

(19)



(11)

EP 4 557 322 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
21.05.2025 Bulletin 2025/21

(21) Application number: **23306978.0**

(22) Date of filing: **15.11.2023**

(51) International Patent Classification (IPC):
H01F 3/10 ^(2006.01) **H01F 17/06** ^(2006.01)
H01F 37/00 ^(2006.01) **H01F 41/02** ^(2006.01)
H01F 3/14 ^(2006.01)

(52) Cooperative Patent Classification (CPC):
H01F 3/10; H01F 3/14; H01F 17/062; H01F 37/00;
H01F 41/0246; H01F 3/12; H01F 2003/106;
H01F 2017/0093; H01F 2017/065

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

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Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI GB GR
HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO
PL PT RO RS SE SI SK SM TR

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(54) **AN ELECTROMAGNETIC INTERFERENCE FILTER USING TWO MAGNETIC CORES AND MAGNETIC COMPOSITE MATERIAL AND PROCESS FOR MAKING THE SAME**

(57) The present invention concerns a dual mode electromagnetic interference filter comprising a first magnetic core and windings, at least a part of the windings is wound around the first magnetic core. The dual mode electromagnetic interference filter further comprises a second magnetic core and a magnetic composite material moulded in an area between the first and second magnetic materials. The invention concerns also the method for manufacturing a dual mode electromagnetic interference filter.

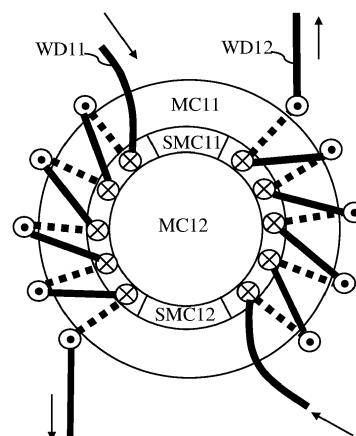


Fig. 1

Description

TECHNICAL FIELD

[0001] The present invention relates generally to an electromagnetic interference filter using two magnetic cores and a magnetic composite material and process for making the same.

RELATED ART

[0002] A common-mode choke is a special application of chokes where it is used to act upon a common mode signal. These chokes are useful for suppression of electromagnetic interference (EMI) and radio frequency interference (RFI) frequently introduced on high current wires such as on power supply lines, which may cause unwanted operation. Reducing this noise is frequently done by using a common mode choke composed of two parallel coil windings on a single core. Common mode chokes allow differential currents to pass through while blocking signals that are affecting both wires. Because the magnetic flux produced by differential-mode currents in the core of a common mode choke tend to cancel each other out, the choke presents little impedance to differential mode currents. It achieves this by the placement of windings such that they generate equal but opposite magnetic fields that cancel each other out for differential mode signals. Normally this also means that the core will not saturate for large differential mode currents but it not achieved anytime.

[0003] The level of conducted emissions, particularly for the common mode, is raised due to the higher level of the voltage variation over the time dv/dt that is converted into an important common mode current through parasitic capacitance brought by for example Wide Band Gap (WBG) devices. In addition, the higher switching frequency of power converters is extending the frequency range of the common mode perturbation.

[0004] Thus, to reach the desired attenuation level, the value of the common mode inductance is generally increased leading to a bigger and heavier component.

[0005] In existing EMI filters, the windings of the common mode choke present a leakage flux inherent to its construction. Electrically speaking, this leakage flux can be modelled as added chokes in series with the common mode choke contributing to the differential noise rejection in the filter. However, the inductance value of these components is limited by the winding structure, the core geometry and the characteristics of the core material.

[0006] Existing solutions for dual mode inductor are mostly relying on a high permeability magnetic core with an air gap for the differential mode integration within a common mode choke.

SUMMARY OF THE INVENTION

[0007] The present invention aims to provide an elec-

tromagnetic interference filter using two magnetic cores and a magnetic composite material to reduce the reluctance of the leakage path and therefore increase the differential mode inductance. In addition, the material selection combined with a particular winding layout allow to both extend the level and the frequency range of the common mode rejection.

[0008] To that end, the present invention concerns a dual mode electromagnetic interference filter comprising a first magnetic core and windings, at least a part of the windings are wound around the first magnetic core, the dual mode electromagnetic interference filter further comprises:

- a second magnetic core,
- a magnetic composite material moulded in an area between the first and second magnetic materials.

[0009] The present invention concerns also a method for manufacturing a dual mode electromagnetic interference filter, characterized in that the method comprises the steps of:

- wounding windings around a first magnetic core,
- insulating each turn of the windings,
- inserting a second magnetic material,
- molding a composite material moulded in an area between the first and second magnetic materials.

[0010] Thus, the common mode and differential mode are integrated within a unique common component reducing the total volume of the filter and optimizing the cost.

[0011] According to a particular feature, the first magnetic core has a higher relative permeability than the second magnetic core and the magnetic composite material has a lower relative permittivity than the second magnetic core.

