(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 185 273 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
28.06.2017 Bulletin 2017/26

(51) Int Cl.:
H01H 51/22 *(2006.01)* ***H01H 51/27*** *(2006.01)*
H01H 50/22 *(2006.01)*

(21) Application number: **16205806.9**

(22) Date of filing: **21.12.2016**

(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 MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(30) Priority: **22.12.2015 EP 15003650**

(71) Applicant: **ABB Schweiz AG**
5400 Baden (CH)

(72) Inventors:
- **Sosale, Guruprasad**
  69469 Weinheim (DE)
- **Mechler, Günther**
  74855 Haßmersheim (DE)
- **Biagini, Veronica**
  68526 Ladenburg (DE)
- **Hozoi, Adrian**
  68219 Mannheim (DE)

(74) Representative: **Marks, Frank**
ABB AG
GF-IP
Wallstadter Strasse 59
68526 Ladenburg (DE)

(54) **BI-STABLE RELAY**

(57) The invention is about a bi-stable relay consisting of a supporting structure carrying at least one set of electrical contacts, a U-shaped magnetic core being fixed to the supporting structure, electrical winding around the said core, and an armature provided with means to pivot around a rotation axis and where the said armature comprises a frame supporting two springs, at least one contact bridge, one or more permanent magnets, and two flux guides characterized in that
- the flux guides are symmetrically or almost symmetrically arranged with respect to the rotation axis
- the flux guides and the magnetic core feature a planar layout
- the major plane of the flux guides is positioned perpendicular to the major plane of the magnetic core
- the flux guides and the magnetic core are made from one or more laminations being stacked together
- the center of mass of the frame is approximately located on the rotation axis.

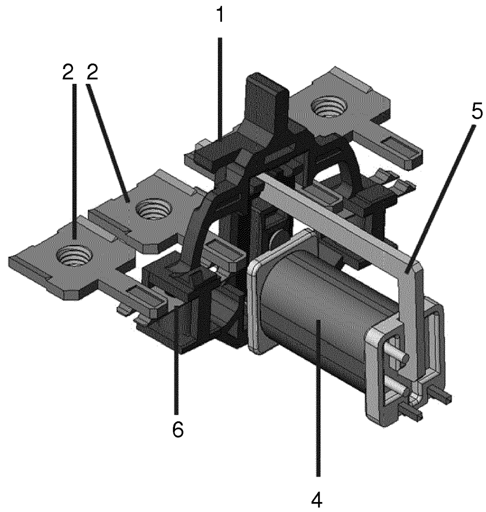


Fig. 2

EP 3 185 273 A1

Description

[0001] This invention deals with a bi-stable electromagnetic relay that features two stable latch positions and features contacts able to handle currents and voltages in excess of 1 A and/or 100 V respectively. While in a latched position, one or more sets of electrical contacts is/are closed or open thereby allowing to be used for control or signaling purposes. The relay can remain in any of the latched positions for an undetermined time period without needing to apply an electrical signal, however, the relay can be switched from one latch position to the other latch position by applying an electrical signal pulse to its winding, generally a current pulse. Such devices are commonly known as bi-stable relays or latching relays and are widely employed in electrical circuits and in apparatus such as electronic overload relays, circuit breakers, protective relays, motor starters and motor controllers.

[0002] In common implementations of bi-stable electromagnetic relays each latched or stable position is achieved by holding a moveable armature against a magnetic core through a clamping magnetic force. The magnetic force is typically produced by deriving magnetic flux from one or two permanent magnets and channeling it to the latch surface between the armature and the magnetic core. The resulting magnetic force at one latch surface is then proportional to the effective magnetic area of the latch surface and to the square value of the magnetic flux density. Various implementations are known.

[0003] One common principle of bi-stable relays involves an armature comprising one or two permanent magnet(s) and two flux guides mounted onto a frame able to rotate around an axis such that the ends of the flux guides can come in contact to a magnetic core, as also described in EP 0 974 155 B1. The magnetic core and the rotation axis of the armature are fixed with respect to an appropriate supporting structure. When the magnetic flux guides are in contact or almost in contact to the magnetic core, the magnetic flux generated by the permanent magnet(s) is concentrated through the contact area(s) between the flux guides and the magnetic core. An attractive magnetic force is thus exerted between the ends of the flux guides and the core resulting in a holding magnetic torque which prevents the armature from rotating and holds it firmly in a defined position. The armature features two possible stable positions where the flux guides come in contact or almost in contact to the magnetic core. The armature may also contain two springs and two contact bridges such that each spring is precompressed by a contact bridge. Each contact bridge is arranged such that it closes a set of electrical contacts provided on a supporting structure in each bi-stable position of the relay. Such contacts arrangements are also described in EP 0 974 155 B1 or DE 10 2009 043 105 A1. They are able to operate with currents and voltages well in excess of 1 A and 100 V respectively.

[0004] The magnetic core is provided with an electrical winding to enable the generation of an excitation magnetic flux within the core by circulating a current through the winding. The direction of the excitation magnetic flux can be controlled by controlling the polarity of the current trough a single winding or by using two windings wound in opposite direction. Switching between the two bi-stable positions of the relay is achieved by generating an excitation magnetic flux opposing the latching flux such that the holding torque is significantly reduced or nulled. The armature starts then rotating towards the other latching position helped by the spring compressing the contacts and eventually by some electromagnetic force coming from the excitation magnetic flux. As the armature approaches the other latching position and passes the middle position, the excitation magnetic flux and the permanent magnet flux are both contributing to a net force towards completing the started motion. Clamping take place once the other latching position is reached. A short current pulse is sufficient to complete switching of the bi-stable relay and may be comprised between 2 ms and 50 ms.

[0005] The springs have two roles: to exert a suitable contact pressure in the latched state and to help initiating the motion of the armature when switching. The minimum contact pressure is dictated by the current carrying capabilities of the contacts. The holding torque exerted on the armature must exceed with some margin the torque resulting from the force of the spring acting on the engaged contact in order to withstand vibration and shock.

[0006] Apart from fulfilling the required operating voltage rating, the main qualities of a bi-stable relay are given by cost, vibration withstand, shock withstand, and energy consumption. Lower energy consumption not only reduces the operation cost but also allows reducing the integration cost of the bi-stable relay by scaling down the energy source and the electrical circuit needed to drive a current through its winding(s).

