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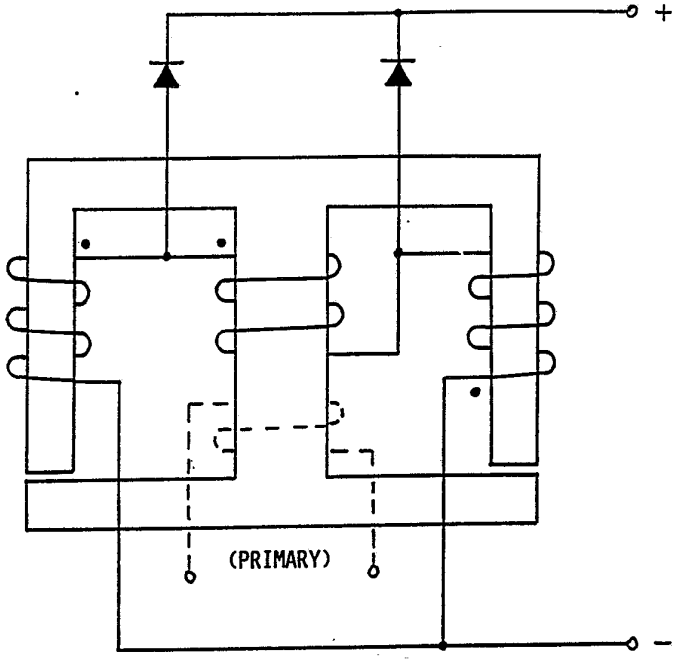
(54) Title: A POWER SUPPLY CIRCUIT WITH INTEGRATED MAGNETIC COMPONENTS



(57) Abstract

A magnetic circuit with several magnetic components integrated on one or more common magnet cores is utilized in a current supply circuit known per se. The circuit comprises a transformer, the secondary winding ends of which are connected to uniform electrodes of a pair of rectifier diodes, the second electrodes of which are connected to one output terminal of the power supply circuit. Additionally, it includes two reactive components, and the first electrodes of the diodes are connected to the second output terminal of the power supply circuit via one of the reactive components. The number of turns of the said two reactive components is essentially chosen to equal the number of secondary turns on the transformer. The said two reactive components are positioned on each separate core part so that the resulting magnetic flux in common core parts substantially equals the difference between the magnetic flux of the two core parts, and the secondary winding of the transformer is positioned on the said common core parts.

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A power supply circuit with integrated magnetic components

The invention concerns a power supply circuit of the kind known from the applicant's US patent specification No. 4 899 271 and use of a magnetic circuit with a number of magnetic components integrated on one or more common magnet cores of such a circuit.

The known circuit i.a. comprises a transformer and two reactive components, e.g. choke coils. The three magnetic components are relatively expensive to produce and in addition a disproportionately large amount of core material is required when the three magnetic components are produced separately.

It has been a long-felt desire to be able to cut down on costs and reduce the amount of core material by integrating the three magnetic components on a common magnet core. However, until now this has been impossible as the voltage curve forms do not match for which reason the flux account does not tally. Further, a transformer's magnetizing current normally causes certain problems, as besides entailing increased loss it may also interact with the load current at low loads and thereby create unfortunate imbalance situations in the power supply circuit.

However, a certain economy has been achieved, as stated in the above patent specification, by integrating the two choke coils on the same core. e.g. by placing each of the choke coils on the outer legs of an E-core. Each of these outer legs must, however, then be provided with an air gap to avoid saturation of the core material, whereas the central leg must be without air gap to avoid coupling between the two choke coil circuits.

Other examples are known where several magnetic components are integrated on a common core, as is the case e.g. with a 3-phase transformer; however, in these cases the curve forms of the flux of the components are uniform but phase displaced so that the flux account tallies.

It is the object of the invention to provide a construction allowing the three magnetic components in the power supply circuit known from US patent specification No. 4 899 271 to be positioned on one or more common magnet cores in order to cut down on production costs and reduce the amount of core material used.

According to the invention this object is achieved by integrating the three magnetic components on one or more common magnet cores, selecting the number of turns of the two choke coils so as to essentially match the number of secondary turns on the transformer, and positioning the two choke coils on each separate core part in such a way that the resulting magnetic flux in a common core part on which the transformer windings are positioned essentially equals the difference between the magnetic flux of the two core parts.