[0012] Thus, the common mode inductance has a high value related to the relative permeability of the first magnetic core while having a high differential mode inductance value thanks to the second magnetic core having a permeability higher than air, increasing the diverted flux toward the composite material which stores the leakage flux.

[0013] According to a particular feature, the dual mode electromagnetic interference filter further comprises an insulation layer around each turn of the windings.

[0014] Thus, displacement current due to the capacitive effect is reduced.

[0015] According to a particular feature, the windings are wound around the first magnetic core and the magnetic composite material is composed of at least one part that is placed in areas wherein no wires are located.

[0016] Thus, the inner volume is fully exploited, and the differential mode inductance is enhanced compared to a standard common mode inductor with the same volume filled with air.

[0017] According to a particular feature, the magnetic composite material is composed of two parts that are placed in areas wherein no wires are located.

[0018] According to a particular feature, the magnetic composite material is composed of the same number of parts as the number of phases of the power converter.

[0019] According to a particular feature, a part of the windings is wound around the first magnetic core, the remaining part of the winding is wound around the second magnetic core and the composite magnetic material is placed in all the area between the first and second magnetic cores.

[0020] Thus, the second part of the windings combined with the second magnetic core form an additional common mode inductor increasing the global common mode rejection compared to solution with windings only on the first magnetic core.

[0021] According to a particular feature, a part of the windings is wound around the first magnetic core and the other part of the winding is wound around the composite magnetic material and the first and second magnetic cores.

[0022] Thus, the second part of the windings combined with the first and second magnetic cores form an additional common mode inductor increasing the global common mode impedance compared to solution with windings only on a unique magnetic core.

[0023] According to a particular feature, the dual mode electromagnetic interference filter further comprises sensing means for producing a detection voltage representative of a common mode and a differential mode current existing in the second magnetic core.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The characteristics of the invention will emerge more clearly from a reading of the following description of example embodiments, the said description being produced with reference to the accompanying drawings, among which:

Fig. 1 represents a first example of realization of an electromagnetic compatibility filter according to the present invention;

Fig. 2 represents a second example of realization of an electromagnetic compatibility filter according to the present invention;

Fig. 3 represents a third example of realization of an electromagnetic compatibility filter according to the present invention;

Fig. 4 represents an architecture of a system for making a dual mode electromagnetic compatibility filter two magnetic cores and a magnetic composite material;

Fig. 5a represents an algorithm for making an electromagnetic compatibility filter according to the first example of realization;

Fig. 5b represents an algorithm for making an elec-

tromagnetic compatibility filter according to the first example of realization;

Fig. 5c represents an algorithm for making an electromagnetic compatibility filter according to the first example of realization.

DESCRIPTION

[0025] Fig. 1 represents a first example of realization of an electromagnetic compatibility filter according to the present invention.

[0026] The electromagnetic compatibility filter is composed of a first magnetic core MC11, a second magnetic core MC12 located in the inner space of the first magnetic core MC11 and a magnetic composite material SMC11 located between the first and second magnetic cores MC11 and MC12.

[0027] The first magnetic core MC11 has a high relative permeability, like for example in the 2000 to 30000 range, the second magnetic core MC12 has a lower relative permeability than the one of the first magnetic core MC11, like for example in 100 to 2000 range and the magnetic composite material has a low relative permeability, like for example under 100.

[0028] The magnetic composite material is for example a Soft Magnetic Composite (SMC). It is a mix of a magnetic powder such as Iron based powder, Nickel based or Zinc based powder and a binder that is fulfilling two requirements: to isolate each magnetic particle to each other to limit the circulation of eddy current and to restrict the losses associated to this phenomenon and to mechanically bind the particles giving the core sufficient strength to be manipulated and integrated in the application.

[0029] In addition, the magnetic composite material particle approach is distributing the air gap into the whole core's volume. This distribution is helping to lower the losses due the fringing effect and a more homogeneous losses distribution can be obtained. Depending on the binder to active material ratio, the equivalent relative permeability of the mixture can be adjusted from ten to a few hundreds.

[0030] The windings WD11 and WD12 are wound around the first magnetic core MC11.

[0031] The windings are connected to the phase of a power converter in such a way that the normal mode current(s) cancelled each other out. In the case of more than two windings (polyphase), the sum of normal mode currents should be equal to zero. The component related to this invention is a modified conventional common mode choke providing superior common mode noise filtering and/or increased differential mode inductance regarding a standard component.

[0032] The common mode is filtered by advantageously taking part of each materials frequency response properties while the differential mode filtering is enhanced by the combination of each winding, the second magnetic core MC12 and the magnetic composite ma-

terial diverting the leakage flux from the main core MC11.

[0033] In the example of Fig. 1 the magnetic composite material is composed of two parts SMC11 and SMC 12 that are placed in areas wherein no wires are located.

[0034] The present invention is also applicable for a single part SMC11 or SMC12 that is placed in an area wherein no wires are located.

[0035] In these areas, no residual air gap is present thanks to the high conforming characteristics of the soft magnetic material before curing. A curing step allows to harden the material and give mechanical strength to the component.

