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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
15 April 2021 (15.04.2021)

WIPO | PCT

(10) International Publication Number
WO 2021/072153 A1

(51) International Patent Classification:
B60K 17/344 (2006.01) *B60K 17/346* (2006.01)
B60K 17/02 (2006.01)

(21) International Application Number:
PCT/US2020/054915

(22) International Filing Date:
09 October 2020 (09.10.2020)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/913,389 10 October 2019 (10.10.2019) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(54) **Title:** A TWO-SPEED ACTIVE TRANSFER CASE

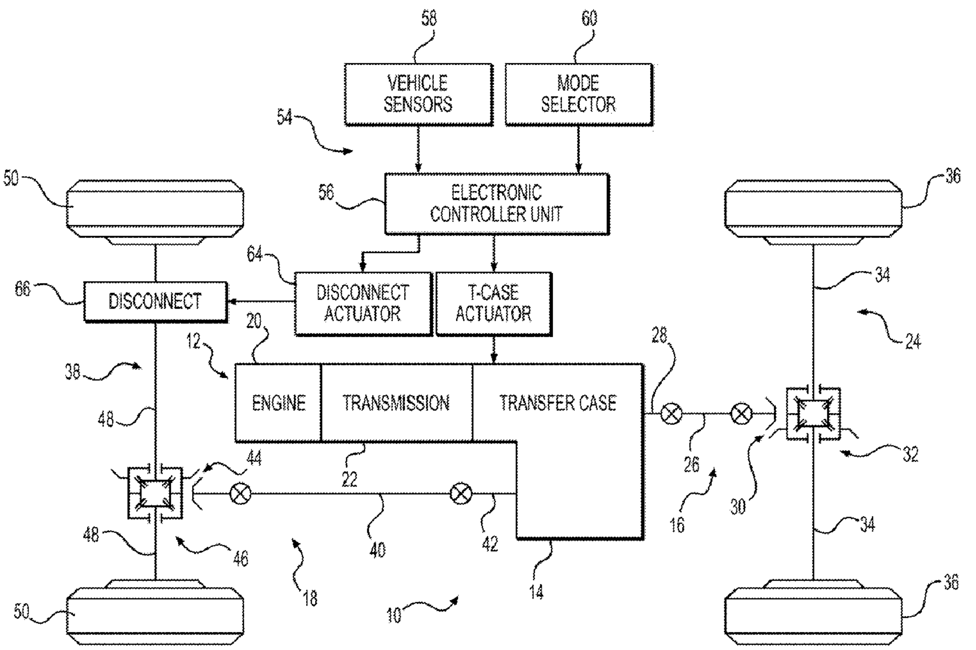

FIG. 1

(57) **Abstract:** A two-speed active transfer case is disclosed having an input shaft adapted to receive drive torque from a powertrain, a rear output shaft adapted for connection to a rear driveline and aligned with the input shaft for rotation about a first rotary axis, a front output shaft adapted for connection to a front driveline and aligned for rotation about a second rotary axis, a transfer mechanism driven by the front output shaft, a two-speed range mechanism operably disposed between the input shaft and the rear output shaft, a range shift mechanism for controlling operation of the two-speed range mechanism, a mode mechanism operably disposed between the transfer mechanism and the rear output shaft, a mode shift mechanism for controlling operation of the mode mechanism, and a clutch actuator arrangement controlling the range and mode shift mechanisms.

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[Continued on next page]

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

A TWO-SPEED ACTIVE TRANSFER CASE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This PCT International Patent Application claims the benefit of and priority to U.S. Provisional Patent Application Serial No. 62/913,389 filed on October 10, 2019, and titled “Independent Control of Planetary and Clutch System in Two-Speed Transfer Case,” the entire disclosure of which is hereby incorporated by reference.

FIELD

[0002] The present disclosure relates generally to power transfer systems for controlling the distribution of drive torque from the powertrain to the front and rear drivelines of a four-wheel drive (4WD) motor vehicle. More particularly, the present disclosure is directed to a transfer case for use in 4WD vehicles equipped with a two-speed planetary-type range clutch, a multi-plate mode clutch, and a clutch actuation arrangement configured to control coordinated actuation of the range and mode clutches.

