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(71) Applicant: **MAGNA POWERTRAIN, INC.** [CA/CA]; 50 Casmir Court, Concord, ON L4K 4J5 (CA).

(72) Inventors: **GREENE, Darrell, F.**; 38 Aishford Road, Bradford, ON L3Z 3E2 (CA). **CIOC, Adrian, C.**; 203 Weldrick Road West, Richmond Hills, ON L4K 4J2 (CA). **STEELE, Sean, A.**; 2619 Kenna Court, Mississauga, ON L5K 2K5 (CA). **LOUI, Dennis, T.**; 18 Pagehurst Court, Richmond Hill, ON L4C 8G6 (CA). **SAMILA, Myron, R.**; 155 Renault Crescent, Toronto, ON M9P 1J8 (CA). **DORIGO, David, C.**; 800 Tesma Way, Concord, ON L4K 5C2 (CA).

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(54) Title: ELECTRONICALLY-CONTROLLED SELECTABLE CLUTCH ASSEMBLY WITH CLUTCH MODULE HAVING INTEGRATED SAFETY SWITCH

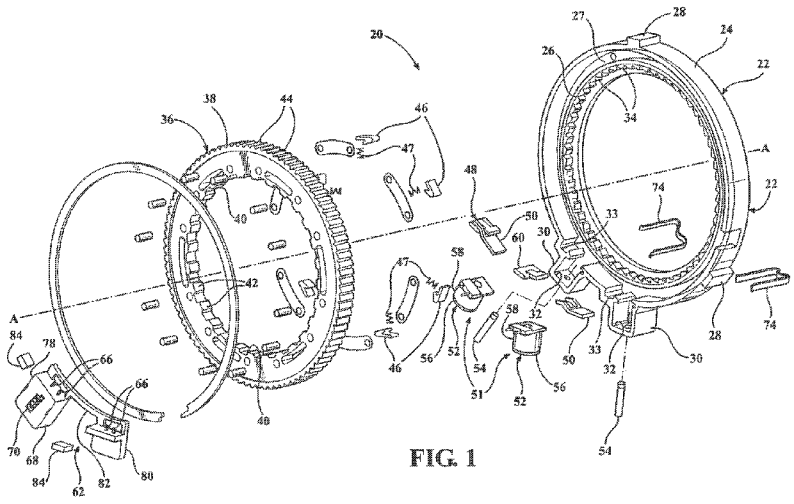

FIG. 1

(57) Abstract: A clutch assembly includes an outer race presenting a plurality of outer ratchet teeth and an inner race presenting a plurality of outer ratchet teeth. A selectable one-way clutch includes at least one active strut pivotably supported by the outer race and at least one electromagnetic actuator. The electromagnetic actuator is selectively energized for effectuating pivoting of the active strut from an unlocked position wherein the active strut is disengaged from the outer ratchet teeth to a locked position for engaging one of the plurality of outer ratchet teeth during rotation of the inner race. The clutch assembly includes a lead frame assembly attached to the outer race and electrically connected to the at least one electromagnetic actuator for controlling selective energization of the at least one electromagnetic actuator.

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ELECTRONICALLY-CONTROLLED SELECTABLE CLUTCH ASSEMBLY WITH CLUTCH MODULE HAVING INTEGRATED SAFETY SWITCH

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/152,137 filed April 24, 2015 and U.S. Provisional Application No. 62/270,212 filed December 21, 2015, the entire disclosures of which are incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present disclosure is generally related to overrunning coupling devices such as one-way clutches or brakes and, more specifically to selectable one-way coupling (SOWC) devices having an electromagnetic actuator assembly.

BACKGROUND OF THE INVENTION

[0003] This section provides background information related to the present disclosure which is not necessarily prior art.

[0004] Automatic transmissions provide a plurality of forward and reverse speed or gear ratios by selectively actuating one or more clutches and/or brakes to establish a torque-transmitting drive connection between a transmission input and a transmission output for supplying motive power (i.e., drive torque) from a powertrain to a driveline in a motor vehicle. One type of brake or clutch widely used in automatic transmission is an overrunning coupling device, commonly referred to as a one-way clutch (OWC), which overruns when one of its races (in radial coupling configuration) or one of its drive plates (in axial coupling configurations) rotates in a first (i.e., freewheel) direction relative to the other race or drive plate, and engages or locks in a second (i.e., lockup) direction. Such conventional one-way clutches provide no independent control over their modes of operation, that is to say whether they lockup or freewheel in both directions and are commonly referred to as passive one-way clutches. Thus, basic one-way clutches provide a "locked" mode in one rotary direction and a

"freewheel" mode in the opposite direction based on the direction that the drive torque is being applied to the input race or drive plate.