[0036] The windings WD11 and WD12 are connected for example to the phase of a power converter in such a way that the normal mode current(s) cancelled each other out. In the case of more than two windings (poly-phase), the sum of normal mode currents should be equal to zero. The component related to this invention is a modified conventional common mode choke providing superior common mode noise filtering and/or increased differential mode inductance regarding a standard component.

[0037] An insulation layer, not shown in Fig. 1, is placed between the first magnetic core MC11 and around the second magnetic core MC12 and more precisely around each turn of each winding WD11 and WD 12.

[0038] The insulation layer can be a sheet of insulation material or a coating.

[0039] The magnetic composite material thickness and/or the binder/material ratio is adjusted to prevent saturation of the second magnetic material MC12 while maximizing the flux diverted from the first magnetic core MC11.

[0040] The type of the first magnetic core shape is preferably a toroid (ring core) but can also be applicable to C-shape, U-shape or E-shape cores.

[0041] The first magnetic core may be a MnZn ferrite core, a NiZn ferrite core, a Nanocrystalline core, an Amorphous core or a Dust core.

[0042] The second magnetic core may be powder core made of FeSiAl Alloy or permalloy material and a binder.

[0043] It has to be noted here that the second magnetic core MC12 and the magnetic composite material SMC11 and SMC 12 may be located at the outer space of the first magnetic core MC11.

[0044] The electromagnetic compatibility filter may comprise sensing means for producing a detection voltage representative of a common mode and a differential mode currents existing in the second magnetic core MC12 as disclosed in the patent application WO 2016 208762.

[0045] Fig. 2 represents a second example of realization of an electromagnetic compatibility filter according to the present invention.

[0046] The electromagnetic compatibility filter is composed of a first magnetic core MC21, a second magnetic core MC22 located in the inner space of the first magnetic core MC21 and a magnetic composite material SMC20

located between the first and second magnetic cores MC21 and MC22.

[0047] The first magnetic core MC21 has a high relative permeability, like for example in the 2000 to 30000 range, the second magnetic core MC22 has a lower relative permeability than the one of the first magnetic core MC21, like for example in 100 to 2000 range and the magnetic composite material has a low relative permeability, like for example under 100.

[0048] The magnetic composite material is for example a Soft Magnetic Composite (SMC). It is a mix of a magnetic powder such as Iron based powder, Nickel based or Zinc based powder and a binder that is fulfilling two requirements: to isolate each magnetic particle to each other to limit the circulation of eddy current and to restrict the losses associated to this phenomenon and to mechanically bind the particles giving the core sufficient strength to be manipulated and integrated in the application.

[0049] In addition, the magnetic composite material particle approach is distributing the air gap into the whole core's volume. This distribution is helping to lower the losses due the fringing effect and a more homogeneous losses distribution can be obtained. Depending on the binder to active material ratio, the equivalent relative permeability of the mixture can be adjusted from ten to a few hundreds.

[0050] A fraction of the total windings WD21 and WD22 are solely wound around the first magnetic core MC21 and the remaining part of the winding are wound around the second magnetic core MC22. By doing so, the equivalent common mode impedance is the sum of a first inductor with an inductance related to the square of the first fraction of turns n_{11} , where n_{11} is the number of turns around the first magnetic core and a series connected inductor with an inductance related to the square of the remaining number of turns n_{12} , where n_{12} is the number of turns around the second magnetic core. Each inductor material can be advantageously selected to extend the frequency range of operation. As an example, a first material can be selected with a high relative permeability in the low frequency spectrum (hundreds of kilohertz) while a second material will have a lower permeability but with a cut-off frequency beyond the tens of megahertz.

[0051] The windings are connected to the phase of a power converter in such a way that the normal mode current(s) cancelled each other out. In the case of more than two windings (polyphase), the sum of normal mode currents should be equal to zero. The component related to this invention is a modified conventional common mode choke providing superior common mode noise filtering and/or increased differential mode inductance regarding a standard component.

[0052] The common mode is filtered by advantageously taking part of each materials frequency response properties while the differential mode filtering is enabled by the second magnetic core MC22 diverting the leakage

flux into the magnetic composite material over-molded partially around the second magnetic core MC22.

[0053] In the example of Fig. 2, the magnetic composite material SMC20 is placed in all the area between the first and second magnetic cores MC21 and MC22.

[0054] In this area, no residual air gap is present thanks to the high conforming characteristics of the magnetic composite material before curing. A curing step allows to harden the material and gives mechanical strength to the component.

[0055] The windings WD21 and WD22 are connected for example to the phase of a power converter in such a way that the normal mode current(s) cancelled each other out. In the case of more than two windings (polyphase), the sum of normal mode currents should be equal to zero.

[0056] An insulation layer, not shown in Fig. 2, is placed between the first magnetic core MC21 and around the second magnetic core MC22 and more precisely around each turn of each winding WD21 and WD22.

[0057] The insulation layer can be a sheet of insulation material or a coating.