[0007] The saturation magnetic induction B_s of the magnetic core and of the flux guides is a critical parameter as the clamping magnetic force is proportional to the square of the magnetic induction, also called magnetic flux density, at the latch surface. A good design would therefore strive to maximize the value of the magnetic induction at the latch surface, and materials with high saturation magnetic induction are thus preferred. Furthermore, the core and the flux guides should ideally provide high magnetic permeability such that the magnetic flux is efficiently channeled through the magnetic circuit at the latch surface. In this way, the leakage of the magnetic flux outside the magnetic circuit is minimized and the energy efficiency of the relay is maximized. Bi-stable electromagnetic relays typically feature switching times in the order of several milliseconds, which is fast enough to generate very high eddy currents in the magnetic core and in the flux guides. The eddy currents may waste a very large amount of the electromagnetic energy employed to switch the relay and they increase rapidly with the frequency of the magnetic flux and with the thickness and electrical conductivity of the parts employed in the construction of the magnetic core and of the flux guides. Eddy currents cause a slower increase of the magnetic induction value in the magnetic circuit and they typically require increasing the magnitude and the duration of the signal pulse employed to switch the relay. They imply low energy efficiency and slow operating time. The losses caused by eddy currents may reach well beyond 50% of the total electromagnetic energy generated in the magnetic circuit of the relay during one switching operation. It is thus highly beneficial to employ materials with low thickness and high electrical resistivity for the parts conducting the magnetic flux. The optimum properties of the parts used for constructing the magnetic core and the flux guides of the bi-stable relay can thus be resumed as: high saturation magnetic induction, high magnetic permeability, high resistivity, and low thickness.

[0008] The bi-stable relays known from prior art employ magnetic cores and flux guides fabricated from materials such as low carbon steels. Most commonly employed materials are mild steels grades like AISI 1006, AISI 1008, AISI 1010 or various structural steels. They are relatively cheap, are available in many different forms such as strip, bar, and bulk, and can be processed using common mechanical processing techniques such as stamping, cutting, machining, and bending. However, their magnetic properties such as saturation magnetic induction, magnetic permeability, and electrical resistivity are limited and prone to wide variations as they are not supplied with guaranteed values.

[0009] The saturation magnetic induction B_s of mild steels is typically comprised between 1.5 T to 1.6 T for magnetic field intensity values around 5000 A/m, without being guaranteed. The maximum relative permeability of mild steels measured in DC conditions is typically comprised between 1000 and 2000 also without being guaranteed. The saturation magnetic induction and the permeability also depend on the processing of the material and stress-relief annealing is recommended to be performed in order to achieve best results, however, annealing procedures for optimizing the magnetic properties of mild steels are not described by any available standard. Actually, stress-relief annealing of relay parts manufactured from mild steels is most often not performed. The electrical resistivity of mild steels is commonly small at around 0.15 $\mu\Omega{\cdot}m$ resulting in high eddy currents and related electromagnetic losses.

[0010] The design of bi-stable relays known from the art must deal with moderate magnetic and electrical properties of the materials employed for the magnetic core and for the flux guides. Moreover, the magnetic and electrical properties of materials such as mild steels are prone to large variations as they are not guaranteed by the manufacturers or applicable standards. The common design approach typically employed to handle these issues has been to oversize the electromagnetic components of the bi-stable relay such as the core, the flux guides, the permanent magnet, and the windings. Oversizing the magnetic cross-section of the core requires increasing the circumference of the electrical windings applied to the core and cause larger length, resistance, and mass of wire which is usually made of copper, resulting in higher cost and electrical losses. Oversizing the magnetic core and the flux guides may also increase the electromagnetic losses caused by eddy currents. The electrical efficiency of bi-stable relays employing materials with moderate magnetic and electrical properties is poor and oversizing the design makes it even worse.

[0011] The standard IEC60404-8-10 describes low carbon steels to be used in electrical relays. They contain less than 0.5 % silicon and are available up to large thickness, however, the only specified magnetic property is the coercivity. The low carbon steels described in IEC60404-8-10 are similar to mild steels such as structural steels and may feature somehow superior magnetic properties. However, their magnetic and electrical properties are still not comprehensively guaranteed for optimum use in bi-stable relays.

[0012] So it is the objective of the current invention to provide a bi-stable relay that consumes less energy and features lower integration and operation costs.

[0013] The objective is achieved by a bi-stable relay according to claim 1. So the flux guides are symmetrically or almost symmetrically arranged with respect to the rotation axis, and the flux guides and the magnetic core feature a planar layout, and the major plane of the flux guides is positioned perpendicular to the major plane of the magnetic core, and the flux guides and the magnetic core are made from one or more laminations being stacked together, and the center of mass of the frame is approximately located on the rotation axis.

[0014] According to an advantageous embodiment, the laminations composing the flux guides and the magnetic core are made from strips or sheets of electrical steel with silicon content between 0.5% and 7%.

[0015] According to an advantageous embodiment, the flux guides are C-shaped or arc shaped such that the plane of the C-shape or of the arc shape is in the plane of the electrical steel strip or sheet.

[0016] According to an advantageous embodiment, where the flux guides are provided with at least one chamfer near the contact surface between the flux guides and the core.

[0017] According to an advantageous embodiment, where the latch surface between the flux guides and the core is rectangular such that the ratio between the long edge to the short edge of the rectangle is smaller than 1.6.

[0018] According to an advantageous embodiment, the flux guides and/or the magnetic core are made from cold-rolled electrical steel strips or sheets which have the thickness comprised between 0.1 mm and 1 mm and are provided with an electrically insulating layer.

[0019] According to an advantageous embodiment, the permanent magnet or magnets is/are mounted such that they partly overlap with the flux guides to result in direct contact or a very small air gap between the magnet(s) and the flux guides.

[0020] According to an advantageous embodiment, the ends of the magnetic core are rigidly inserted into holes provided into the supporting structure and the width of the core features at least one step near the inserted ends to limit the insertion depth, and where the cross-section profile of the insertion holes present recessed and/or protruded regions to enable smooth and precise mounting of the core to the supporting structure by press fit.

[0021] According to an advantageous embodiment, including a pivot pin and a bearing hole enabling free rotation motion of the armature with respect to the supporting structure and where the pivot pin is provided with a stopper such as a collar or a bump to prevent free translation motion between the pivot pin and the bearing hole or separation of the two.

[0022] According to an advantageous embodiment, where the pivot pin is part of the supporting structure or is a separate part having one of its end rigidly inserted into a hole provided in the supporting structure and where the pivot pin passes through a bearing hole provided in the armature such that the armature can freely rotate around the pivot pin.