It has been found that the magnetizing current of the transformer hereby can be generated by the integrated choke coils which furthermore determine the magnetic cross-sectional area of the common magnet core, whereas the transformer does not require additional magnetic material.

As stated in claim 3 use may advantageously be made of a so-called E-core where the choke coils are positioned on the outer legs and the transformer on the central leg.

As stated in claim 4 an E-core can be composed of a combination of ferrite and amorphous material which makes feasible greater DC-flux in the outer legs and greater AC-flux in the central leg.

As stated in claim 5, use may also be made of two toroid cores where the two choke coils are wound on each separate toroid core, whereas the transformer is wound through both cores.

In the following the invention will be described in more detail, reference being made to the drawing, in which

fig. 1 shows a variant of the power supply circuit disclosed in US patent specification No. 4 899 271 and the appertaining magnetic circuits of the transformer and the two choke coils,

fig. 2 shows the magnetic circuits of the transformer and the two choke coils, respectively, the latter being integrated on a common core,

fig. 3 shows the integrated magnetic circuit according to the invention, and

fig. 4 shows an embodiment in which the core is composed of a combination of ferrite and amorphous, tape wound magnetic material.

The power supply circuit disclosed in US 4 899 271 is shown in fig. 1. Initially, its mode of operation will be explained.

The circuit comprises a transformer T, two choke coils L1, L2, two rectifier diodes D1, D2 and a positive and a negative output terminal.

When the secondary voltage V_T from the transformer T is positive, this voltage will force the rectifier D1 to be conductive. Consequently, a current will flow from the negative output terminal through L2, the secondary winding of the transformer, the rectifier D1 onto the positive output terminal.

When the secondary voltage V_T vanishes (V_T = 0) in the dead periods, the current in L2 will continue to flow (free-wheel), this time from the negative output terminal through D2 and onto the positive output terminal.

If the secondary voltage V_T becomes negative, this voltage forces a current to flow from the negative output terminal through L1, the secondary winding and the rectifier D2, which is already conductive due to the free-wheeling current from L2. Thus, now both a free-wheeling current from L2 and a current through the secondary winding and L1 will flow onto the positive output terminal.

When the secondary voltage V_T vanishes again (V_T = 0) both the current from L1 and L2 will continue to free-wheel through D1 and D2, respectively, both of which will consequently be conductive.

In other words, the circuit maintains a continuous (not pulsating) current flowing from the negative to the positive output terminal, irrespective of the instantaneous value of the transformer secondary voltage.

At the bottom of the figure are shown the magnetic circuits of each of the three magnetic components T, L1, L2.

As the two choke coils are serially connected directly

across the terminals of the secondary winding it follows that the sum of the instantaneous voltages across these choke coils must equal the instantaneous value of the secondary voltage, i.e.

$$V_T(t) = V_1(t) - V_2(t) \qquad (1)$$

with polarities as shown in fig. 1.

Below the magnetic flux in the various parts of the transformer and the choke coils is considered. From Faraday's Law it is known that:

$$V = N \frac{d\phi}{dt},$$

where ϕ designates the flux, N the number of turns and V the voltage. For the transformer with the secondary number of turns N_T it thus follows that:

$$V_T = N_T \frac{d\phi_T}{dt}$$

Correspondingly, for the choke coil L1 with the number of turns N_1 it follows that:

$$V_1 = N_1 \frac{d\phi_1}{dt}$$

and finally for L2 with number of turns N_2 that:

$$V_2 = N_2 \frac{d\phi_2}{dt}$$

Thus equation (1) can now be written:

$$N_T \frac{d\phi_T}{dt} = N_1 \frac{d\phi_1}{dt} - N_2 \frac{d\phi_2}{dt}$$

If L1 and L2 are adapted to have the same number of turns ($N_1 = N_2 = N$), then:

$$N_T \frac{d\phi_T}{dt} = N(d\phi_1 - d\phi_2)/dt = N\, d(\phi_1 - \phi_2)/dt$$

As disclosed in US patent specification No. 4 899 271 the two choke coils can be integrated together e.g. by positioning each of them on the outer legs of an E-core.