[0058] The magnetic composite material thickness is adjusted to prevent saturation of the second magnetic material MC22 while maximizing the flux leaving the first magnetic core MC21.

[0059] The type of the first magnetic core shape is preferably a toroid (ring core) but can also be applicable to C-shape, U-shape or E-shape cores.

[0060] The second magnetic core may be powder core made of FeSiAl Alloy or permalloy material and a binder.

[0061] The first magnetic core may be a MnZn ferrite core, a NiZn ferrite core, a Nanocrystalline core, an Amorphous core or a Dust core.

[0062] It has to be noted here that the second magnetic core MC22 and the magnetic composite material SMC20 may be located at the outer space of the first magnetic core MC21.

[0063] The electromagnetic compatibility filter may comprise sensing means Sen for producing a detection voltage representative of a common mode and a differential mode currents existing in the second magnetic core MC21 as disclosed in the patent application WO 2016 208762.

[0064] The sensing means Sen is wound around the second magnetic core MC22.

[0065] Fig. 3 represents a third example of realization of an electromagnetic compatibility filter according to the present invention.

[0066] The electromagnetic compatibility filter is composed of a first magnetic core MC31, a second magnetic core MC32 located in the inner space of the first magnetic core MC31 and a magnetic composite material SMC30 located between the first and second magnetic cores MC31 and MC32.

[0067] The first magnetic core MC31 has a high relative permeability, like for example in the 2000 to 30000 range, the second magnetic core MC32 has a lower relative

permeability than the one of the first magnetic core MC31, like for example in 100 to 2000 range and the magnetic composite material has a low relative permeability, like for example under 100.

[0068] The magnetic composite material is for example a Soft Magnetic Composite (SMC). It is a mix of a magnetic powder such as Iron based powder, Nickel based or Zinc based powder and a binder that is fulfilling two requirements: to isolate each magnetic particle to each other to limit the circulation of eddy current and to restrict the losses associated to this phenomenon and to mechanically bind the particles giving the core sufficient strength to be manipulated and integrated in the application.

[0069] In addition, the magnetic composite material particle approach is distributing the air gap into the whole core's volume. This distribution is helping to lower the losses due the fringing effect and a more homogeneous losses distribution can be obtained. Depending on the binder to active material ratio, the equivalent relative permeability of the mixture can be adjusted from ten to a few hundreds.

[0070] A part of the windings WD31 and WD32 are wound around the first magnetic core MC31 and the other part of the winding are wound around the magnetic composite material SMC30 and the first and second magnetic cores MC31 and MC32. By doing so, the equivalent common mode impedance is the sum of a first inductor with an inductance related to the square of the total number of turns $n_{11}+n_{12}$ where n_{11} is the number of turns around the first magnetic core and n_{12} is the number of turns around the second magnetic core and the magnetic composite material and a series connected inductor with an inductance related to the square of the number of turns n_{12} . Each inductor material can be advantageously selected to extend the frequency range of operation. As an example, a first material can be selected with a high relative permeability in the low frequency spectrum (hundreds of kilohertz) while a second material will have a lower permeability but with a cut-off frequency beyond the tens of megahertz.

[0071] The windings are connected to the phase of a power converter in such a way that the normal mode current(s) cancelled each other out. In the case of more than two windings (polyphase), the sum of normal mode currents should be equal to zero. The component related to this invention is a modified conventional common mode choke providing superior common mode noise filtering and/or increased differential mode inductance regarding a standard component.

[0072] The common mode is filtered by advantageously taking part of each materials frequency response properties while the differential mode filtering is enabled by the second magnetic core MC32 diverting the leakage flux into the magnetic composite material over-molded partially around the second magnetic core MC32.

[0073] In the example of Fig. 3, the magnetic composite material SMC30 is placed in all the area between the

first and second magnetic cores MC31 and MC32.

[0074] In this area, no residual air gap is present thanks to the high conforming characteristics of the magnetic composite material before curing. A curing step allows to harden the material and gives mechanical strength to the component.

[0075] The windings WD31 and WD32 are connected for example to the phase of a power converter in such a way that the normal mode current(s) cancelled each other out. In the case of more than two windings (poly-phase), the sum of normal mode currents should be equal to zero.

[0076] An insulation layer, not shown in Fig. 3, is placed between the first magnetic core MC31 and around the second magnetic core MC32 and more precisely around each turn of each winding WD31 and WD32.

[0077] The insulation layer can be a sheet of insulation material or a coating.

[0078] The magnetic composite material thickness is adjusted to prevent saturation of the second magnetic material MC32 while maximizing the flux leaving the first magnetic core MC31.

[0079] The type of the first magnetic core shape is preferably a toroid (ring core) but can also be applicable to C-shape, U-shape or E-shape cores.

[0080] The second magnetic core may be powder core made of FeSiAl Alloy or permalloy material and a binder.

[0081] The first magnetic core may be a MnZn ferrite core, a NiZn ferrite core, a Nanocrystalline core, an Amorphous core or a Dust core.