[0005] There are however, requirements in modern automatic transmissions where a "controllable" overrunning coupling device, commonly referred to as a selectable one-way clutch (SOWC), can be selectively controlled to provide additional functional modes of operation. Specifically, a selectable one-way clutch may further be capable of providing a freewheel mode in both rotary directions until a command signal (i.e., from the transmission controller) causes a power-operated actuator to shift the coupling device into its lockup mode. Thus, a selectable one-way clutch may be capable of providing a drive connection between an input member and an output member in one or both rotational directions and it may also be operable to freewheel in one or both directions. It is also known in modern automatic transmissions to integrate a passive one-way clutch and a selectable one-way clutch into a combined coupling device, commonly referred to as a bi-directional clutch.

[0006] A need exists to continue development of new and improved overrunning coupling devices that advance the art and provide enhanced functionality.

SUMMARY OF THE INVENTION

[0007] A clutch assembly includes an outer race presenting a plurality of inner ratchet teeth and an inner race presenting a plurality of outer ratchet teeth. A selectable one-way clutch includes at least one active strut pivotably supported by the outer race and at least one electromagnetic actuator. The electromagnetic actuator is selectively energized for effectuating pivoting of the active strut from an unlocked position wherein the active strut is disengaged from the outer ratchet teeth to a locked position for engaging one of the plurality of outer ratchet teeth during rotation of the inner race.

[0008] The clutch assembly includes a lead frame assembly attached to the outer race and electrically connected to the at least one electromagnetic actuator for

controlling the selective energization of the at least one electromagnetic actuator. The integration of the lead frame assembly into the clutch assembly disposes the electronic controls near the electromagnetic actuator which leads to improved packaging and reduced wiring.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The drawings described herein are for illustrative purposes only of selected embodiments and are not intended to limit the scope of the present disclosure. The inventive concepts associated with the present disclosure will be more readily understood by reference to the following description in combination with the accompanying drawings wherein:

[0010] FIG. 1 is an exploded perspective view of a clutch assembly configured to include a passive one-way clutch and a selectable one-way clutch having an electromechanical actuator;

[0011] FIG. 2 is an assembled perspective view of the clutch assembly illustrating a lead frame assembly attached to the clutch assembly and electrically connected to an electromagnetic actuator;

[0012] FIG. 3 is a front view of the lead frame assembly of FIGs 1 and 2; and

[0013] FIG. 4 is an examplary circuit of a printed circuit board (PCB) integrated into the lead frame assembly.

DESCRIPTION OF THE ENABLING EMBODIMENTS

[0014] Example embodiments will now be described more fully with reference to the accompanying drawings. In general, each embodiment is directed to an overrunning coupling device (i.e. brake and/or clutch) having at least a controllable one-way locking device including a moveable locking component (i.e. sprag, strut, etc.) that is controlled via an electromagnetic actuator. Thus, the electromechanical rocker clutch

transmits torque mechanically but is actuated via an electrical actuation system. However, the example embodiments are only provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail.

[0025] Referring to the Figures, wherein like numerals indicate corresponding parts throughout the several views, a bi-directional clutch assembly 20 is generally shown. As will be detailed, bi-directional clutch assembly 20 generally includes a stationary outer race, a rotatable inner race, a passive one-way clutch having a plurality of passive struts, and a selectable one-way clutch having at least one active strut assembly and an electromagnetic actuator. The clutch assembly 20 includes an outer race 22 that extends annularly about an axis A. The outer race 22 includes an outer ring segment 24 and an inner ring segment 26 that are spaced radially from one another and interconnected via a radial web segment 27. The outer ring segment 24 presents a plurality of outer lugs 28 that extend radially outwardly for mating with a first component. The first component can be a stationary component (such as a housing of a transmission) or a rotary component (such as a shaft). The outer ring segment 24 further presents a pair of protrusions 30 that extend radially outwardly. Each of the protrusions 30 defines a radially extending actuator pocket 32 and a strut pocket 33. It should be appreciated that more or fewer protrusions 30 could be utilized. The inner ring segment 26 presents a plurality of inner ramp surfaces, hereinafter referred to as inner ratchet teeth 34,

that extend radially inwardly and are evenly distributed or spaced from one another about the axis A.