BACKGROUND

[0003] This section provides background information related to 4WD vehicles and transfer cases which is not necessarily prior art to the inventive concepts associated with the present disclosure.

[0004] In view of the continuing popularity of four-wheel drive (4WD) vehicles, advanced power transfer systems are currently utilized in vehicular drivetrain applications for automatically controlling the distribution of power (i.e., drive torque) from the powertrain to all four wheels of the vehicle. Typically, the power transfer system includes a transfer case interconnecting the powertrain to the primary (i.e., rear) and the secondary (i.e., front) drivelines and which is equipped with a multi-plate friction clutch assembly (i.e., mode clutch) and a power-operated actuator (i.e., mode clutch actuator) that are interactively associated with an electronically-controlled traction control system. During normal road and operating conditions, the mode clutch is maintained in a released state with the mode clutch actuator in a non-actuated state such that drive torque is only transmitted from the powertrain to the rear driveline, whereby a two-wheel drive (2WD) mode is established. However, when the traction control system detects a low traction condition, the mode clutch actuator is shifted into an actuated state to place the mode clutch in an engaged state for transmitting drive torque from the powertrain to both the front and rear drivelines, whereby a 4WD mode is established. The amount of drive torque transmitted to the front driveline can be varied as a function of specific vehicle dynamics and road conditions to establish an adaptive (i.e., on demand) 4WD mode, commonly referred to as AUTO-4WD. In some situations, the mode clutch can be held in its fully engaged state to effectively lock the front and rear drivelines and establish a LOCK-4WD mode.

[0005] In addition to controlling torque distribution through the mode clutch, many transfer cases are also equipped with a planetary-type reduction gearset and a range clutch assembly (i.e., range clutch) operable via control of a power-operated actuator (i.e., range clutch actuator) to establish a direct-ratio (i.e., high-range) and a reduced-ratio (i.e., low-range) drive connection upstream of the mode clutch. In many two-speed transfer cases, the mode clutch actuator and the range clutch actuator are associated with an integrated clutch actuation arrangement such as is shown, for example, in U.S. Patent No. 7,644,598. In this arrangement, the range clutch and the mode clutch are aligned along a common axis and rotation of a motor-driven actuator shaft controls operation of a scissor-type ballramp mode clutch actuator as well as a cam-type range clutch actuator. In other two-speed transfer cases, the mode clutch actuator and the range clutch actuator are associated with a non-integrated clutch actuation arrangement such as is shown, for example, in U.S. Publication No. US2016/0363201. In this arrangement, the range clutch is aligned along a first (i.e., rear output shaft) axis while the mode clutch is aligned along a second (i.e., front output shaft) axis.

[0006] As is evident from consideration of the above-identified prior art, both integrated and non-integrated clutch actuation arrangements require significant component and packaging requirements which detrimentally impact the overall cost and weight of the transfer case. In view of these shortcomings, a need exists to develop and implement advanced clutch actuation arrangements for two-speed transfer cases that improve upon the prior art.

SUMMARY

[0007] This section provides a general summary of various aspects, objectives and features associated with some of the inventive concepts of the present disclosure. However, this summary is not intended to be interpreted as a complete and comprehensive listing of all such aspects, objectives and features and therefor does not limit the present disclosure to only those inventive concepts specifically mentioned herein.

[0008] It is a general aspect of the present disclosure to provide a two-speed transfer case for use in a four-wheel drive (4WD) vehicle that is operable to transmit drive torque through a range clutch and a multi-plate mode clutch to define various distinct drive modes including a two-wheel high-range (2H) drive mode, an on-demand four-wheel high-range (4H-AUTO) drive mode, and a locked four-wheel high-range (4H-LOCK) drive, and a locked four-wheel low-range (4L-LOCK) drive mode.

[0009] It is a related aspect of the present disclosure to operate the range clutch in association with a planetary gear reduction unit to establish the high-range and low-range drive connections between an input shaft driven by the powertrain and a rear output shaft driving the rear driveline.

[0010] It is yet another related aspect of the present disclosure to control operation of the mode clutch for transferring drive torque from the rear output shaft to a front output shaft driving the front driveline.

[0011] It is a further aspect of the present disclosure to equip the two-speed active transfer case with a clutch actuation arrangement configured to include a range clutch actuation mechanism operably associated with the range clutch, a mode clutch actuation mechanism operably with the mode clutch, and a power actuator mechanism controlling actuation of the range and mode clutch actuation mechanisms.