Dependent upon how the integrated choke coils are inter-polarized, it is achievable that the flux in the central leg either will be the total of or the difference between the flux of the outer legs. By the polarization shown in fig. 2 is achieved that the flux of the central leg will be $\phi = \phi_1 - \phi_2$, and consequently it follows that:

$$\frac{d\phi}{dt} = \frac{d(\phi_1-\phi_2)}{dt} \Rightarrow N_T \frac{d\phi_T}{dt} = N \frac{d\phi}{dt}$$

If the number of turns is then chosen to be $N = N_T$, it follows that

$$\frac{d\phi_T}{dt} = \frac{d\phi}{dt} = d(\phi_1-\phi_2)/dt$$

Thus, it is seen that when the number of turns is chosen as above, and the choke coils are polarized as described, the flux of the transformer equals the flux which has already been provided in the central leg by the choke

coils. This means that the transformer can now be integrated into the central leg of the combined L1-L2 choke coil without this calling for any increase of the cross-section of the core or any magnetization current in the transformer.

In fig. 3 this has been done on an E-core. The inter-polarity of the windings are shown in the figure by black dots. The primary winding of the transformer, indicated by stippled line, calls for no polarization relatively to the other windings.

However, in some cases it may be desirable to use a somewhat smaller number of turns on the central leg, thereby - intentionally - creating a certain imbalance in the magnetic circuit. In certain cases such imbalance can reduce the ripple component in the choke coils. However, the differences in the number of turns are negligent.

Fig. 4 shows an embodiment in which the core is composed of a combination of ferrite and amorphous tape wound magnetic material. The magnetic system comprises a core part 1 of ferrite, two core parts 2 of amorphous cut tape core, air gaps 3, a transformer winding 4 and choke coil windings 5.

Like laminated iron cores amorphous magnetic materials can sustain a far higher DC-magnetizing level than ferrite. Saturation does not occur until at 1-1.5 Tesla as opposed to ferrite where saturation occurs at 0.3-0.4 Tesla.

Consequently, it is particularly advantageous to use one of the amorphous materials for outer legs in the core where the magnetization preferably consists of DC-flux.

Here a so-called cut tape core has been used, i.e. a core wound from amorphous material in tape form, which has subsequently been cut in two halves.

In the central leg of the core the DC-flux of the outer legs will be outbalanced, whereas the flux variations will be added and entail a higher AC-flux density than in the outer legs.

Consequently, here use is most advantageously made of ferrite, as ferrite typically will be the least lossy material.

The air gaps shown in the figure can e.g. be provided by spacers of insulation material onto which the individual core parts may optionally be glued.

The core parts can also e.g. be tightened together by means of a tape of a non-conductive material. A conductive material could cause eddy current loss in such areas of the tightening tape which are close to the air gaps.

The magnetic circuit can also be provided with other core types than the previously mentioned E-core. E.g. low permeable toroid cores (powder cores) may be used. The two choke coils are then merely wound on each separate toroid core, while the transformer is wound through both cores.

C l a i m s :

1. Use of a magnetic circuit having several magnetic components integrated on one or more common magnet cores of a power supply circuit known per se of the kind comprising a transformer, the secondary winding ends of which are connected to uniform, first electrodes of a pair of rectifier diodes, the second electrodes of which are connected to one output terminal of the power supply circuit, and further including two reactive components, and the first electrodes of the diodes further being connected to the second output terminal of the power supply circuit via a respective one of the reactive components, where the number of turns of the said two reactive components substantially is selected so as to equal the number of secondary turns on the transformer, the said two reactive components are positioned on each separate core part so that the resulting magnetic flux in common core parts substantially equals the difference between the magnetic flux of the two core parts, and the windings of the transformer are positioned on the said common core parts.

2. A power supply circuit in which use is made of a circuit known per se, comprising a transformer the secondary winding ends of which are connected to uniform, first electrodes of a pair of rectifier diodes, the second electrodes of which are connected to one output terminal of the power supply circuit, and further including two reactive components, and the first electrodes of the diodes further being connected to the second output terminal of the power supply circuit via a respective one of the reactive components, c h a r a c t e r i z e d in that all magnetic components are integrated on one or more common magnet cores, where the number of turns of the said

two reactive components substantially equals the number of secondary turns on the transformer, and the said two reactive components are positioned on each separate core part in such a way that the resulting magnetic flux in common core parts, on which the windings of the transformer are positioned, essentially equals the difference between the magnetic flux of those core parts.

3. A power supply circuit according to claim 2 comprising a common core part, c h a r a c t e r i z e d in that the magnetic components are integrated on a common magnet core of the E-type, the said two reactive components being positioned on the outer legs of the core, and the common core part being constituted by the central leg of the core.