[0026] The clutch assembly 20 further includes an inner race 36 that also extends annularly about the axis A. The inner race 36 has an outer rim 38 and an inner rim 40 that are spaced radially from one another. The outer rim 38 is disposed radially between the outer and inner ring segments 24, 26 of the outer race 22, and the inner rim 40 is disposed radially inwardly from the inner ring segment 26 of the outer race 22. The inner rim 40 of the inner race 36 presents a plurality of inner lugs 42 that extend radially inwardly for mating with a second component (typically a rotary component). Commonly, lugs 42 interconnect a shaft or clutch plates for rotation with inner race 36. Further, the outer rim 38 of the inner race 36 presents a plurality of outer ramp surfaces, hereinafter referred to as outer ratchet teeth 44, that extend radially outwardly and are evenly distributed or spaced from one another about the axis A.

[0027] The passive one-way forward clutch includes a plurality of locking elements or passive struts 46 that are pivotally supported in strut apertures formed in the inner race 36 for pivoting between a locking position and an unlocking position. As best shown in Figure 1, the passive struts are biased towards the locking position by a biasing member 47, such as a spring or the like. In the locking position, the passive struts 46 engage the inner ratchet teeth 34 of the outer race 22 to define a forward engagement position for connecting the outer and inner races 22, 36 to one another during counter-clockwise rotation of the inner race 36 relative to the outer race 22. Therefore, the forward engagement position established by one or more of the passive struts 46 prevents relative displacement of the outer and inner races 22, 36 in the counter-clockwise direction. However, the passive struts 46 still allow relative displacement, i.e., overrun, in the clockwise direction when located in the locking position since they ratchet over the ramped profile of the inner ratchet teeth 34 and

are radially spaced from the inner ratchet teeth 34 of the outer race 22 to establish the unlocking position.

[0028] As shown in Figure 1, the selectable one-way reverse clutch includes an active strut assembly 48 received by each of the strut pockets 33 of the outer ring segment 24. Each of the active strut assemblies 48 includes an active strut 50 that is selectively pivotable between a locked and an unlocked position. In the locked position, the active strut 50 lockingly engages the outer ratchet teeth 44 of the inner race 36 during clockwise movement of the inner race 22 relative to the outer race 22 to define a reverse engagement position thereby locking the outer and inner races 22, 36 to one another. However, the active strut 50 still allows relative displacement, i.e., overrun, in the counter-clockwise direction. In the unlocked position, the active strut 50 is radially spaced from the outer ratchet teeth 44, allowing the inner and outer races 22, 36 to rotate relative to one another. Furthermore, as best illustrated in Figure 1, each of the active strut assemblies 48 includes an armature 60 that is disposed adjacent to the active strut 50 for providing the pivotal movement of the active strut 50.

[0027] The selectable one-way reverse clutch also includes at least one electromagnetic actuator 51, each including a coil assembly 52 mounted in the actuator pocket 32 and radially spaced from the active strut 50 and armature 60. The coil assembly 52 includes a core 54 of a magnetically permeable material, a bobbin 56 disposed about the core 54, and a coil 58 wrapped about the bobbin 56. Furthermore, the armature 60 is disposed between the active strut 50 and the coil 58 for pivoting toward the core 54 and thus providing the pivotal movement of the active strut 50 in response to energization of the coil 58.

[0028] More specifically, when voltage and/or current are applied to the coil 58, the coil 58 becomes an electromagnet producing an electric field (or flux). The flux flows outwards in all directions and transfers through the small air gap between the armature 60 and

core 54 in the center of the coil assembly 52. The core 54 becomes magnetized, therefore attracting the armature 60 towards the core 54. The resulting motion forces the active strut 50 to mechanically deploy due to the linkage between the active strut 50 and the armature 60. On deployment, the active strut 50 moves from its unlocked position to its locked position where it locates itself against one of the outer ratchet teeth 44 of the inner race 36 to define the reverse engagement position, effectively locking the inner race 36 from rotating in that direction. Disengagement occurs as voltage and/or current is removed from the coil assembly 52, wherein the armature 60 is demagnetized and free from the coil assembly 52. A biasing spring (not shown) is positioned between the active strut 50 and the outer race 22, causing the active strut 50 to move back to its unlocked position during disengagement.

[0029] It should be appreciated that the arrangement of the armature 60, active strut 50, and coil assembly 52 can act to apply a locking force in a radial direction (as shown in FIG. 1) or an axial direction, depending on the layout and/or requirements of the clutch assembly 20. Radial stacked clutch assembly 20 designs offer packaging advantages over their axial counterparts in situations where axial space is tight, e.g., in automatic transmissions. Further, radially applied clutches transmit driving torque directly outwards to be grounded against the transmission housing without the fear of forces being directed axially which could cause problems for the sizing of other system components to compensate for axial force.