[0082] It has to be noted here that the second magnetic core MC22 and the magnetic composite material SMC30 may be located at the outer space of the first magnetic core MC31.

[0083] The electromagnetic compatibility filter may comprise sensing means Sen for producing a detection voltage representative of a common mode and a differential mode currents existing in the second magnetic core MC32 as disclosed in the patent application WO 2016 208762.

[0084] Fig. 4 represents an architecture of a system for making a dual mode electromagnetic compatibility filter two magnetic cores and a magnetic composite material.

[0085] The system 40 has, for example, an architecture based on components connected by a bus 401 and a processor 400 controlled by a program as disclosed in Fig. 5a or 5b or 5c.

[0086] The bus 401 links the processor 400 to a read only memory ROM 402, a random access memory RAM 403, an input output I/O IF interface 405.

[0087] The input output I/O IF interface 405 enables the control of the different apparatus that are used to produce electromagnetic compatibility filters.

[0088] The memory 403 contains registers intended to receive variables and the instructions of the program related to the algorithm as disclosed in Fig. 5a or 5b or 5c.

[0089] The read-only memory, or possibly a Flash memory 402, contains instructions of the programs re-

lated to the algorithm as disclosed in Fig. 5a or 5b or 5c, when the system 40 is powered on, that are loaded to the random access memory 403. Alternatively, the program may also be executed directly from the ROM memory 402.

[0090] The system 40 may be implemented in software by execution of a set of instructions or program by a programmable computing machine, such as a PC (*Personal Computer*), a DSP (*Digital Signal Processor*) or a microcontroller; or else implemented in hardware by a machine or a dedicated component, such as an FPGA (*Field-Programmable Gate Array*) or an ASIC (*Application-Specific Integrated Circuit*).

[0091] In other words, the system 40 includes circuitry, or a device including circuitry, causing the system 40 to perform the program related to the algorithm as disclosed in Fig. 5a or 5b or 5c.

[0092] Fig. 5a represents an algorithm for making an electromagnetic compatibility filter according to the first example of realization.

[0093] At step S500, a first magnetic core MC11 is selected to fit the requirements on the common mode filtering. The windings are wound around the first magnetic core MC11 in a classical manner.

[0094] At step S501, an insulation layer is deposited around each turn of each winding.

[0095] For example, the insulation is a wound tape, an enamel coating, a vinyl or PVC sheath. In another implementation, the insulation layer can be done by a part made of vertical fences placed between each turn to fill the space between each turn and prevent insertion of the magnetic composite material.

[0096] At step S502, the second magnetic core MC12 is inserted within the first magnetic core MC11.

[0097] At step S503, the magnetic composite materials SMC11 and SMC 12 are placed in areas wherein no wires are located.

[0098] The present invention is also applicable for a single part SMC11 or SMC12 that is placed in an area wherein no wires are located.

[0099] Fig. 5b represents an algorithm for making an electromagnetic compatibility filter according to the first example of realization.

[0100] At step S520, a first magnetic core MC21 is selected to fit the requirements on the common mode filtering. A part of the turn of the windings are wound around the first magnetic core in a classical manner.

[0101] At step S521, an insulation layer is deposited around each turn of each winding.

[0102] For example, the insulation is a wound tape, an enamel coating, a vinyl or PVC sheath. In another implementation, the insulation layer can be done by a part made of vertical fences placed between each turn to fill the space between each turn and prevent insertion of the magnetic composite material.

[0103] At step S522, the second magnetic core MC22 is inserted within the first magnetic core MC21.

[0104] At step S523, the magnetic composite material

SMC20 is placed between the first and second magnetic cores MC21 and MC22.

[0105] At step S523, the remaining part of the turn of the windings are wound around the second magnetic core MC22 in a classical manner.

[0106] Fig. 5c represents an algorithm for making an electromagnetic compatibility filter according to the first example of realization.

[0107] At step S540, a first magnetic core MC31 is selected to fit the requirements on the common mode filtering. A part of the turn of the windings are wound around the first magnetic core MC31 in a classical manner.

[0108] At step S541, an insulation layer is deposited around each turn of each winding.

[0109] For example, the insulation is a wound tape, an enamel coating, a vinyl or PVC sheath. In another implementation, the insulation layer can be done by a part made of vertical fences placed between each turn to fill the space between each turn and prevent insertion of the magnetic composite material.

[0110] At step S542, the second magnetic core MC32 is inserted within the first magnetic core MC31.

[0111] At step S543, the magnetic composite material SMC30 is placed between the first and second magnetic cores MC31 and MC32.

[0112] At step S543, the remaining part of the turn of the windings are wound around the first and second magnetic cores MC31 and MC32 in a classical manner.

[0113] Naturally, many modifications can be made to the embodiments of the invention described above without departing from the scope of the present invention.

Claims

1. A dual mode electromagnetic interference filter comprising a first magnetic core and windings, at least a part of the windings is wound around the first magnetic core, the dual mode electromagnetic interference filter further comprises:

- a second magnetic core,
- a magnetic composite material moulded in an area between the first and second magnetic materials.