4. A power supply circuit according to claim 3, c h a r a c t e r i z e d in that the outer legs are composed of an amorphous tape wound material, that the central leg is composed of a ferrite material and that air gaps are provided at such locations where the two materials adjoin.

5. A power supply circuit according to claim 1, comprising two common core parts, c h a r a c t e r i z e d in that the magnetic components are positioned on two common toroid cores, the said two reactive components being positioned on each separate toroid core, and the windings of the transformer being wound through both cores.

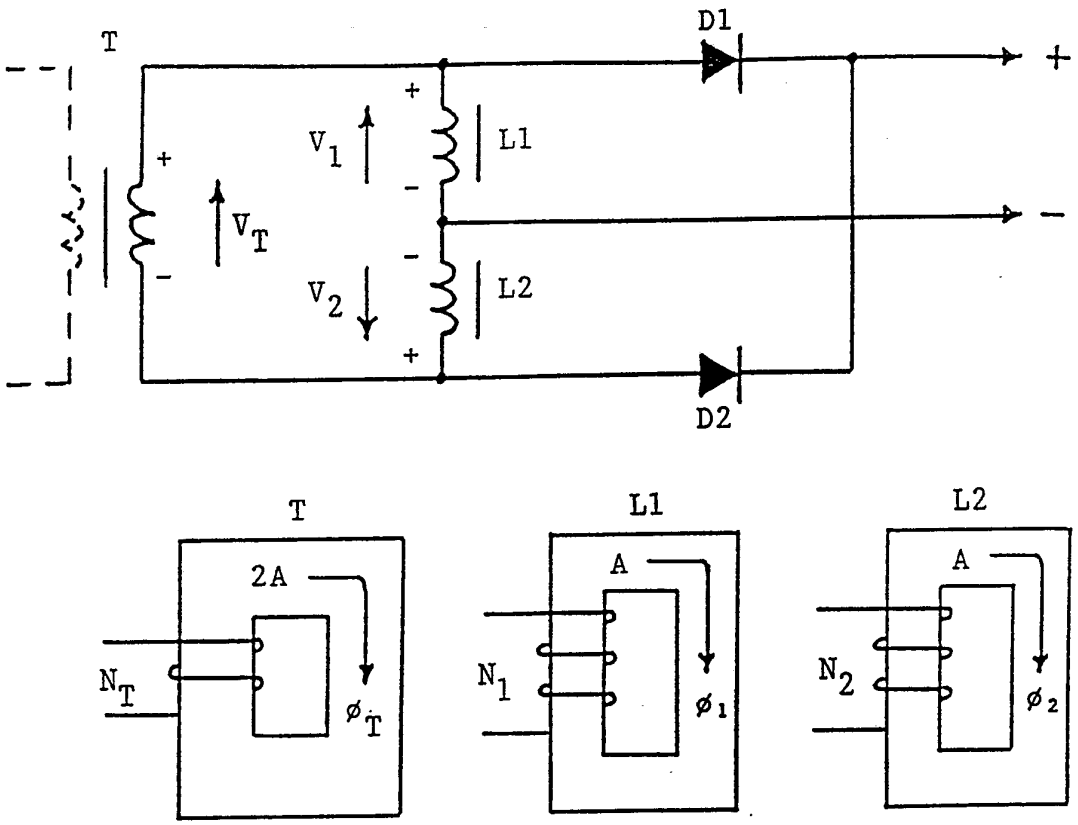

T
D1
+
V1
L1
+
-
VT
-
-
V2
L2
+
D2
T
L1
L2
2A
A
A
NT
N1
N2
ØT
Ø1
Ø2

Fig 1

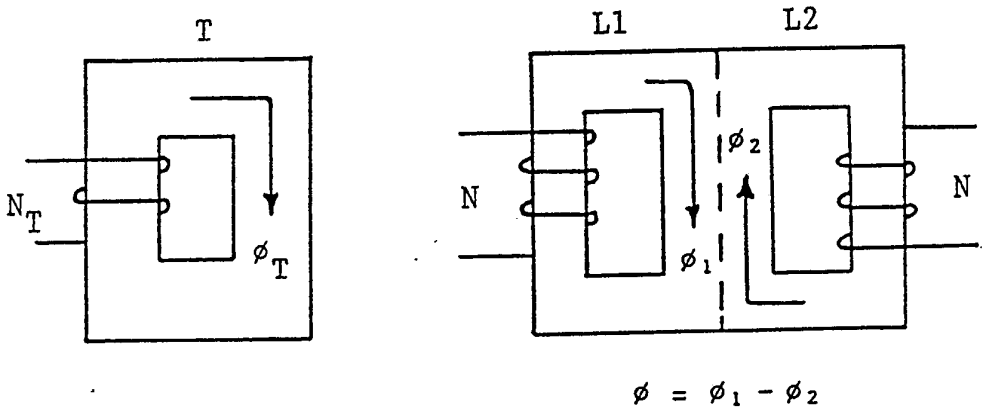

T
L1
L2
NT
N
N
ØT
Ø1
Ø2
Ø = Ø1 - Ø2

Fig 2

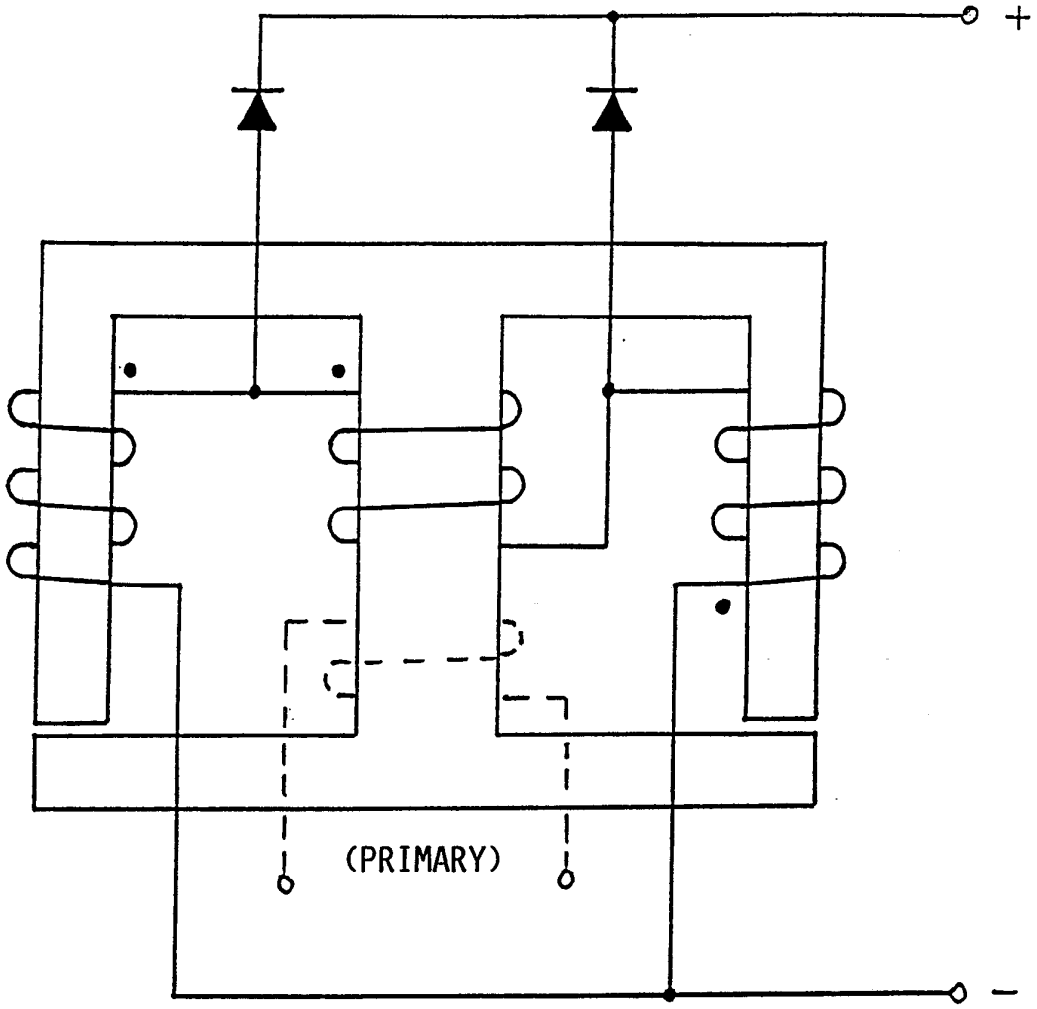
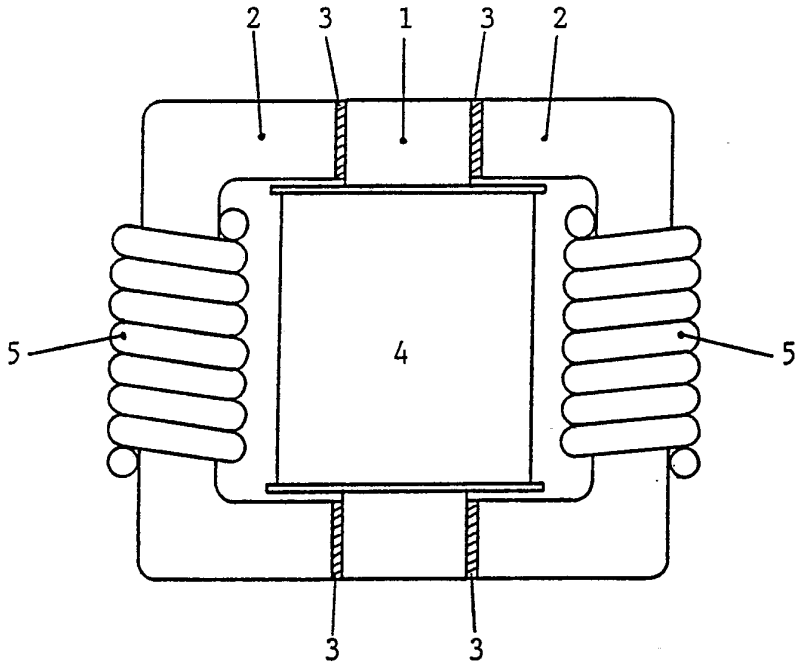
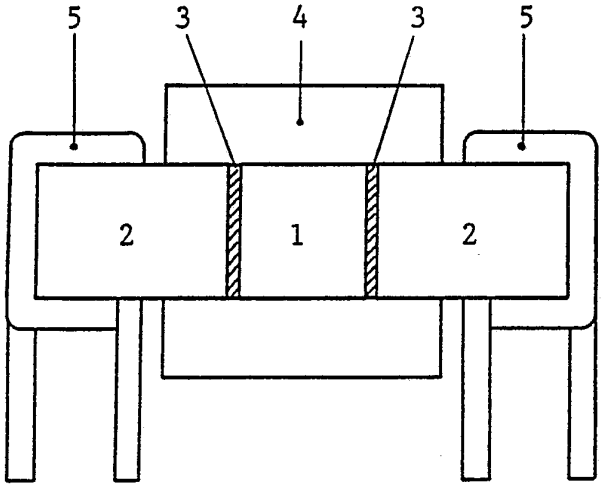