[0023] According to an advantageous embodiment, the pivot pin is part of the armature frame or is a separate part having one of its end rigidly inserted into a hole provided into the armature frame and where the pivot pin passes through a bearing hole provided in the supporting structure such that the pin can freely rotate inside the bearing hole.

[0024] According to an advantageous embodiment, where the pivot pin is a separate part and its diameter is smaller around the rigidly inserted end than around the bearing region and where the pivot pin is preferably made of metal such as brass.

[0025] According to an advantageous embodiment, the core laminations are cut or stamped from electrical steel strips or sheets such that the longest dimension of the laminations is aligned along the rolling direction of the material.

[0026] According to an advantageous embodiment, the flux guide laminations are cut or stamped from electrical steel strips or sheets such that the direction of the latching surface is aligned perpendicularly to the rolling direction of the material.

[0027] According to an advantageous embodiment, the armature comprises two magnets mounted on the sides of the pivot pin in a symmetric arrangement.

[0028] According to an advantageous embodiment, the armature comprises a single magnet with a hole through its center mounted such that the pivot pin passes through the hole in the magnet.

[0029] According to an advantageous embodiment, the frame of the armature is provided with clips to retain all or some of the components mounted to the frame.

[0030] According to an advantageous embodiment, the magnet(s) and the flux guides are mounted to the frame of the armature from opposing sides such that the magnetic force exerted between the magnet(s) and the flux guides keep them firmly into position.

[0031] According to an advantageous embodiment, the electrical winding is provided on one or two bobbins being mounted onto the core and including suitable terminals for electrical connections.

[0032] According to an advantageous embodiment, the supporting structure comprises two sets of electrical contacts and the armature comprises two contact bridges.

[0033] According to an advantageous embodiment, the frame of the armature and the supporting structure are made by molding from a polymer based material, such as polyamide, which may also include non-organic fillers such as glass fiber in concentrations greater than or equal to 10%.

[0034] According to an advantageous embodiment, the supporting structure is the housing of the relay.

[0035] The invention will be described in greater detail by description of eight embodiments with reference to the accompanying drawings, wherein

Fig. 1	shows a bistable relay as known from the art,
Fig. 2	shows an overview of an embodiment of an electromagnetic bistable relay according to this invention,
Fig. 3a and 3b:	shows an isolated view of core, flux guides, magnets and shaft ,
Fig. 4	shows a C or arc shaped flux guide,
Fig. 5	shows the mounting of magnet(s) on the flux guides,
Fig. 6	shows a round shaft with head, middle and base section of decreasing diameter for their respective functions.

[0036] Figure 1 shows a bistable relay with rotating armature housing magnets 66 about a center of rotation 16 and mechanical flux guides 62, 64 that latch onto a U shaped core with extensions 72 and 70. The latching contacts 22 and 20 are held in place with springs 48, 58 that rotate with the armature. A large extension/ lever arm protrudes from the armature. No attention is given to the nature of the flux guides or the center of mass.

[0037] The invention describes a switch mechanism suitable for bi-stable relays and featuring a novel design of the magnetic circuit where the magnetic core and the flux guides feature a planar layout and are arranged such that the major plane of the flux guides is positioned perpendicular to the major plane of the magnetic core.

[0038] Figure 2 shows an overview of an electromagnetic bistable relay 1 as described by this invention disclosure. The three-dimensional view shows auxiliary contacts 2, 3 and a driving coil 4, the latching core 5 and the contact bridge 6.

[0039] The switch mechanism comprises a supporting structure carrying at least one set of electrical contacts with the contact bridge 6, the U-shaped magnetic latching core 5 provided with electrical winding, and an armature provided with means to pivot around a rotation axis and where the said armature comprises a frame supporting two springs, at least the one contact bridge 6, one or more permanent magnets 8, and two flux guides 7, see figure 3.

[0040] Figure 3 shows an isolated view of core 5, flux guides 7, magnets 8 and shaft 9. The core 5 and flux guides 7 are made of one or more laminations and arranged with the major plane perpendicular to one another. The core 5 is also designed such that the longest sections are along the rolling direction due to the enhanced magnetic properties. Figure 3a shows a top view, figure 3b as viewed from the cross section of the core 5.

[0041] Figure 4 shows a C or arc shaped flux guide 7. This is intended to be used with the switching mechanism shown in figure 2. The in plane dimensions are adjusted to ensure that saturation occurs at the gaps. Figure 4a shows a top view. The ratio of the cross sectional dimensions in the portions Y and X is greater than or equal to 1.6:1. Dimensions are adjusted to account for variation in magnetic properties due to the rolling direction, indicated by the arrow R. Figure 4b shows a zoom view of chamfered edges 11 beside the latching or contact surface 12 that have an angle up 50° to the horizontal. Figure 4c shows a 3D view showing a square cross section of latching surface 12 .

[0042] Figure 5 shows the mounting of magnets 8 on the flux guides 7 and the symmetry about a hole in the center. Figure 5a shows the use of two equal magnets 8 on either side of a center shaft (not shown). Figure 5b shows the use of a magnet 8a with the hole. The magnets 8, 8a are mounted in a manner such that the magnet 8, 8a partially overlaps both flux guides 7. The polarization of the magnets 8, 8a is in the direction that links one flux guide 7 to the other.

[0043] Figure 6 shows a round shaft 9 with head section 13 to hold the relay in place, middle section 14 to provide a bearing surface, and a base section 15 of decreasing diameter that is pushed in the housing for its respective functions.

[0044] Features of the relay as shown in the embodiments are as follows.

[0045] The flux guides are symmetrically or almost symmetrically arranged with respect to the rotation axis.

[0046] The flux guides and the magnetic core feature a planar layout.

[0047] The major plane of the flux guides is positioned perpendicular to the major plane of the magnetic core.

[0048] The flux guides and the magnetic core are made from one or more laminations being stacked together.

[0049] The center of mass of the frame is approximately located on the rotation axis.

[0050] The switch mechanism as shown in the figures 2 to 6 may feature one or more contact bridges, however, two contact bridges 6 may often be preferred as it allows balancing the mechanical design and offering normally closed and normally open contacts. The permanent magnet 8, 8a is preferably placed in close proximity of the flux guides 7 such that optimum magnetic coupling is achieved and a symmetric arrangement of the magnet 5 with respect to the two flux guides 7 would typically be preferred.