[0030] A lead frame assembly 62 is attached to the outer race 22 and electrically connected to the at least one electromagnetic actuator 51 for controlling the energizing of the coil assemblies 52. As best illustrated in Figures 2 and 3, the lead frame assembly 62 includes and integrates a printed circuit board (PCB) 64 for selectively controlling the energization of the at least one electromagnetic actuator 51, and specifically the coils 58 of the coil assemblies 52. In that regard, and as best illustrated in Figure 3, the

lead frame assembly 62 includes at least one set of power output contacts 66 that extend from the lead frame assembly 62 and are disposed in electrical contact with the coil 58 to provide power to the coil 58. In a preferred arrangement, a resistance welded connection is utilized to connect the power output contacts 66 and the coil 58, however, other connections could alternatively be utilized without departing from the scope of the subject disclosure. The lead frame assembly 62 includes at least one wire which extends between the printed circuit board 64 and each of the power output contacts 66 for electrically connecting the circuit board 64 and the set of power output contacts 66. The selective energization of the coils 58 by way of the printed circuit board 64 effectuates pivotable movement of the active clutch 50 from the unlocked to the locked position for engaging one of the plurality of outer ratchet teeth 44 during rotation of the inner race 36.

[0031] As best illustrated in Figures 1-3, the lead frame assembly 62 includes a casing 68 which encapsulates the printed circuit board 64 to protect the printed circuit board 64 and its associated electrical wiring from an operating environment of the clutch assembly 20. As an example, the casing 68 allows the lead frame assembly 62 to be submerged in automatic transmission fluid and operate in a wide range of temperatures, such as from -40C to +140C. In a preferred and non-limiting embodiment, the casing 68 is molded and comprised of plastic material, such as Nylon 6/6 or the like, and the printed circuit board 64 is soldered into the lead frame assembly 62 with an epoxy acting as a hermetic seal to ATF. As best illustrated in Figure 3, the casing 68 includes a connection interface 70 for establishing an electrical connection between the printed circuit board 64 and an external control module (not expressly shown), such as a transmission control module (TCM) or a powertrain control module (PCM) for allowing data and power to be transmitted the printed circuit board 64.

[0032] Figure 4 illustrates an exemplary embodiment of a circuit 72 that could be utilized with the printed circuit board 64 according to an aspect of the disclosure. With reference to Figure 4, the voltage applied to the coils 58 via the exiting terminals of the circuit 72 is comprised of a High Side HS and Low Side LS which, in a non-limiting example, is supplied by the TCM or the PCM of a vehicle. The High Side HS is typically a shared power supply with other loads, and the Low Side LS is typically a discrete channel that controls the discrete/individual circuit. The Low Side LS is capable of controlling the amount of current across the coils 58. The circuit 72 also includes a power ground G. A High Side Fail Safe Switch HSFSS is incorporated into the circuit 72 of the printed circuit board 64, and thus integrated into lead frame assembly 62, to add another level of logic in order to control the shared High Side HS supply. The High Side Fail Safe Switch HSFSS is comprised of a High Side Switch, a transistor, and passive components each electrically integrated into the lead frame assembly 62. Thus, it should be appreciated that the configuration of the lead frame assembly 62 protects the integrated electronic components (including the HSFSS) and provides improved packaging and reduced wiring. Additionally, the direct connection of the circuit 72 (including the HSFSS) to the coil assemblies 52 through the lead frame assembly 62 provides a low-cost, modular solution that provides for a more simplified manufacturing process.

[0033] As best illustrated in Figure 3, the lead frame assembly 62 which includes the printed circuit board 64 is attached or connected to the outer race 22 and is disposed next to or adjacent the electromagnetic actuator 51. Specifically, in a non-limiting arrangement, the lead frame assembly 62 is disposed in overlaying relationship with and interconnected to the protrusions 30 to cover the actuator pockets 32 and enclose the electromagnetic actuators 51 therein. Accordingly, the circuit board 64 is disposed radially and axially adjacent to each one of the coils 58 of the electromagnetic actuators 51. As best

illustrated in Figures 1 and 2, a clip 74 is disposed in surrounding relationship with each of the protrusions 30, and the lead frame assembly 62 defines a plurality of detents 76 for receiving the clip 74 and establishing an interlocked relationship between the lead frame assembly 62 and the outer race 22.