[0012] The clutch actuation arrangement of the preset disclosure is configured to utilize a single solenoid actuator to shift between a range shift operation and a mode shift operation. A second solenoid actuator functions as a brake. A motor actuator controls actuation of a range shift mechanism to shift a range collar between distinct range positions during the range shift operation and to control actuation of a mode shift mechanism to engage a multi-plate clutch during the mode shift operation.

[0013] It is another aspect of the of the present disclosure to provide a transfer case for use in a four-wheel drive motor vehicle having a powertrain and first and second drivelines. The transfer case comprises an input shaft adapted to receive drive torque from the powertrain and aligned for rotation about a first axis. A first output shaft is adapted to be interconnected to the first driveline and aligned for rotation about the first axis. A second output shaft is adapted to be interconnected to the second driveline and aligned for rotation about a second axis. A transfer mechanism includes a first transfer component rotatably supported on the first output shaft for rotation about the first axis, and a second transfer component fixed to the second output shaft for rotation about the second axis. The second transfer component is driven by the first transfer component. The transfer case further includes a range mechanism having a reduction unit and a range clutch. The reduction unit is driven at a reduced speed relative to the input shaft. The range clutch is operable in a first range position to establish a drive connection between the input shaft and the first output shaft and is further operable in a second position to establish a drive connection between the reduction unit and the first output shaft. A range shift mechanism controls movement of the range clutch between the first and second range positions. A mode mechanism is disposed between the first transfer component and the first output shaft. The mode mechanism includes a mode clutch having a first clutch member coupled to the first transfer component, a second clutch member coupled to the first output shaft, a multi-plate clutch pack disposed between the first and second clutch members, and an apply member moveable into and out of engagement with the clutch pack. A mode shift mechanism is further included for controlling movement of the apply member relative to the clutch pack so as to control the magnitude of a clutch engagement force applied to the clutch pack and concurrently control the amount of drive torque transferred from the first output shaft through the transfer mechanism and the mode clutch to the second output shaft. The transfer case further includes a clutch actuation arrangement having a range clutch actuation mechanism for controlling actuation of the range shift mechanism, a mode clutch actuation mechanism for controlling actuation of the mode shift mechanism, and a power actuator mechanism for controlling actuation of the range clutch actuation mechanism and the mode clutch actuation mechanism.

[0014] It is another aspect of the of the present disclosure to provide a transfer case for use in a four-wheel drive motor vehicle having a powertrain and first and second drivelines. The transfer case comprises an input shaft adapted to receive drive torque from the powertrain and aligned for rotation about a first axis. A first output shaft is adapted to be interconnected to the first driveline and aligned for rotation about the first axis and a second output shaft is adapted to be interconnected to the second driveline and aligned for rotation about a second axis. The transfer case further includes a transfer mechanism having a first transfer component rotatably supported on the first output shaft for rotation about the first axis and a second transfer component fixed to the second output shaft for rotation about the second axis, the second transfer component being driven by the first transfer component. A mode mechanism is disposed between the first transfer component and the first output shaft. The mode mechanism includes a mode clutch having a first clutch member coupled to the first transfer component, a second clutch member coupled to the first output shaft, a multi-plate clutch pack disposed between the first and second clutch members, and an apply member moveable into and out of engagement with the clutch pack. The transfer case further includes a mode shift mechanism for controlling movement of the apply member relative to the clutch pack so as to control the magnitude of a clutch engagement force applied to the clutch pack and concurrently control the amount of drive torque transferred from the first output shaft through the transfer mechanism and the mode clutch to the second output shaft. A mode clutch actuation mechanism controls actuation of the mode shift mechanism and a power actuator mechanism for controlling actuation of the mode clutch actuation mechanism.

[0015] Further areas of applicability will become apparent from the description provided herein. As is understood, the description and specific examples of various embodiments listed in this summary are only intended to illustrate some of the inventive concepts and are not intended to limit the full and fair scope of the present disclosure.

DRAWINGS

[0016] The drawings described herein and appended to this application provide non-limiting illustrations of selected embodiments and are not intended to limit the scope of the present disclosure.