[0051] The planar design of the magnetic core 5 and the flux guides 7 feature manifold advantages going from practical fabrication to device scalability and excellent energy efficiency. The arrangement allows precise and cost efficient fabrication of the magnetic core 5 and/or flux guides 7 from metallic sheets using well established processes such as stamping or precision stamping. Other cutting techniques such as laser cutting are also possible. The magnetic core 5 and the flux guides 7 can be built from single laminations or from a stack of multiple laminations allowing easily scaling the design according to the switching and reliability needs. Due to the planar design it is not necessary to perform any bending of the magnetic core 5 or of the flux guides 7, which allows eliminating manufacturing steps and avoids the degradation of the magnetic properties caused by mechanical stresses and strains induced during bending. Optimum magnetic properties of the materials can thus be maintained leading to better performance of the switching mechanism.

[0052] Furthermore, the planar design allows employing electrical steels such as silicon steels featuring superior magnetic and electrical performance and being available in sheet and strip form. Silicon steels are electrical steels with silicon content between 0.5% and 7% and provide reduced magnetostriction, significantly higher magnetic permeability and higher resistivity than mild steels. The resistivity of silicon steels increases with the silicon content ranging approximately from 0.2 $\mu\Omega\cdot$m to 0.9 $\mu\Omega\cdot$m, as compared to around 0.15 $\mu\Omega\cdot$m for mild steels. The higher resistivity of silicon steels compared to mild steels results in drastic reduction of the electromagnetic losses caused by eddy currents in bi-stable switch mechanisms, up to several times lower. Reducing the electromagnetic losses caused by eddy currents results in faster switching operation and in lower magnetic field intensity required to perform the switch operation. This means that the current pulse required to energize the winding of the core in order to perform the switch operation can feature lower time duration and lower magnitude resulting in much lower energy consumption and higher operating efficiency of the relay.

[0053] Silicon steels are usually available with guaranteed magnetic properties and electrical resistivity and allow thus better optimizing the design of bi-stable relays. Silicon steels are most commonly available in sheets and strips but other forms, such as bars, are also possible as for example the Class C alloys covered in the standard IEC60404-8-6. In order to minimize eddy currents it is preferred to use thin laminations produced from sheets and strips. If necessary, more laminations may be stacked in order to reach thicker assembles for the magnetic core and/or for the flux guides, in which case it is beneficial to provide a thin electrically insulating layer between the laminations in order to reduce the eddy currents. Silicon steel sheets and strips provided with thin insulating layers are being widely employed for manufacturing electrical motors, generators, and transformers. They have been optimized for providing superior magnetic and electrical properties, being well covered in standards such as IEC60404-8-3, IEC60404-8-4, and IEC60404-8-7. Commonly known as cold-rolled electrical steels, these materials are the most widely available processed silicon steels and can be grain-oriented or non-oriented. The magnetic properties of cold-rolled electrical steels are better along the rolling direction, especially for the grain-oriented materials. Depending on the material type and grade, the saturation magnetic induction B_s at a magnetic field of 5000 A/m ranges between 1.7 T and 2.0 T. The relatively high saturation induction of cold-rolled electrical steels allows achieving higher clamping forces and building more efficient devices. The thickness of the cold-rolled electrical steels sheets is typically comprised between 0.05 mm and 1.0 mm. The small thickness of the sheets is very advantageous for reducing the losses caused by eddy currents but it is not compatible with traditional designs of bistable relays.

[0054] The planar design of the magnetic core 5 and of the flux guides 7 described in this invention overcomes the limitations of traditional solutions and makes optimum use of the enhanced magnetic and electrical properties of cold-rolled electrical steels.

[0055] The losses caused by eddy currents are reduced both by providing a material with much higher resistivity and also by reducing the thickness of the laminations. Moreover, in the same time, the magnetic properties such as the saturation magnetic induction and the magnetic permeability are enhanced resulting in higher clamping forces and lower flux leakage. It is thus possible to drastically reduce the operation energy of the bi-stable switching mechanism, but also to reduce its size and mass and to improve its reliability, e.g. by providing faster switching time and/or better vibration and shock withstand.

[0056] The magnetic core 5 and flux guides 7 consist of one or more laminations, see figure 3, with the components fabricated in plane by standard manufacturing processes such as stamping. It is convenient to design the flux guides 7 such that their ends come in close vicinity to the magnetic core 5 in order to minimize the air gaps between the flux guides 7 and the core 5 leading to lower reluctance and better efficiency of the magnetic assembly. However, it is beneficial to increase the separation between the body of the flux guides 7 and the magnetic core 5 in order to reduce the magnetic flux leaking between the body of the flux guides 7 and the core 5. The magnetic flux shall be concentrated at the ends of the flux guides 7 such that the magnetic force between the flux guides and the magnetic core is maximized. The magnetic flux leaking between the body of the flux guides and the magnetic core does not contribute efficiently to support the desired magnetic force during latching or switching operation and decreases the magnetic efficiency of the assembly. It is thus desired to minimize the leakage flux and maximize the magnetic flux guided through the ends of the flux guides and the magnetic induction achieved at and near the latching surface.

[0057] This is achieved by using flux guides 7 which are C-shaped or arc shaped such that the plane of the C-shape or of the arc shape is in the plane of the electrical steel strip or sheet, as shown in Figure 3. The latching surface of the flux guide is used here to refer to the surface of the flux guide which is designed to come in contact or almost in contact to the magnetic core in a latched position.

[0058] In plane fabrication also allows for easy implementation of flux concentrator features near the ends of the flux guides. As shown in Figure 4, the ends of the flux guides may feature chamfers 11 on one or both sides with angles up to 50° from the latching surface 12. These chamfers 11 serve to concentrate the magnetic flux at the latching surface 12 of the flux guide 7 and maximize the value of the magnetic induction, resulting in increased latching force and efficiency of the relay.

[0059] Furthermore, the invention described here incorporates flux guides 7 with almost square cross section at the latching surface 12 which provides an approximately uniform distribution of the magnetic flux over the latching area. The almost uniform distribution of the magnetic flux allows maximizing the magnetic flux per unit area allowing further boosting the efficiency of the relay.

[0060] Electrical steel strips typically feature better magnetic properties along a preferred direction, which for example, is given by the rolling direction in cold-rolled electrical steel strips. Surprisingly it was found that the enhanced magnetic properties along the preferred direction of the electrical strip can be employed to boost the performance of the relay such as improving the efficiency and the clamping force. This is achieved by judiciously orienting the laminations employed to fabricate the magnetic core and the flux guides with respect to the preferred magnetic direction of the electrical steel strips. The magnetic reluctance and the magnetic losses of the core are decreased by orienting the core lamination(s) such that the longest dimension of the laminations is aligned along the preferred magnetic direction of the strips. It was found here that the optimum orientation of the laminations employed in the flux guides shall be selected with respect to the latching surface. The magnetic induction at the latching surface is maximized by orienting the flux guide laminations such that the latching surface is almost orthogonal to the preferred magnetic direction of the electrical steel strips. In this way it can be ensured that clamping force and the efficiency of the relay are maximized.