[0034] In a preferred and non-limiting arrangement, the outer race 22 includes two protrusions 30 which each define an actuator pocket 32 for receiving an electromagnetic actuator 51. The lead frame assembly 62 has a first portion 78 disposed in overlaying relationship with a first of the two actuator pockets 32 and a second portion 80 disposed in overlaying relationship with a second of the two actuator pockets 32. The lead frame assembly also includes a first set of power output contacts 66 disposed in electrical contact with a first coil assembly 52 and a second set of power output contacts 66 disposed in electrical contact with a second coil assembly 52. The lead frame assembly has a bridge portion 82 which interconnects the first portion 78 and the second portion 80 and includes a wire extending therethrough to establish electrical connection of the first and second coil assemblies 52 of the electromagnetic actuators 51 to one another in series or in parallel. As best illustrated in Figure 2, a terminal cap 84 is interconnected to each set of power output contacts 66 to shield each power output contact 66 within the first and second sets of power contacts 66 from one another. Although the clutch assembly 20 is illustrated and described with respect to a pair of electromagnetic actuators 51, it should be appreciated that the lead frame assembly 62 could connect any number of coils assemblies 52 in series, and that any number of power contacts 66 could be utilized to power any number of coils 58.

[0035] It should be appreciated that the foregoing description of the embodiments has been provided for purposes of illustration and the modular configuration of the lead frame assembly 62 and associate components could be utilized on other clutch

assembly configurations, e.g., axially engaging clutch assemblies. In other words, the subject disclosure it is not intended to be exhaustive or to limit the disclosure. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varies in many ways. Such variations are not to be regarded as a departure from the disclosure, and all such modifications are intended to be included within the scope of disclosure.

CLAIMS

What is claimed:

1. A clutch assembly comprising:

an outer race presenting a plurality of inner ratchet teeth;

an inner race presenting a plurality of outer ratchet teeth;

a selectable one-way clutch including at least one active strut pivotably supported by said outer race and at least one electromagnetic actuator supported by said outer race for selectively pivoting said at least one active strut from an unlocked position wherein said active strut is disengaged from said outer ratchet teeth to a locked position for engaging one of said plurality of outer ratchet teeth during rotation of said inner race; and

a lead frame assembly attached to said outer race and electrically connected to said at least one electromagnetic actuator for controlling energization of said at least one electromagnetic actuator.

2. A clutch assembly as set forth in claim 1 wherein said lead frame assembly includes an integrated printed circuit board (PCB) for selectively controlling the energization of said at least one electromagnetic actuator.

3. A clutch assembly as set forth in claim 2 wherein said integrated printed circuit board includes a fail safe switch.

4. A clutch assembly as set forth in claim 1 wherein said at least one electromagnetic actuator includes a coil assembly and said lead frame includes at least one power output contact disposed in electrical contact with said coil assembly.

5. A clutch assembly as set forth in claim 2 wherein said lead frame assembly includes a casing to encapsulate said integrated PCB.

6. A clutch assembly as set forth in claim 5 wherein said casing is molded to and said integrated PCB is soldered into the molded casing.

7. A clutch assembly as set forth in claim 5 wherein casing of said lead frame assembly includes a connection interface to establish an electrical connection to an external control module for receiving data and power at said integrated PCB.

8. A clutch assembly as set forth in claim 1 further comprising:

said outer race including at least one protrusion which defines an actuator pocket,

said at least one electromagnetic actuator disposed within said at actuator pocket, and

said lead frame assembly disposed in overlaying relationship with said at least one protrusion to enclose said electromagnetic actuator within said actuator pocket.

9. A clutch assembly as set forth in claim 8 wherein said lead frame assembly is interconnected to said at least one protrusion of said outer race.

10. A clutch assembly as set forth in claim 9 further comprising a clip disposed in surrounding relationship with said at least one protrusion and interlocked to said lead frame assembly to interconnect said lead frame assembly to said outer race.

11. A clutch assembly as set forth in claim 10 wherein said lead frame assembly defines a plurality of detents for receiving said clip to establish said interlocked relationship.

12. A clutch assembly as set forth in claim 8 wherein said outer race includes a plurality of protrusions each defining an actuator pocket, and said at least one electromagnetic actuator includes a plurality of electromagnetic actuators each

disposed within a respective actuator pocket, and said lead frame assembly is disposed in overlaying relationship with each of said plurality of protrusions to enclose said plurality of electromagnetic actuators within said plurality of actuator pockets.

13. A clutch assembly as set forth in claim 12 wherein each of said plurality of electromagnetic actuators includes a coil assembly and said lead frame assembly includes a plurality of power output contacts each disposed in electrical contact with one of said coil assembly to electrically connect said coil assemblies to one another in series or in parallel.

14. A clutch assembly as set forth in claim 13 further comprising:

wherein said outer race defines two actuator pockets,

wherein said plurality of electromagnetic actuators including two electromagnetic actuators each disposed within a respective actuator pocket,

said lead frame assembly having a first portion disposed in overlaying relationship with a first actuator pocket and including a first set of power output contacts disposed in electrical contact with a first coil assembly,

said lead frame assembly having a second portion disposed in overlaying relationship with a second actuator pocket and including a second set of power output contacts disposed in electrical contact with a second coil assembly, and

said lead frame assembly having a bridge portion interconnecting said first portion and said second portion to establish said electrical connection of said first and second coil assemblies to one another in series.