[0017] FIG. 1 is a schematic illustration of a four-wheel drive motor vehicle equipped with a power transfer system having a two-speed active transfer case constructed in accordance with the teachings of the present disclosure;

[0018] FIG. 2 is a schematic illustration of the two-speed active transfer case of the present disclosure equipped with a planetary-type gear reduction unit, a range clutch, a multi-plate mode clutch, and a clutch actuation arrangement having a range clutch actuation mechanism associated with the range clutch, a mode clutch actuation mechanism associated with the mode clutch, and a power actuator mechanism configured to control actuation of the range and mode actuation mechanisms;

[0019] FIG. 3 illustrates the two-speed active transfer case of FIG. 2 having the clutch actuation arrangement constructed in accordance with a first non-limiting embodiment of the present disclosure;

[0020] FIG. 4 is side view of a gear associated with each of the range clutch actuation mechanism and the mode clutch actuation mechanism and having a releasable coupling feature;

[0021] FIG. 5 is an end sectional view of various components associated with the range clutch and the range clutch actuation mechanism and which are configured to provide a rotary-to-linear conversion function for axially moving a range collar between first and second range positions relative to the planetary gear reduction unit;

[0022] FIG. 6 illustrates a non-limiting version of cam ramp profile associated with the range clutch actuation mechanism shown in FIG. 5;

[0023] FIG. 7A is a vertical sectional view of the components shown in FIG. 5 illustrating the range collar located in its first range position relative to the planetary gear reduction unit while FIG. 7B illustrates the range collar located in its second range position;

[0024] FIG. 8 illustrates a component associated with a ballramp unit of the mode clutch assembly integrated with a component of the mode clutch actuation mechanism;

[0025] FIG. 9 is similar to FIG. 3 but further illustrates, in an enlarged view, the components of the clutch actuation arrangement associated with the two-speed active transfer case of the present disclosure;

[0026] FIG. 10 illustrates the positioning and operational states of the components associated with the clutch actuation arrangement shown in FIG. 9 to establish either of a locked four-wheel high-range (4H-LOCK) drive mode and a locked four-wheel low-range (4L-LOCK) drive mode;

[0027] FIGS. 11 and 12 illustrate control of the clutch actuation arrangement during a range shift operation for moving the range collar between its first and second range positions;

[0028] FIGS. 13 and 14 illustrate control of the clutch actuation arrangement during a mode shift operation;

[0029] FIG. 15 illustrates the two-speed active transfer case of FIG. 2 having a clutch actuation arrangement constructed in accordance with a second non-limiting embodiment of the present disclosure;

[0030] FIG. 16 is similar to FIG. 15 but now includes an enlarged view illustrating the components of the alternative version of the clutch actuation arrangement used to control range and mode shifting in the two-speed active transfer case;

[0031] FIG. 17 illustrates a geared orientation associated with the clutch actuation arrangement shown in FIGS. 15 and 16;

[0032] FIG. 18 illustrates the positioning and operational states of the components shown in FIGS. 15-17 to establish either of the 4H-LOCK drive mode and the 4L-LOCK drive mode for the two-speed active transfer case;

[0033] FIG. 19 illustrates control of the clutch actuation arrangement of FIGS. 15-17 during a range shift operation;

[0034] FIG. 20 illustrates control of the clutch actuation arrangement of FIGS. 15-17 during a mode shift operation; and

[0035] FIGS. 21A and 21B illustrate a third non-limiting embodiment of a clutch actuation arrangement constructed according to the teachings of the present disclosure.

DETAILED DESCRIPTION

[0036] Example embodiments will now be described more fully with reference to the accompanying drawings. In particular, several example embodiments of a two-speed active transfer case adapted for use with four-wheel drive vehicles are provided so that this disclosure will be thorough and will fully convey the true and intended 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.

[0037] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms “a,” “an,” and “the” may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms “compromises,” “comprising,” “including,” and “having,” are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps operations, elements, components, and/or groups or combinations thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

[0038] When an element or layer is referred to as being “on,” “engaged to,” “connected to,” or “coupled to” another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being “directly on,” directly engaged to,” “directly connected to,” or “directly coupled to” another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., “between” versus “directly between,” “adjacent” versus “directly adjacent,” etc.). As used herein, the term “and/or” includes any and all combinations of one or more of the associated listed items.