2. The dual mode electromagnetic interference filter according to claim 1, wherein the number of windings is equal to the number of phases of a power converter.

3. The dual mode electromagnetic interference filter according to claim 1 or 2, wherein the first magnetic core has a higher relative permeability than the second magnetic core and the magnetic composite material has a lower relative permittivity than the second magnetic core.

4. The dual mode electromagnetic interference filter according to any of the claims 1 to 3, wherein the dual mode electromagnetic interference filter further comprises an insulation layer around each turn of the windings.

5. The dual mode electromagnetic interference filter according to any of claims 1 to 4, wherein the windings are wound around the first magnetic core and the composite magnetic material is composed of at least one part that is placed in areas wherein no wires are located.

6. The dual mode electromagnetic interference filter according to claim 4, wherein the magnetic composite material is composed of two parts that are placed in areas wherein no wires are located.

7. The dual mode electromagnetic interference filter according to claim 4, wherein the magnetic composite material is composed of the same number of parts as the number of phases of the power converter.

8. The dual mode electromagnetic interference filter according to any of claims 1 to 4, wherein a part of the windings is wound around the first magnetic core, the remaining part of the winding is wound around the second magnetic core and the magnetic composite material is placed in all the area between the first and second magnetic cores.

9. The dual mode electromagnetic interference filter according to any of claims 1 to 4, wherein a part of the windings is wound around the first magnetic core and the other part of the winding are wound around the magnetic composite material and the first and second magnetic cores.

10. The dual mode electromagnetic interference filter according to any of claims 1 to 9, wherein the dual mode electromagnetic interference filter further comprises sensing means for producing a detection voltage representative of a common mode and a differential mode currents existing in the second magnetic core.

11. A method for manufacturing a dual mode electromagnetic interference filter, **characterized in that** the method comprises the steps of:

- wounding windings around a first magnetic core,
- insulating each turn of the windings,
- inserting a second magnetic material,
- molding a composite material moulded in an area between the first and second magnetic materials.

12. The method according to claim 11, wherein the windings are wound around the first magnetic core and the magnetic composite material is composed of two parts that are placed in areas wherein no wires are located. 5
13. The method according to claim 11, wherein a part of the windings are wound around the first magnetic core and the method further comprises the step of wounding the remaining part of the winding around the second magnetic core and the magnetic composite material is placed in all the area between the first and second magnetic cores. 10
14. The method according to claim 11, wherein a part of the windings are wound around the first magnetic core and the method further comprises the step of wounding the other part of the winding around the magnetic composite material and the first and second magnetic cores. 15
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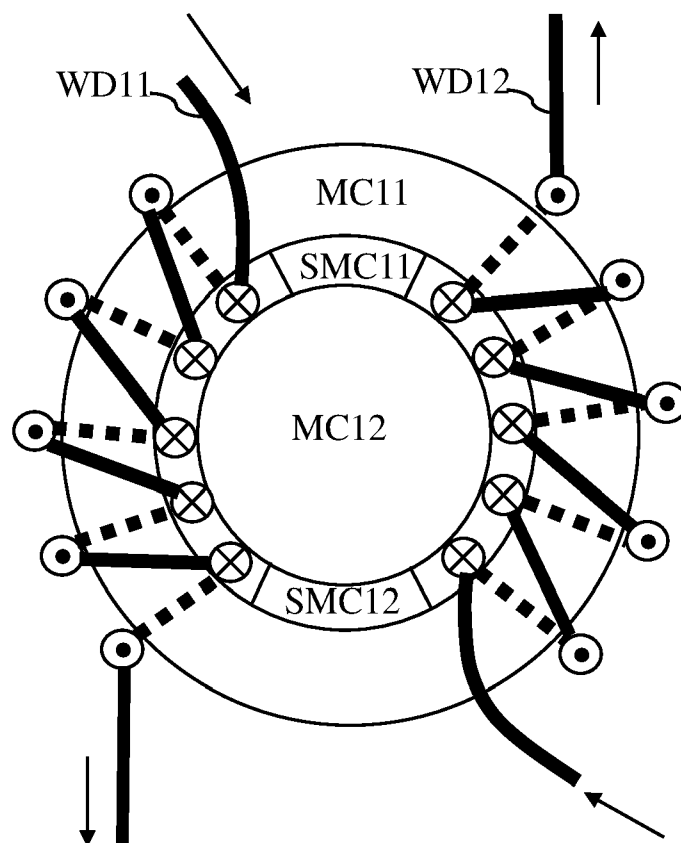