15. A clutch assembly as set forth in claim 14 further comprising:

a terminal cap interconnected to each set of power output contacts to shield each power output contact within said first and second sets of power contacts from one another.

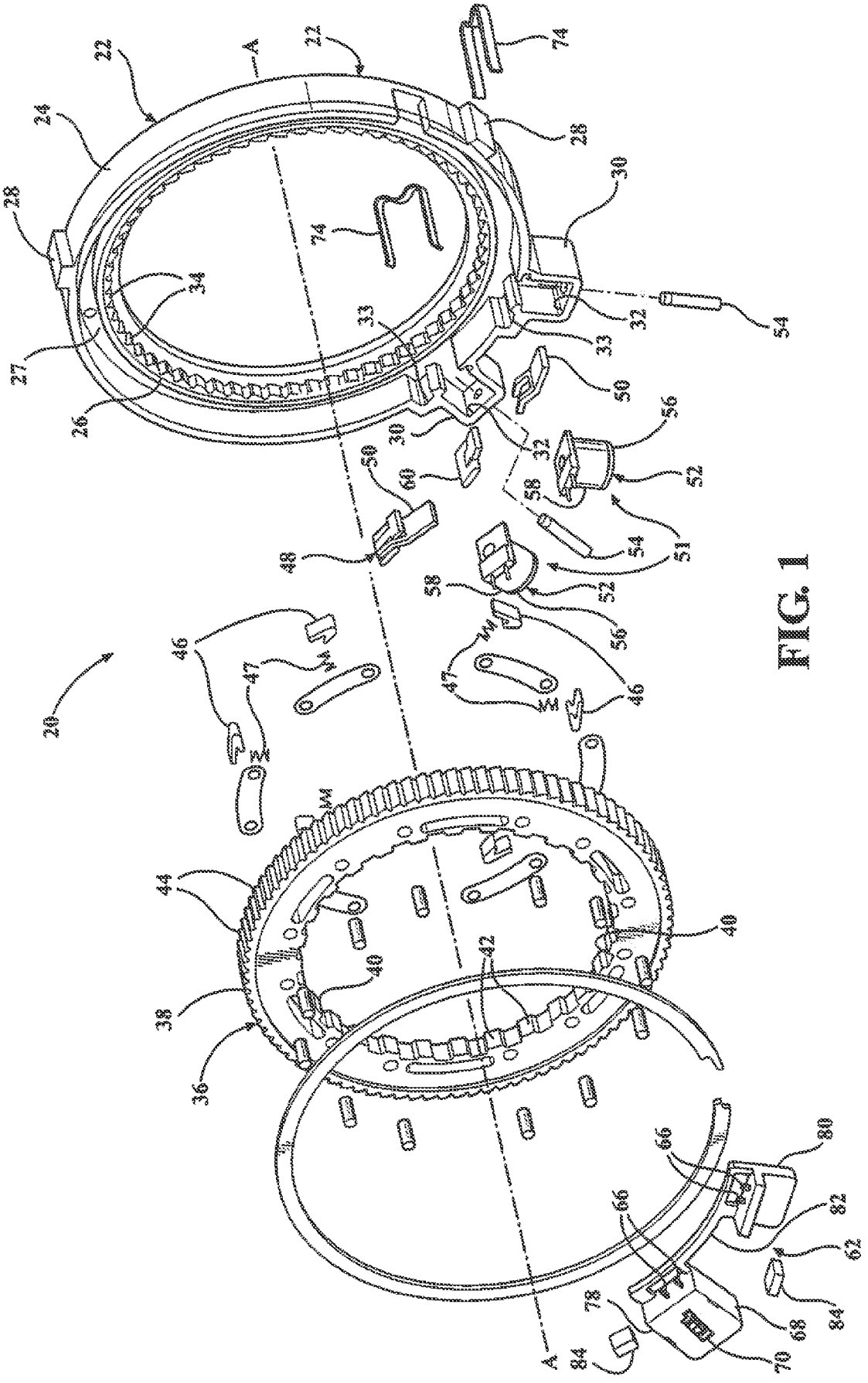
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FIG. 1