Fig 3

FIG 4





1 FERRITE CORE
2 AMORPHOUS CUT TAPE CORE
3 AIR GAP
4 TRANSFORMER WINDING
5 CHOKE WINDING

INTERNATIONAL SEARCH REPORT

International Application No PCT/DK 91/00341

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: H 02 M 7/06, H 01 F 31/00

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	H 02 M, H 01 F

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
Y	US, A, 4899271 (OLE S SEIERSEN) 6 February 1990, see the whole document	1-3,5
A	--	4
Y	Patent Abstracts of Japan, Vol 10, No 184, E415, abstract of JP 61- 32506, publ 1986-02-15 IWASAKI ELECTRIC CO LTD	1-3,5
A	--	4
A	US, A, 4914561 (M. W RICE ET AL) 3 April 1990, see column 2, line 66 - column 3, line 51	1-5
	--	
A	US, A, 3231841 (MASAYASU OHTAKE) 25 January 1966, see column 1, line 9 - line 50	1-5
	--	

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
17th February 1992	1992 -02- 20
International Searching Authority	**Signature of Authorized Officer**
SWEDISH PATENT OFFICE	HÅKAN SANDH

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	US, A, 4766365 (L. BOLDUC ET AL) 23 August 1988, see column 4, line 29 - line 36 --	1-5

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.PCT/DK 91/00341

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 30/12/91
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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A- 4899271	90-02-06	NONE		
US-A- 4914561	90-04-03	NONE		
US-A- 3231841	66-01-25	NONE		
US-A- 4766365	88-08-23	AU-B-	603437	90-11-15
		AU-D-	1524588	90-02-15
		CA-A-	1258881	89-08-29
		EP-A-	0339164	89-11-02