[0039] Although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as “first,” “second,” and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

[0040] Spatially relative terms, such as “inner,” “outer,” “beneath,” “below,” “lower,” “above,” “upper,” and the like, may be used herein for ease of description to describe one element or feature’s relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as “below” or “beneath” other elements or features would then be oriented “above” the other elements or features. Thus, the example term “below” can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0041] Referring initially to FIG. 1 of the drawings, an example drivetrain for a four-wheel drive motor vehicle 10 is shown to include a powertrain 12 operable to generate rotary power (i.e., drive torque) which is transmitted through a power transfer unit, hereinafter referred to as transfer case 14, to a primary driveline 16 and to a secondary driveline 18. Powertrain 12 is shown, in this non-limiting example, to include a power source such as an internal combustion engine 20 and a transmission 22. In the particular arrangement shown, primary driveline 16 is the rear driveline and generally includes a rear axle assembly 24 and a rear propshaft 26 arranged to drivingly interconnect a rear output shaft 28 of transfer case 14 to an input of rear axle assembly 24. The input to rear axle assembly 24 includes a hypoid gearset 30 connected to rear propshaft 26. Rear axle assembly 24 includes a rear differential assembly 32 driven by hypoid gearset 30, and a pair of rear axleshafts 34 interconnecting rear differential assembly 32 to a pair of ground-engaging rear wheels 36. Secondary driveline 18 is the front driveline and includes a front axle assembly 38 and a front propshaft 40 arranged to drivingly interconnect a front output shaft 42 of transfer case 14 to an input of front axle assembly 38. The input to front axle assembly 38 includes a hypoid gearset 44 connected to front propshaft

40. Front axle assembly 38 includes a front differential assembly 46 driven by hypoid gearset 44, and a pair of front axleshafts 48 interconnecting front differential assembly 46 to a pair of ground-engaging front wheels 50.

[0042] Motor vehicle 10 is also shown to include a traction control system 54 having an electronic controller unit (ECU) 56 configured to receive input signals from vehicle sensors 58 and a mode selector 60 and to subsequently generate and send control signals to one or more actuators. Mode selector 60 is, in this non-limiting example, a manually-operable device within the passenger compartment of vehicle 10 and, for example, may include a push button, rotary knob, or a shift lever. ECU 56 provides control signals to a transfer case actuator 62 and an axle disconnect actuator 64. As will be detailed with much greater specificity, transfer case actuator 62 controls actuation of a two-speed range shift mechanism to provide high-range and low-range drive connections and controls actuation of a mode shift mechanism to provide various two-wheel drive (2WD) and four-wheel drive (4WD) modes of operation.

[0043] In the particular embodiments of transfer case 14 to be described hereinafter, mode selector 60 provides a mode signal to ECU 56 that is indicative of the particular drive mode selected. Disconnect actuator 64 controls operation of a disconnect device 66 associated with front axle assembly 38 for selectively coupling and uncoupling front driveline 18 relative to transfer case 14. Sensors 58 are configured to provide information to ECU 56 indicative of the current operational characteristics of vehicle 10 and/or road conditions for use in controlling operation of transfer case 14. The information provided by sensors 58 may include, without limitations, information related to vehicle speed, driveline/wheel speeds, acceleration, braking status, steering angle, throttle position, lateral displacement, and/or rain sensors. Mode selector 60 permits a vehicle operator to select operation of vehicle 10 in one of the available drive modes which may include, without limitation, a two-wheel high-range (2H) drive mode, an automatic four-wheel high-range (AUTO-4H) drive mode, a locked four-wheel high-range (LOCK-4H) drive mode, a locked four-wheel low-range (LOCK-4L) drive mode, and an automatic four-wheel low-range (AUTO-4L) drive mode.

[0044] Referring now to FIG. 2 of the drawings, a stick diagram of an example embodiment of transfer case 14 constructed in accordance with the teachings of the present disclosure is provided. Transfer case 14 is generally shown to include: a housing 70; an input shaft 72 driven by powertrain 12; a two-speed range mechanism 74 disposed between input shaft 72 and rear output shaft 28; a range shift mechanism 76 controlling operation of range mechanism 74; a transfer mechanism 78 drivingly connected to front output shaft 42; a mode mechanism 80 disposed between rear output shaft 28 and transfer mechanism 78; and a mode shift mechanism 82 controlling actuation of mode mechanism 80. As will be detailed hereinafter, transfer case actuator 62 functions to control actuation of range shift mechanism 76 and mode shift mechanism 82 in a manner that is novel and non-obvious in comparison to other known arrangement.