[0061] The magnetic flux is generated by one or more permanent magnets 8, 8a mounted between the flux guides 7, as shown for example in Figure 5. A unique feature of the inventive design is that the magnets 8, 8a are positioned on one side of the flux guides 7 so as to create a partially overlap not exceeding 40% of the width of the flux guide 7.

[0062] The permanent magnet(s) are positioned in close vicinity to the flux guides 7 and may come in contact with the flux guides 7 or be separated by a small gap. This approach has the advantages of better flux coupling, reduction of errors due to tolerances, as the magnets 8, 8a sit close and overlap with the flux guides 7. In addition, this arrangement increases the reliability of the relay body as the flux guides 7 are also held in place on the relay body by attractive forces exerted by the permanent magnets 8, 8a. This reduces the requirements on the mechanical fixations for the flux guides and/or for the permanent magnet(s) resulting in easier and cheaper construction of the relay..

[0063] Whether the holding force is achieved with a single magnet 8a or for instance, two separate magnets 8, the design according to the invention as shown here in the figures incorporates a hole through the center of mass of the relay body which acts as the bearing surface for a shaft 9 that fixes the axis of rotation, see figure 5. The careful selection of the center of mass as the axis of rotation greatly increases the reliability and resistance to the relay accidentally unlatching due to mechanical shock or vibration. In the various potential embodiments of the design, the flux guides 7 are either symmetrically mounted around the center of mass with a single magnet 8a that has a hole through the center or with two separate, equivalent, magnets 8 with the hole passing symmetrically between the two magnets 8.

[0064] One of the most important and assumed criteria for an ultra low energy relay, is that the switching motion has little resistance due to friction. In the design according to the invention as shown in the figures, low friction is achieved by the use of a shaft 9 made of non-ferroelectric metalling materials with copper as the main constituent. The shaft 9 has a head 13, middle and base section 14, 15, see Figure 6. The head 13 is designed to hold the relay in place and minimize motion along the shaft; while the middle section 14 provides a low fiction rotation surface. The base section 15 ensures that the shaft 9 is held in the housing at a specific position to prevent a compressive load on the relay from the remainder of the assembly.

[0065] The novel design presented in this invention allows maximizing the magnetic forces and the efficiency of bi-stable relays by employing an improved construction of the relay and superior magnetic materials such as electrical steels. This approach allows reducing the size of the magnetic parts involved in the construction of the relay resulting in lower cost, faster switching operation, and improved withstand of vibrations and shock due to the lower mass of the components. The reduced size of the magnetic core 5 allows to significantly reduce the size and the resistance of the electrical windings allowing to save on expensive wire material, usually copper, and to further improve the efficiency of the relay.

List of reference signs

1	Bistable relay
2	Auxiliary contact
3	Auxiliary contact
4	Driving coil
5	Latching core
6	Contact bridge
7	Flux guide
8, 8a	Permanent magnet
9	Shaft
11	Chamfered edge
12	Latching or contact surface
13	Head
14	Middle section
15	Base section
16	Center of rotation
20	Latching contact
22	Latching contact
48	Spring
58	spring
62	Mechanical flux guide
64	Mechanical flux guide
66	Housing magnets
70	Extension
72	Extension
R	Arrow indicating rolling direction

Claims

1. A bi-stable relay (1) consisting of a supporting structure carrying at least one set of electrical contacts, a U-shaped magnetic core (5) being fixed to the supporting structure, electrical winding around the said core (5), and an armature provided with means to pivot around a rotation axis and where the said armature comprises a frame supporting two springs, at least one contact bridge (6), one or more permanent magnets (8, 8a), and two flux guides (7) **characterized in that**

- the flux guides (7) are symmetrically arranged with respect to the rotation axis
- the flux guides (7) and the magnetic core (5)

feature a planar layout

- the major plane of the flux guides (7) is positioned perpendicular to the major plane of the magnetic core (5)
- the flux guides (7) and the magnetic core (5) are made from one or more laminations being stacked together
- the center of mass of the frame is approximately located on the rotation axis.

2. A bi-stable relay (1) according to claim 1, where the laminations composing the flux guides (7) and the magnetic core (5) are made from strips or sheets of electrical steel with silicon content between 0.5% and 7%.

3. A bi-stable relay (1) according to any of claims 1 or 2, where the flux guides (7) are C-shaped or arc shaped such that the plane of the C-shape or of the arc shape is in the plane of the electrical steel strip or sheet.

4. A bi-stable relay (1) according to any of claims 1 to 3, where the flux guides (7) are provided with at least one chamfer near the contact surface (12) between the flux guides (7) and the core (5).

5. A bi-stable relay (1) according to any of claims 1 to 4, where the latch surface (12) between the flux guides (7) and the core (5) is rectangular such that the ratio between the long edge to the short edge of the rectangle is smaller than 1.6.

6. A bi-stable relay (1) according to any of claims 2 to 5, where the flux guides (7) and/or the magnetic core (5) are made from cold-rolled electrical steel strips or sheets which have the thickness comprised between 0.1 mm and 1 mm and are provided with an electrically insulating layer.

7. A bi-stable relay (1) according to any of claims 1 to 6, where the permanent magnets (8, 8a) are mounted such that they partly overlap with the flux guides (7) to result in direct contact or a very small air gap between the magnets (8, 8a) and the flux guides (7).

8. A bi-stable relay (1) according to any of claims 1 to 7, where the ends of the magnetic core (5) are rigidly inserted into holes provided into the supporting structure and the width of the core features at least one step near the inserted ends to limit the insertion depth, and where the cross-section profile of the insertion holes present recessed and/or protruded regions to enable smooth and precise mounting of the core to the supporting structure by press fit.

9. A bi-stable relay (1) according to any of claims 1 to 8, including a pivot pin and a bearing hole enabling free rotation motion of the armature with respect to the supporting structure and where the pivot pin is provided with a stopper such as a collar or a bump to prevent free translation motion between the pivot pin and the bearing hole or separation of the two.

