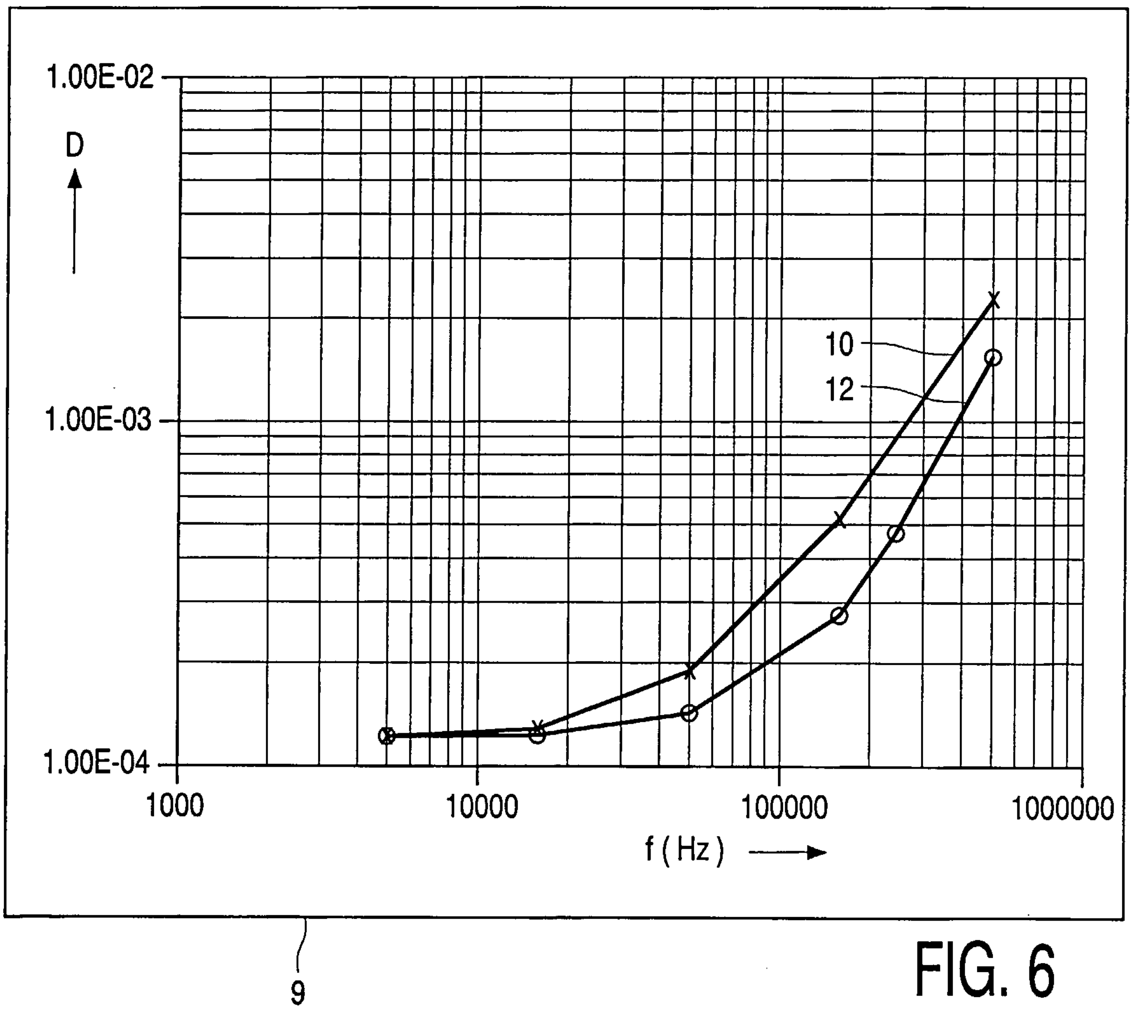
1.00E-02
D
1.00E-03
1.00E-04
10
12
1000
10000
100000
1000000
f (Hz)
9