[0045] Range mechanism 74 is shown, in this non-limiting embodiment, to include a planetary gearset 100 and a range clutch 102. Planetary gearset 100 includes a sun gear 110 formed integrally on input shaft 72, a ring gear 112 non-rotatably fixed to housing 70, a carrier unit 114 having a plurality of pins (not shown) and a plurality of planet gears 116 each rotatably mounted (via a bearing assembly) on a corresponding one of the pins and which are each in constant meshed engagement with sun gear 110 and ring gear 112. Input shaft 72 includes a clutch ring segment having clutch teeth 120 formed thereon. Carrier unit 114 includes a clutch ring segment having clutch teeth 121 formed thereon. Range clutch 102 is configured as a sliding range collar 103 that is splined for common rotation with rear output shaft 28. Range collar 103 also includes clutch teeth 122 and is axially moveable on rear output shaft 28 between three (3) distinct range positions.

[0046] Range collar 103 is axially moveable between a high-range (H) position, a neutral (N) position, and a low-range (L) position. When range collar 103 is located in its H range position, its clutch teeth 122 engage clutch teeth 120 on input shaft 72 so as to establish a first or "direct" (i.e., high-range) speed ratio drive connection between input shaft 72 and rear output shaft 28. In contrast, when range collar 103 is located in its L range position, its clutch teeth 122 engage clutch teeth 121 on carrier unit 114 so as to establish a second or "reduced" (i.e., low-range) speed ratio drive connection between input shaft 72 and rear output shaft 28. Location of range collar 103 in its N range position disengages rear output shaft 28 from driven connection with input shaft 72 and carrier unit 114 so as to interrupt the transfer of drive torque and permit relative rotation therebetween. Accordingly, the high-range drive connection is established when range collar 103 is located in its H range position and the low-range drive connection is established when range collar 103 is located in its L range position. The two-speed range mechanism shown and described is intended to exemplify any suitable gear reduction device capable of establishing two distinct speed ratio drive connections between input shaft 72 and rear output shaft 28.

[0047] A non-limiting version of range shift mechanism 76 is shown in FIGS. 5-7B to generally include a barrel cam 130 defining an internal ramp groove 132, and a range fork 134 having a follower section 136 retained in ramp groove 132 and a forked section 138 extending into a groove 140 formed in range collar 103. This arrangement functions to convert rotation of barrel cam 130 into translational movement of range collar 103 between its distinct range positions. FIG. 7A illustrates range collar 103 located in its H range position while FIG. 7B illustrates range collar 103 located in its L range position. As will be detailed, bi-directional rotation of barrel cam 130 is controlled by transfer case actuator 62 so as to control bi-directional translation of range collar 103.

[0048] As best illustrated in FIG. 3, transfer mechanism 78 is shown to include a first sprocket 140 rotatably supported on rear output shaft 28, a second sprocket 142 fixed for common rotation with front output shaft 42, and a continuous power chain 144 encircling both sprockets 140,142. Thus, transfer mechanism 78 is configured to be drivingly connected to front output shaft 42. Mode mechanism 80 includes a multi-plate mode clutch 150 disposed between rear output shaft 28 and first sprocket 140. Mode clutch 150 generally includes a first clutch member (i.e., clutch drum) 152 fixed for common rotation with first sprocket 140, a second clutch member (i.e., clutch hub) 154 fixed for common rotation with rear output shaft 28, and a multi-plate clutch pack 156 disposed therebetween. Clutch pack 156 includes a set of alternatively interleaved inner clutch plates and outer clutch plates. The inner clutch plates are coupled to rotate with clutch hub 154 while the outer clutch plates are coupled to rotate with clutch drum 152.