10. A bi-stable relay (1) according to claim 9, where the pivot pin is part of the supporting structure or is a separate part having one of its end rigidly inserted into a hole provided in the supporting structure and where the pivot pin passes through a bearing hole provided in the armature such that the armature can freely rotate around the pivot pin.

11. A bi-stable relay (1) according to claim 9, where the pivot pin is part of the armature frame or is a separate part having one of its end rigidly inserted into a hole provided into the armature frame and where the pivot pin passes through a bearing hole provided in the supporting structure such that the pin can freely rotate inside the bearing hole.

12. A bi-stable relay (1) according to any of claims 9 to 11, where the pivot pin is a separate part and its diameter is smaller around the rigidly inserted end than around the bearing region and where the pivot pin is preferably made of metal such as brass.

13. A bi-stable relay (1) according to any of claims 6 to 12, where the core laminations are cut or stamped from electrical steel strips or sheets such that the longest dimension of the laminations is aligned along the rolling direction of the strip.

14. A bi-stable relay (1) according to any of claims 6 to 13, where the flux guide laminations are cut or stamped from electrical steel strips or sheets such that the direction of the latching surface is aligned orthogonal to the rolling direction of the strip.

15. A bi-stable relay (1) according to any of claims 9 to 14, where the armature comprises two magnets (8) mounted on the sides of the pivot pin in a symmetric arrangement.

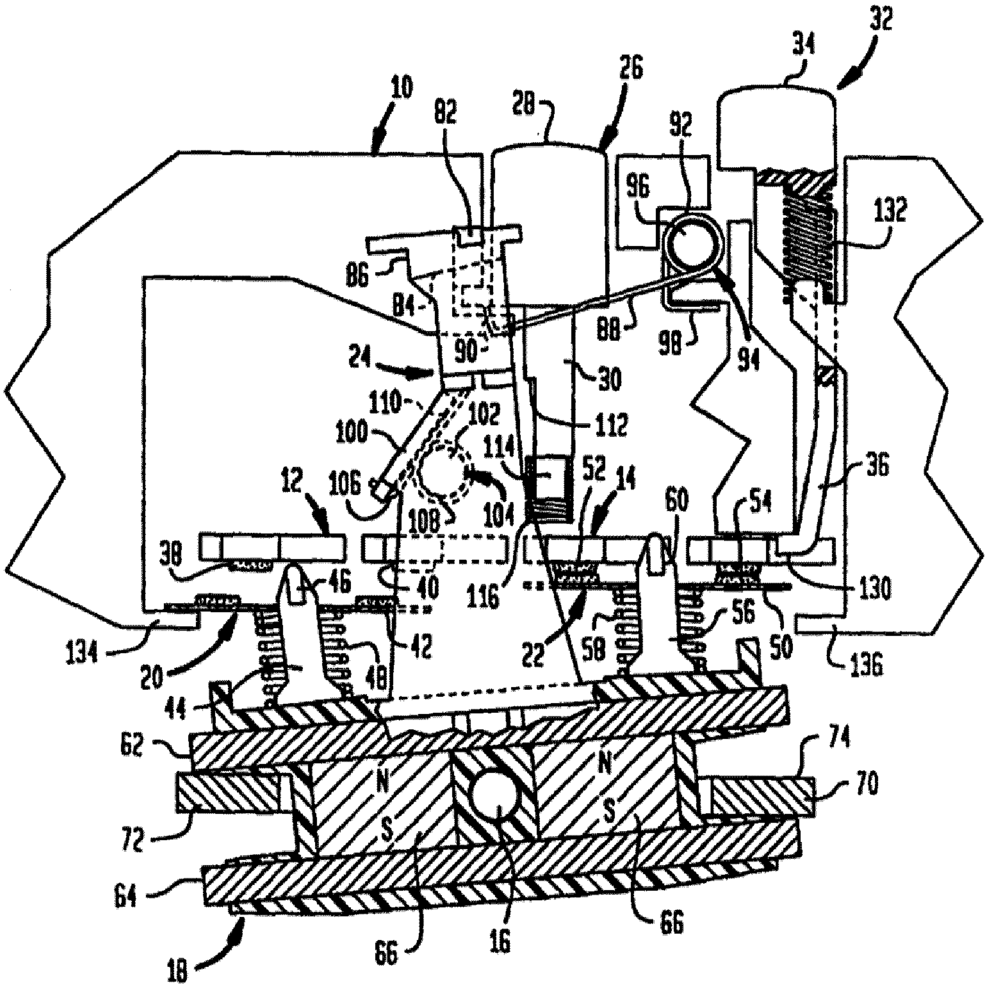

10
82
28
26
34
32
92
96
132
86
84
90
88
98
94
24
30
110
102
112
100
114
52
14
60
54
36
106
108
104
12
38
46
40
116
22
130
134
20
42
48
58
56
50
136
44
62
N
N
S
S
74
70
72
64
66
16
66
18