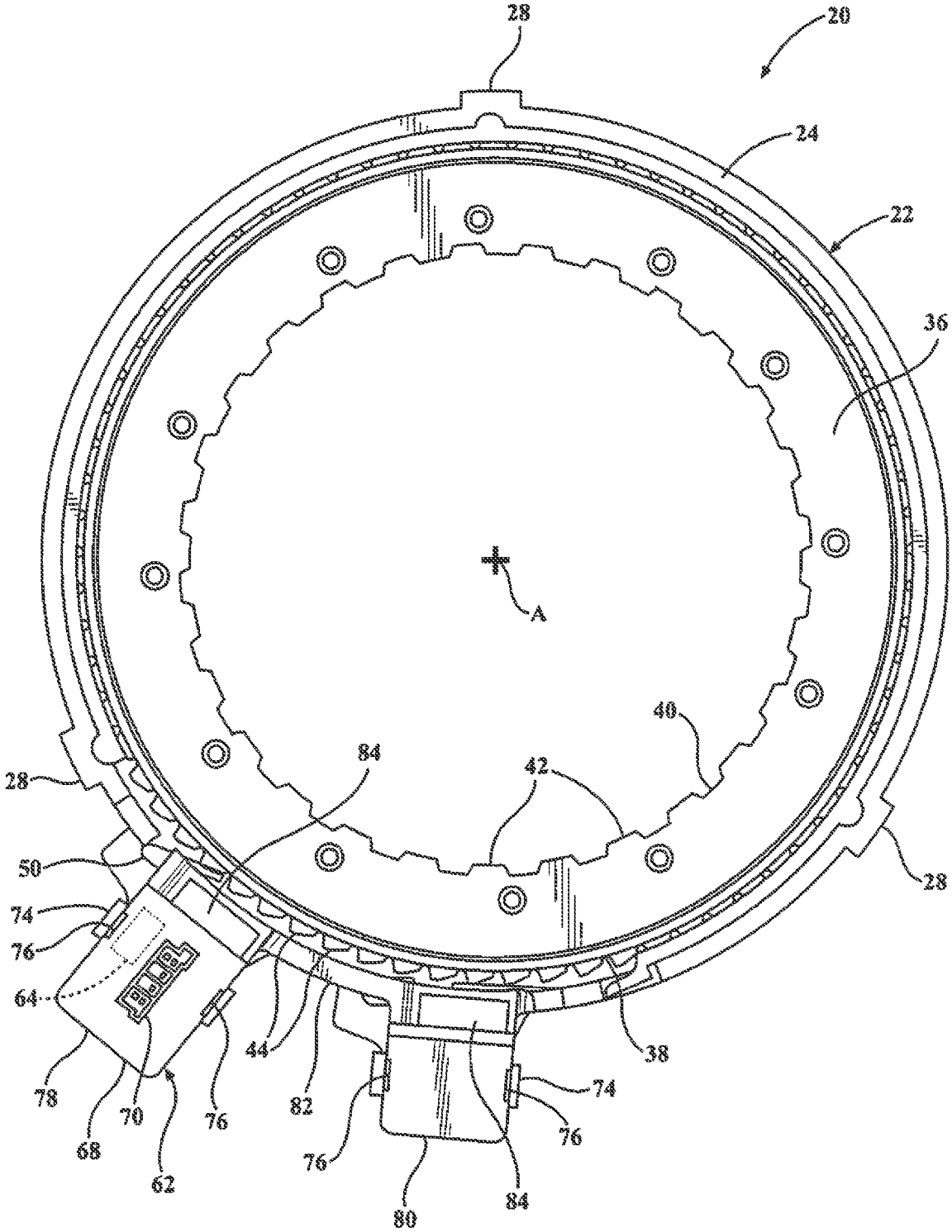
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FIG. 2