[0049] Mode shift mechanism 82 includes a rotary-to-linear conversion device, commonly referred to as ballramp unit 160, having a first cam ring 162, a second cam ring 164 and balls 166 disposed in aligned sets of cam tracks formed in first and second cam rings 162,164. First cam ring 162 is rotatable, but axially restrained, while second cam ring 164 moves axially in response to rotation of first cam ring 162. Axial movement of second cam ring 164 functions to regulate the magnitude of a compressive clutch engagement force exerted on clutch pack 156. As known, the profile and/or contour of the cam tracks controls the linear travel characteristics of second cam ring 164 in response to relative rotation between cam rings 162,164.

[0050] Axial movement of second cam ring 164 is configured to control concurrent axial movement of an apply plate (not shown) between a first (i.e., minimum) clutch engagement position and a second (i.e., maximum) clutch engagement position relative to clutch pack 156 of mode clutch 150. With the apply plate located in its first position, a predetermined minimum clutch engagement force is exerted on clutch pack 156, thereby transferring a minimum amount of drive torque from rear output shaft 28 (through mode clutch 150 and transfer mechanism 78) to front output shaft 42. Typically, no drive torque is transmitted from rear output shaft 28 to front output shaft 42 when the apply plate is located in its first position, thereby establishing a “released” state for mode clutch 150 and the two-wheel drive mode (2WD) for transfer case 14. In contrast, with the apply plate located in its second position, a predetermined maximum clutch engagement force is exerted on clutch pack 156, thereby transferring a maximum amount of drive torque from rear output shaft 28 (through mode clutch 150 and transfer mechanism 78) to front output shaft 42. In this position, a “fully engaged” state is established for mode clutch 150 and a locked four-wheel drive mode (LOCK-4WD) is established for transfer case 14. Precise control over the axial location of the apply plate between its first and second positions via actuation of ballramp unit 160 permits adaptive (i.e., variable) torque transfer from rear output shaft 28 to front output shaft 42 so as to establish the on-demand four-wheel drive (AUTO-4WD) mode.

[0051] In accordance with the present disclosure, transfer case actuator 62 is configured as a clutch actuation arrangement 200 generally comprised of a range clutch actuation mechanism 202, a mode clutch actuation mechanism 204, and a power actuator mechanism 206. With particular attention directed to FIGS. 3-14 of the drawings, a first non-limiting embodiment of clutch actuation arrangement 200 will now be described in detail.

[0052] Range clutch actuation mechanism 202 includes a constant mesh gearset having a first (i.e., output) range gear 210 and a second (i.e., input) range gear 212, both of which are shown configured as spur gears. FIG. 6 illustrates barrel cam 130 to be integrally formed within first range gear 210. Thus, bi-directional rotation of first range gear 210 functions to actuate range shift mechanism 78 for controlling bi-directional axial translation of range collar 103 between its range positions. FIGS. 4, 9, and 10 best illustrate second range gear 212 as having a side surface 214 defining a continuous series of circumferentially-arranged first coupling features, shown as drive slots 216. Second coupling features, shown as a continuous series of circumferentially-arranged drive lugs 218, are formed on a first drive component 219. First drive component 219 is axially moveable relative to second range gear 212 between a first position whereat drive lugs 218 are displaced from retention within drive slots 216 and a second position whereat drive lugs 218 are disposed within drive slots 216. With first drive component 219 located in its first position, second range gear 212 is in a non-driven or “disconnected” state relative to first drive component 219. In contrast, movement of first drive component 219 to its second position establishes a driving or “connected” state with second range gear 212. As will be detailed, first drive component 219 is associated with a first solenoid actuator 240 of power actuator mechanism 206.

[0053] With continued reference to FIGS. 3-14, mode clutch actuation mechanism 204 is shown to include a constant mesh gearset having a first (i.e., output) mode gear 220 and a second (i.e., input) mode gear 222, both of which are shown configured a spur gears. Fig. 10 best illustrates second mode gear 222 as having a first side surface 224 defining a continuous series of circumferentially-arranged first coupling features, shown as drive slots 226. In addition, a second side surface 228 of second mode gear 222 defines a continuous series of circumferentially-arranged first braking features, shown as brake slots 230. Second coupling features, shown as a continuous series of circumferentially-arranged drive lugs 232, are formed on a second drive component 233. Second drive component 233 is axially moveable relative to second mode gear 222 between a first position whereat drive lugs 232 are located within drive slots 226 and a second position whereat lugs 232 are displace from brake slots 230. With second drive component 233 located in its first position, second mode gear 222 is in a driving or “connected” state relative to second drive component 233. In contrast, movement of second drive component 233 to its second position establish a non-driven or “disconnected” state with respect to second mode gear 222. As will be detailed, second drive component 233 moves in concert with first drive component 219 via control of first solenoid actuator 240.