Fig. 1

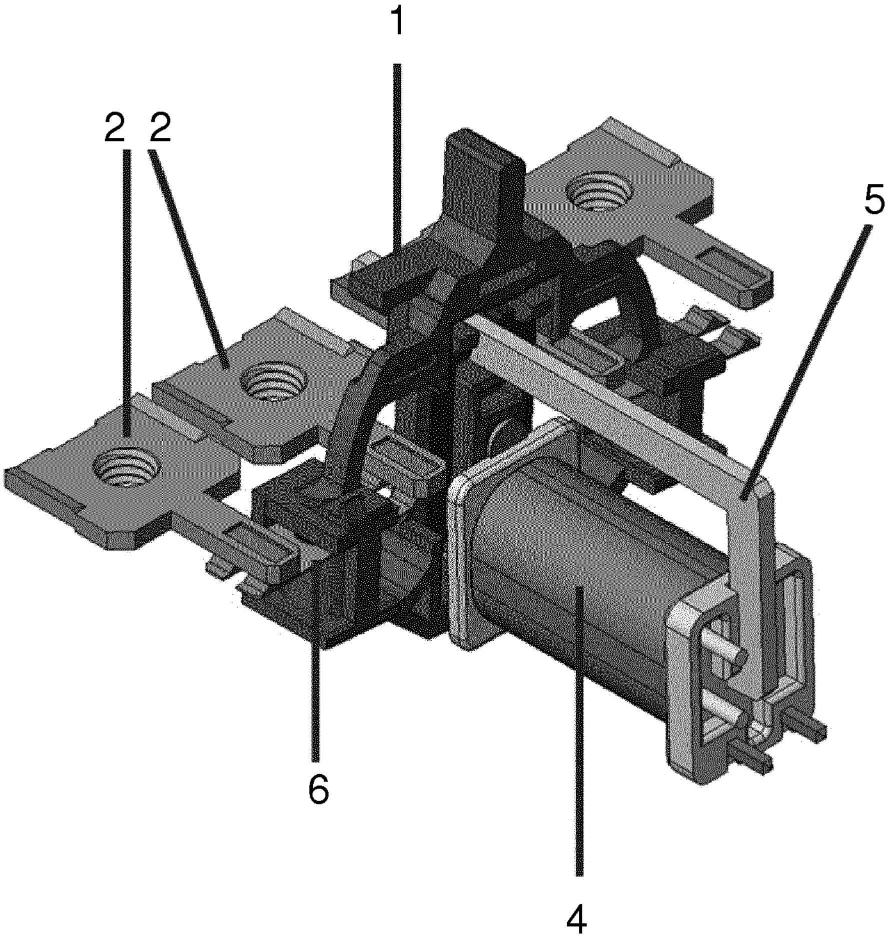


Fig. 2

Fig. 3(b)

Fig. 3(a)

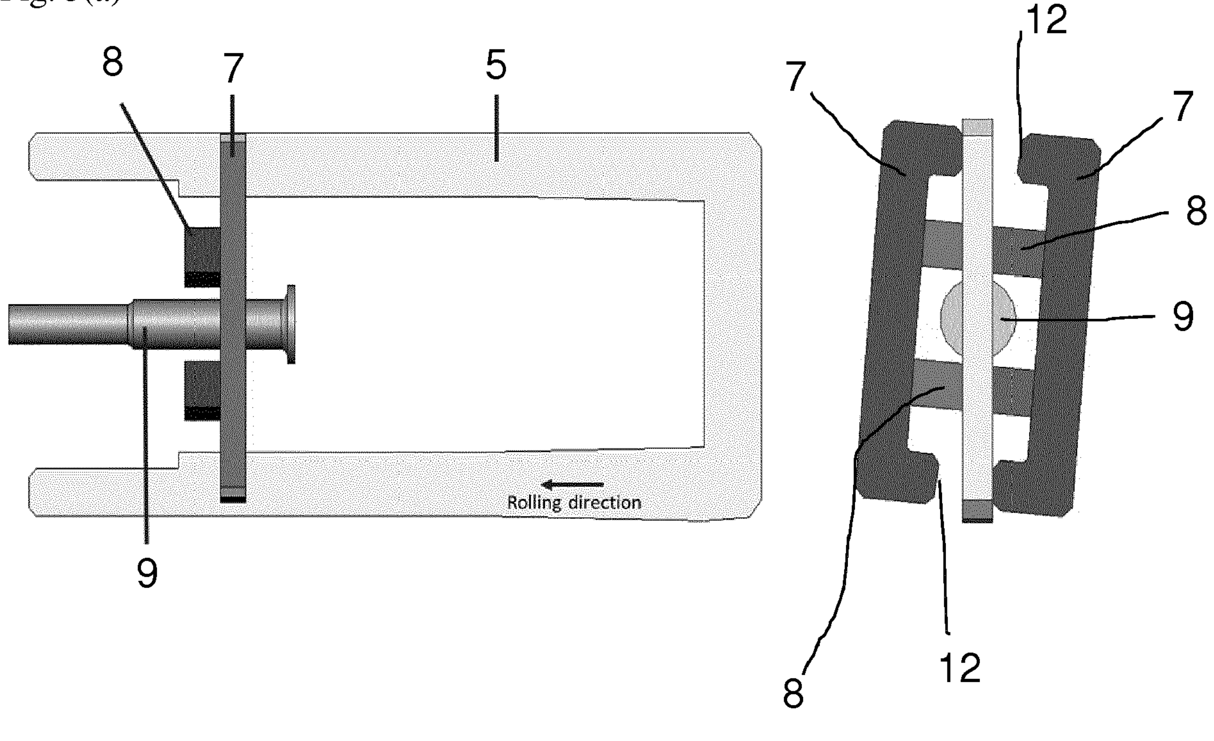
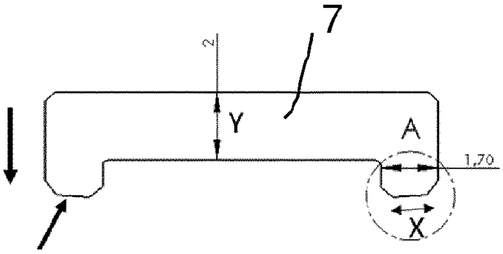


Fig. 3

Fig. 4(a)



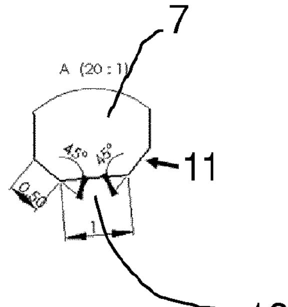


Fig. 4(b)

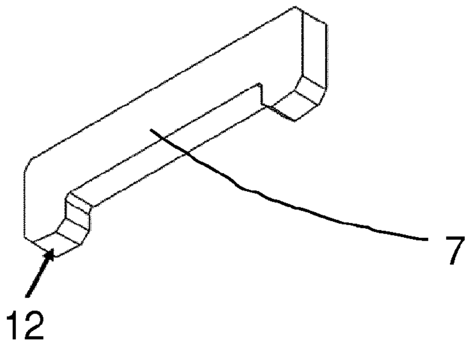


Fig. 4 (c)

Fig. 4

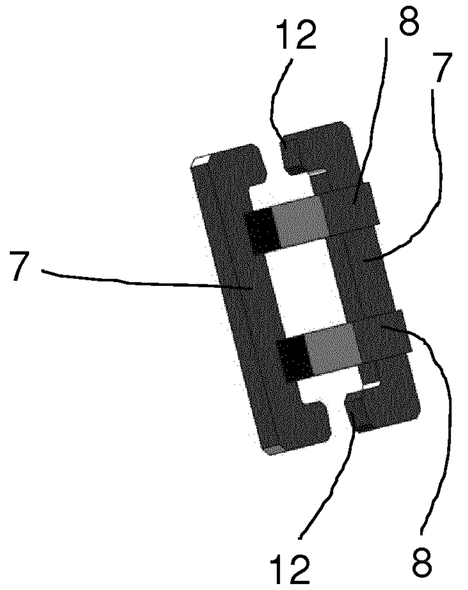


Fig. 5(a)