FIG. 6

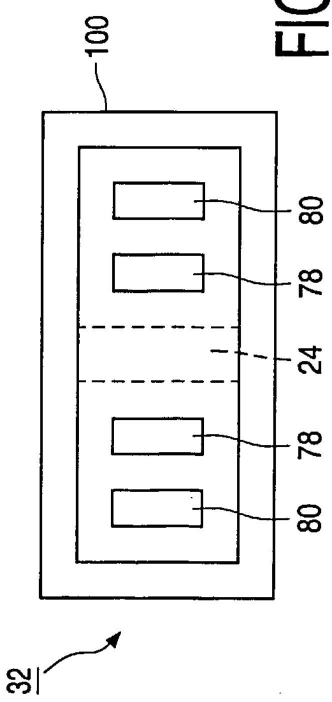

FIG. 7a

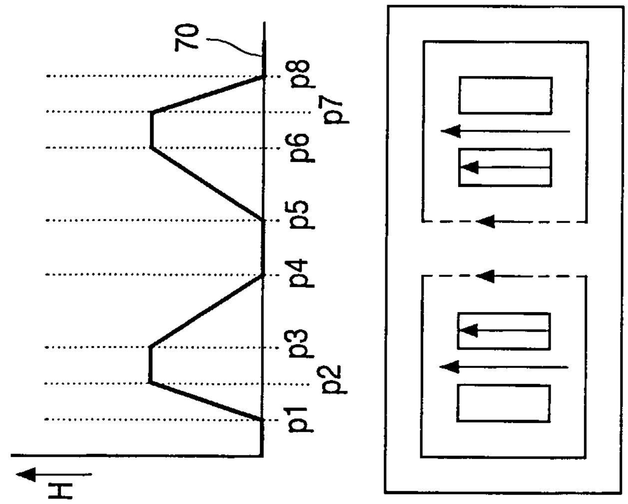

FIG. 7b

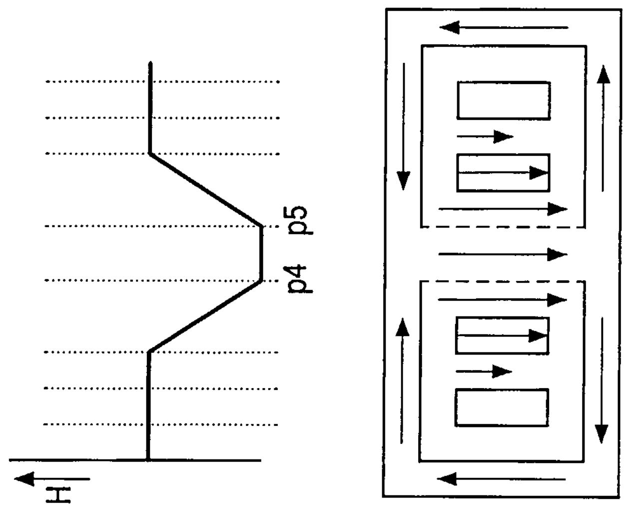

FIG. 7c

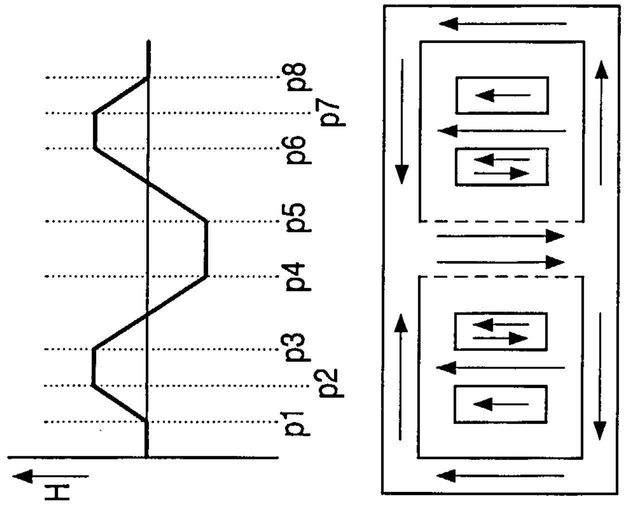

FIG. 7d

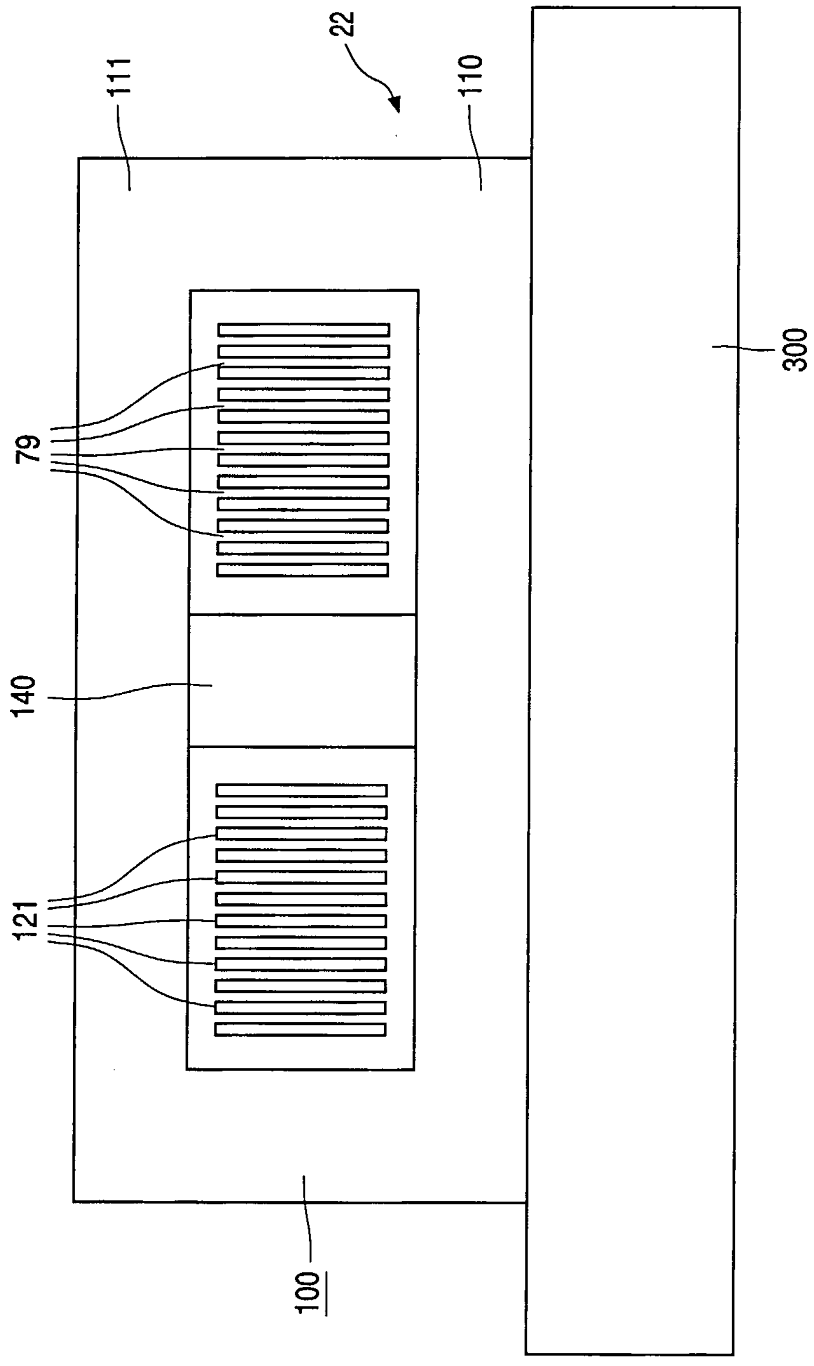

FIG. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 01/01501

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01F27/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 014 189 A (CANADIAN GENERAL ELECTRIC COMPANY) 19 December 1961 (1961-12-19) figure 4	1-4
X	KIRCHENBERGER U ET AL: "A CONTRIBUTION TO THE DESIGN OPTIMIZATION OF RESONANT INDUCTORS FOR HIGH POWER RESONANT DC-DC CONVERTERS*" PROCEEDINGS OF THE INDUSTRY APPLICATIONS SOCIETY ANNUAL MEETING,US,NEW YORK, IEEE, vol. -, 4 October 1992 (1992-10-04), pages 994-1001, XP000368903 ISBN: 0-7803-0635-X page 994 -page 1001	1-5
X	EP 0 117 515 A (HITACHI LTD) 5 September 1984 (1984-09-05) figures 1-7	1-9

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 May 2001	15/05/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Vanhulle, R

Form PCT/ISA/210 (second sheet) (July 1992)

International Application No
PCT/EP 01/01501

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 3 362 000 A (SEALEY WILLIAM C ET AL) 2 January 1968 (1968-01-02)	
A	PATENT ABSTRACTS OF JAPAN vol. 007, no. 229 (E-203), 12 October 1983 (1983-10-12) & JP 58 119617 A (TOKYO SHIBAURA DENKI KK), 16 July 1983 (1983-07-16) abstract	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 01/01501

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
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			DE 3463704	D	19-06-1987
US 3362000	A	02-01-1968	NONE		
JP 58119617	A	16-07-1983	NONE		