Fig. 1

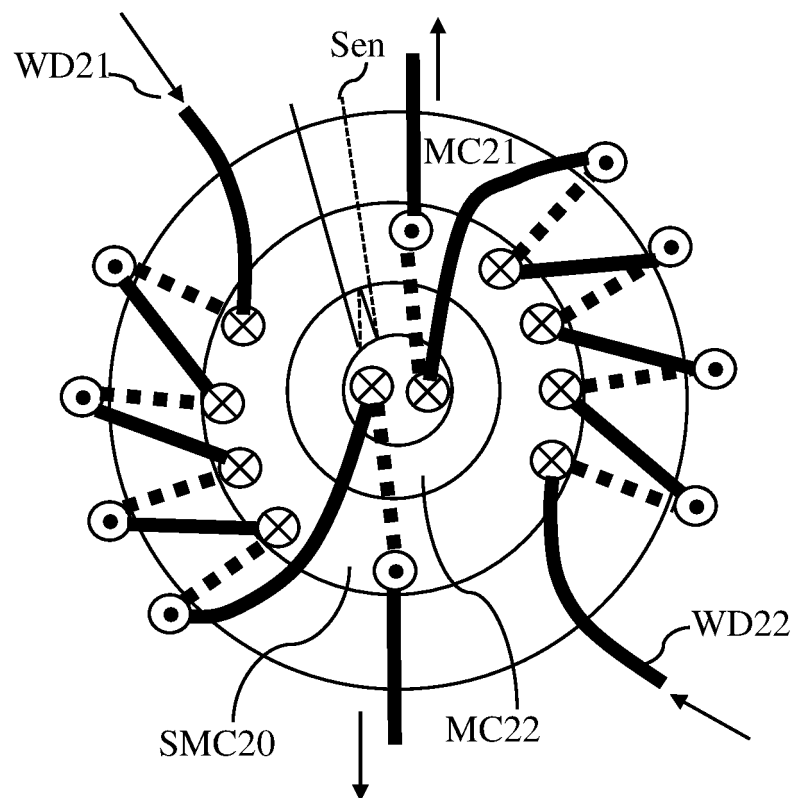


Fig. 2

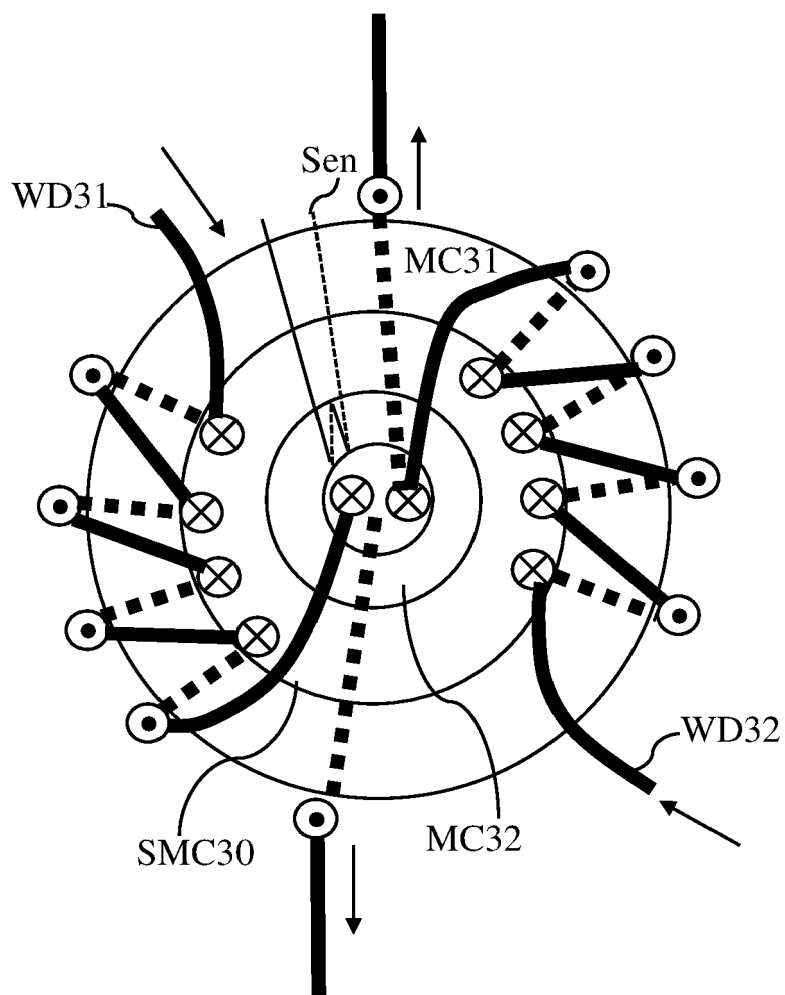


Fig. 3

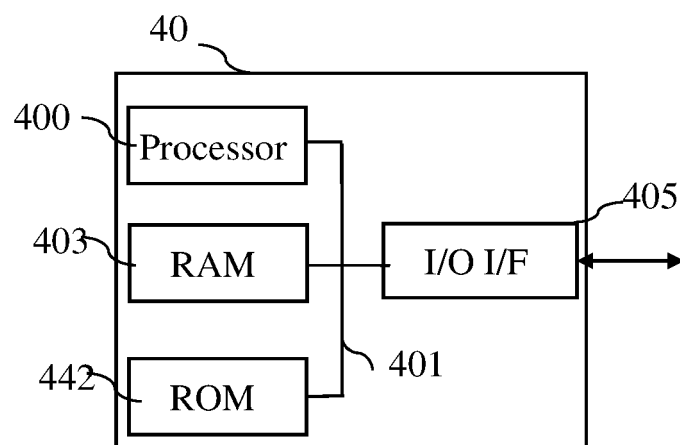


Fig. 4

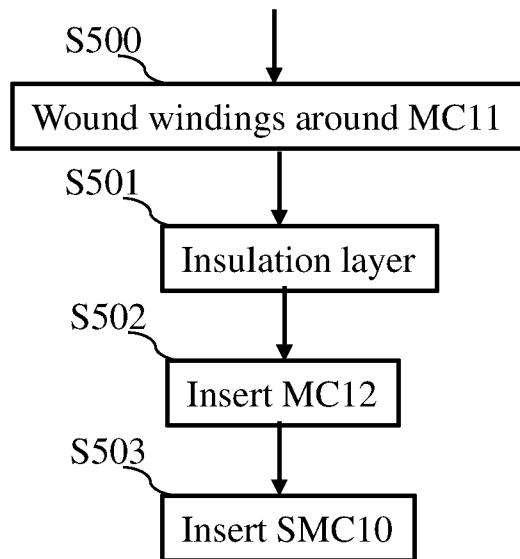