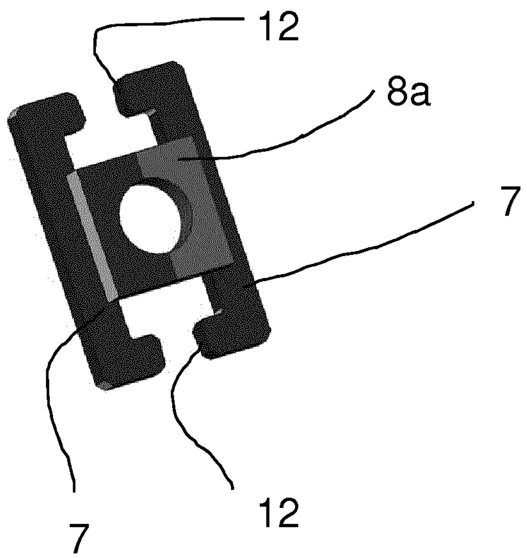


Fig. 5(b)

Fig. 5

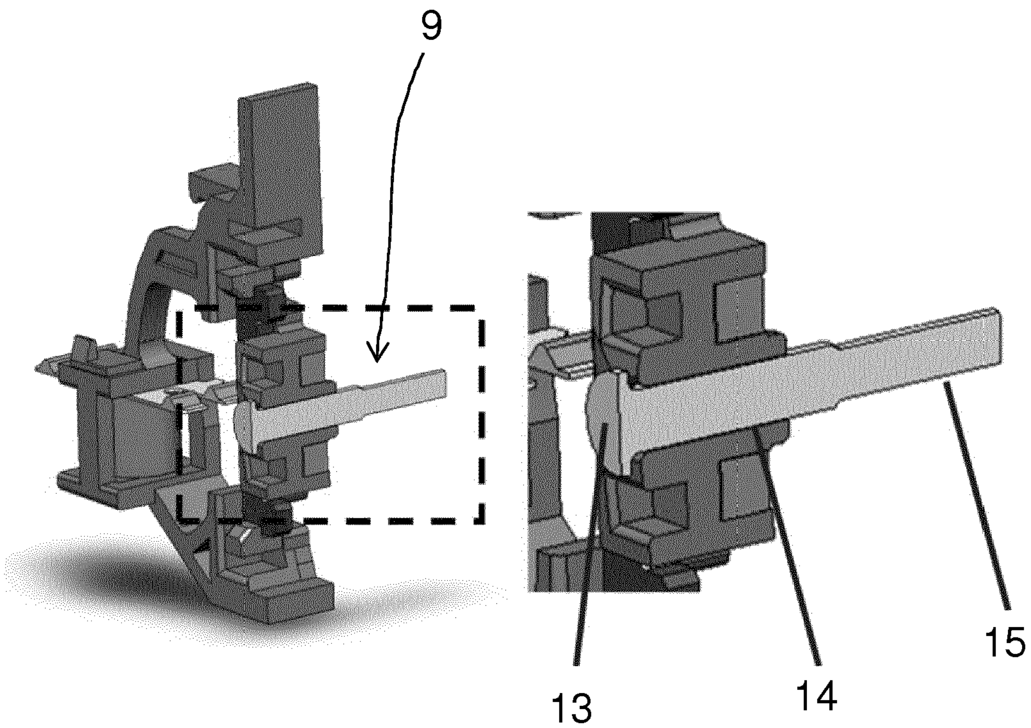


Fig. 6

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 16 20 5806

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y,D	EP 0 974 155 B1 (SIEMENS ENERGY & AUTOMAT [US]) 2 October 2002 (2002-10-02) * paragraph [0001] * * paragraph [0015] - paragraph [0024] * * figures 1-12 * -----	1-15	INV. H01H51/22 H01H51/27 ADD. H01H50/22
Y	GB 2 193 041 A (BACH & CO) 27 January 1988 (1988-01-27) * page 1, lines 5-14 * * page 1, line 107 - page 2, line 99 * * page 3, line 90 - page 4, line 25 * * figures 1-4 * -----	1-15	
Y	US 2013/229246 A1 (FUJITA KEN [JP] ET AL) 5 September 2013 (2013-09-05) * paragraph [0001] * * paragraph [0069] - paragraph [0071] * * figures 1-18B * -----	3-5	
Y	US 2009/039989 A1 (REUBER CHRISTIAN [DE]) 12 February 2009 (2009-02-12) * paragraph [0002] * * paragraph [0038] * * paragraph [0051] * -----	2,6,13, 14	TECHNICAL FIELDS SEARCHED (IPC) H01H
Y	JP 2012 102398 A (DOWA METALTECH KK) 31 May 2012 (2012-05-31) * paragraph [0001] * * paragraph [0025] - paragraph [0026] * * paragraph [0036] - paragraph [0039] * -----	2,6,13, 14	

1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	17 February 2017	Hristov, Stefan

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 16 20 5806

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

17-02-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0974155 B1	02-10-2002	CN 1252163 A	03-05-2000
		DE 69808446 D1	07-11-2002
		DE 69808446 T2	20-03-2003
		EP 0974155 A1	26-01-2000
		ES 2185158 T3	16-04-2003
		JP 4365457 B2	18-11-2009
		JP 2001520795 A	30-10-2001
		US 6020801 A	01-02-2000
		US 6025766 A	15-02-2000
		WO 9847164 A1	22-10-1998
GB 2193041 A	27-01-1988	DE 3645337 C2	14-08-1997
		GB 2193041 A	27-01-1988
US 2013229246 A1	05-09-2013	CN 103222023 A	24-07-2013
		EP 2648203 A1	09-10-2013
		KR 20130111566 A	10-10-2013
		US 2013229246 A1	05-09-2013
		WO 2012073780 A1	07-06-2012
US 2009039989 A1	12-02-2009	AT 515785 T	15-07-2011
		AU 2007233934 A1	11-10-2007
		BR PI0710042 A2	02-08-2011
		CN 101410923 A	15-04-2009
		EP 1843375 A1	10-10-2007
		EP 2005456 A1	24-12-2008
		ES 2369372 T3	30-11-2011
		HK 1131254 A1	26-10-2012
		RU 2008143300 A	10-05-2010
		UA 93899 C2	25-03-2011
		US 2009039989 A1	12-02-2009
		WO 2007113006 A1	11-10-2007
JP 2012102398 A	31-05-2012	JP 5734156 B2	10-06-2015
		JP 2012102398 A	31-05-2012

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- EP 0974155 B1 **[0003]**
- DE 102009043105 A1 **[0003]**