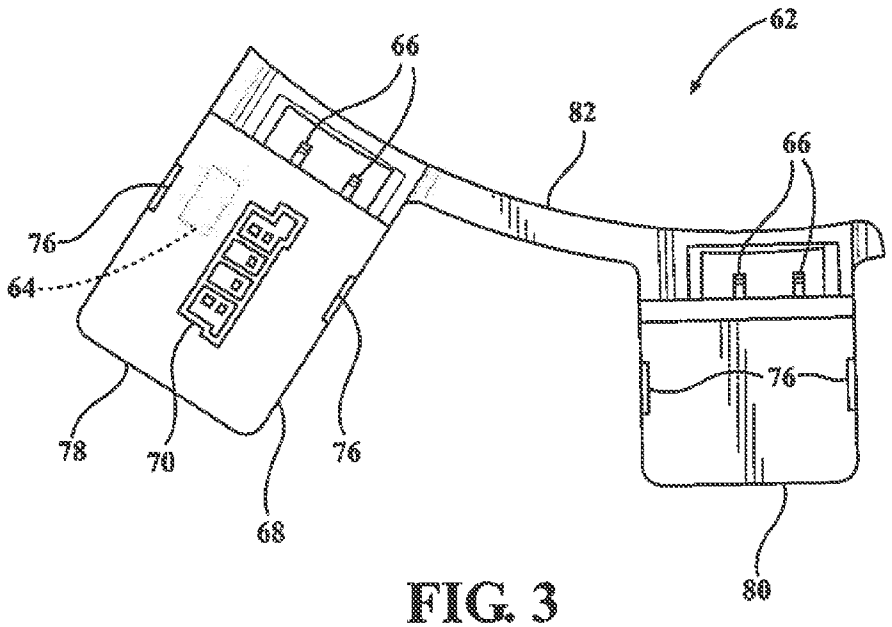

FIG. 3

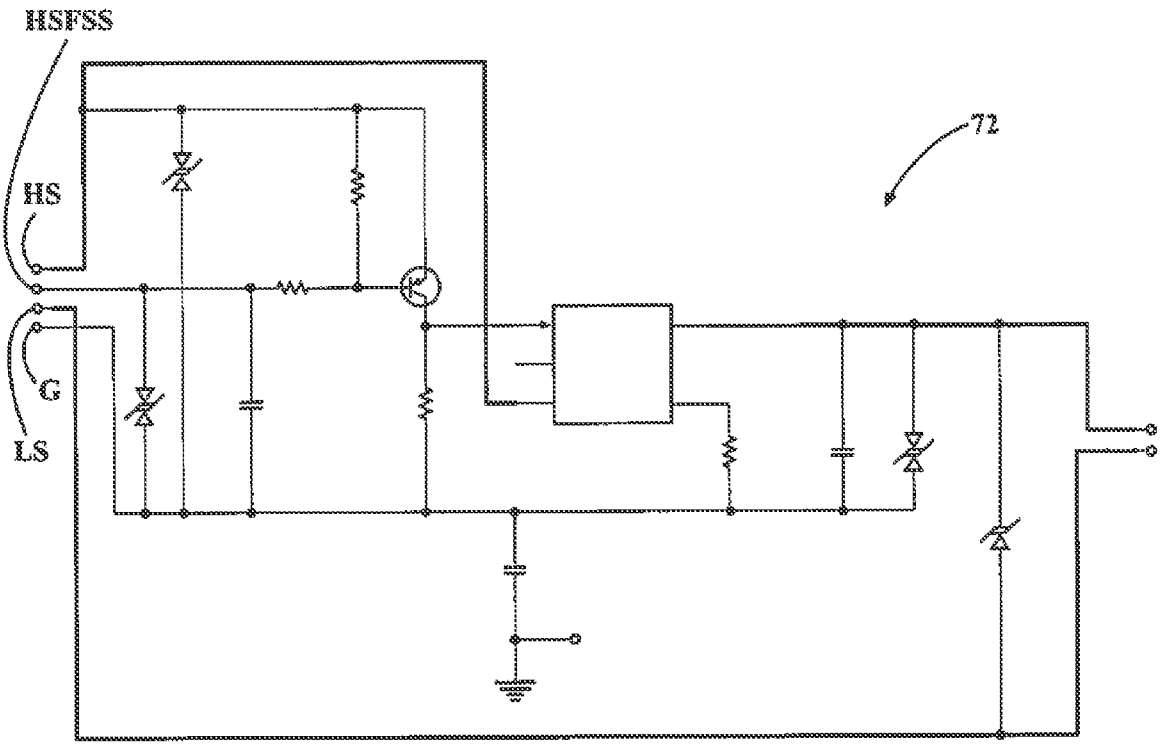

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2016/000616

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***F16D 41/12*** (2006.01), ***F16D 27/00*** (2006.01), ***F16D 41/16*** (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: ***F16D 41/12*** (2006.01), ***F16D 27/00*** (2006.01), ***F16D 41/16*** (2006.01)

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
DB: QUESTEL-ORBIT
KW: STRUT, PCB, CIRCUIT BOARD

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US2013319812A1 (WYS et al.) 05 December 2013 (05-12-2013)	1, 4 2-3, 5-15
A	US2014102844A1 (GREENE et al.) 17 April 2014 (17-04-2014)	1-15
A	US2015060225A1 (KIMES) 05 March 2015 (05-03-2015)	1-15
A	US2015001023A1 (KIMES et al.) 01 January 2015 (01-01-2015)	1-15
A	US2015204392A1 (KIMES) 23 July 2015 (23-07-2015)	1-15

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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Date of the actual completion of the international search 01 August 2016 (01-08-2016)	Date of mailing of the international search report 03 August 2016 (03-08-2016)
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 819-953-2476	Authorized officer Alan Jones (819) 934-8531

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
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