Fig. 5a

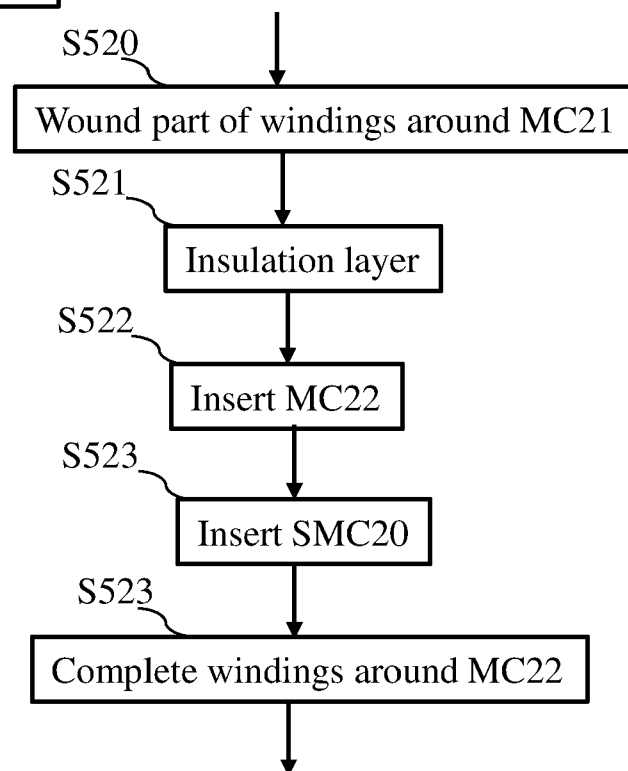


Fig. 5b

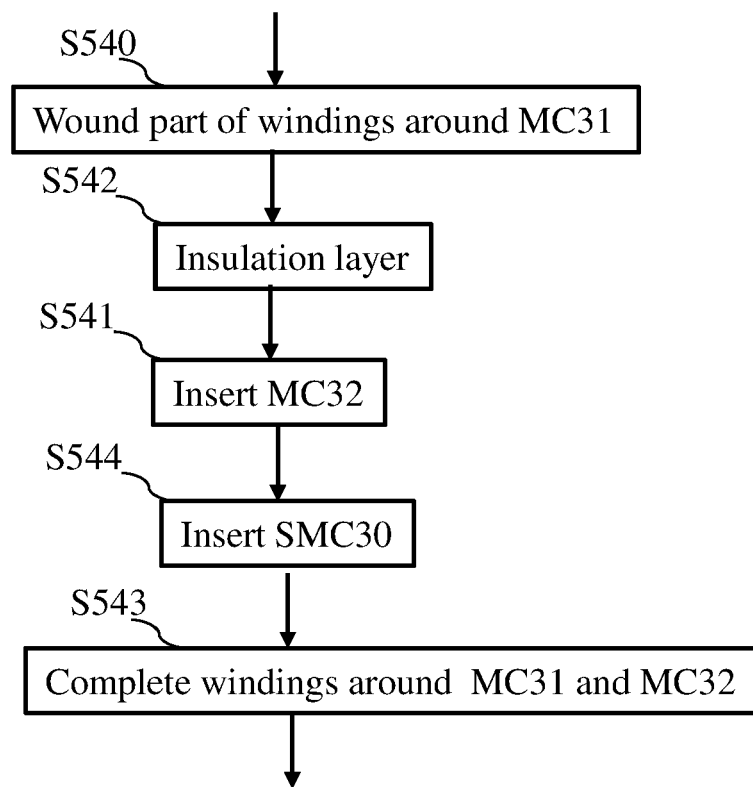


Fig. 5c



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