[0054] With continued reference to FIGS. 9 and 10, second braking features, shown as continuous series of circumferentially-arranged brake lugs 234, are formed on a brake component 235. Brake component 235 is axially moveable relative to second mode gear 222 between a first position whereat brake lugs 234 are retained within brake slots 230 and a second position whereat brake lugs 234 are displace from brake slots 230. With brake component 235 located in its first position, second mode gear 222 is held in a non-rotary or “braked” state. In contrast, movement of brake component 235 to its second position permits rotation of second mode gear 222 so as to define a “non-braked” state. As will be detailed, movement of brake component 235 between its first and second positions is controlled via a second solenoid actuator 242 associated with power actuator mechanism 206.

[0055] Power actuator mechanism 206 is configured to generally include first solenoid actuator 240, second solenoid actuator 242, and a motor actuator 246. First solenoid actuator 240 includes a first electromagnetic coil 250, a first solenoid shaft 252 configured to move axially relative to first coil 250 between an extended (i.e., power off) position and retracted (i.e., power on) position, and a biasing device 254 arranged to normally bias first solenoid shaft 252 toward its extended position, as is indicated by arrow 256. FIGS. 9 and 10 illustrate first solenoid actuator 240 operating in a “Power Off” state with first coil 250 non-energized and first solenoid shaft 252 located in its extended position. First drive component 219 is rotatably supported via suitable bearings (not shown) on first solenoid shaft 252. Likewise, second drive component 233 is also rotatably supported via bearings (not shown) on first solenoid shaft 252. First drive components 219 and second drive component 233 are axially restrained on first solenoid shaft 252 so as to maintain a distance “D” therebetween during axial movement of first solenoid shaft 252 between its extended and retracted positions. With first solenoid shaft 252 located in its extended position and first solenoid actuator 240 operating in its Power Off state, first drive component 219 is located in its first position and second drive component 233 also located in its first position. As will be detailed, subsequent energization of first coil 250 functions to shift first solenoid actuator 240 into a “Power On” state for causing first solenoid shaft 252 to move from its extended position into its retracted position against the biasing exerted thereon by biasing device 254, whereby both first drive component 219 and second drive component 233 are moved to their respective second positions. Biasing device 254 drives first solenoid shaft 252 back to its extended position in response to subsequent de-energization of first coil 250.

[0056] Second solenoid actuator 242 is shown to include a second electromagnetic coil 260, a second solenoid shaft 262 configured to move axially relative to second coil 260 between an extended (i.e., power off) position and a retracted (i.e., power on) position, and a biasing device 264 arranged to normally bias second solenoid shaft 262 toward its extended position, as is indicated by arrow 266. FIG. 10 illustrates second solenoid actuator 242 operating in a “Power Off” state with a second coil 260 de-energized and second solenoid shaft 262 located in its extended position. Brake component 235 is fixed to second solenoid shaft 262. With second solenoid actuator 242 operating in its Power Off state, second solenoid shaft 262 is located in its extended position, whereby brake component 235 is located in its first position for preventing rotation of second mode gear 222. In contrast, energization of second coil 260 acts to shift second solenoid actuator 242 from its Power Off state into a “Power On” state for causing second solenoid shaft 262 to move axially from its extended position into its retracted position, whereby brake component 235 is moved to its second position for permitting rotation of second mode gear 222.

[0057] Referring still to FIGS. 9 and 10, power actuator mechanism 206 illustrates motor actuator 246 to generally include an electric motor 270 having a rotary motor shaft 272, a first drive pinion 274 fixed to motor shaft 272, and a second drive pinion 276 fixed to motor shaft 272. In addition, a first drive gear 278 is fixed to first drive component 219 and a second drive gear 280 is fixed to second drive component 233. First drive gear 278 moves axially with first drive component 219 in response to axial movement of first solenoid shaft 252 but maintains constant meshed engagement with first drive pinion 274. Likewise, second drive gear 280 moves axially with second drive component 233 in response to axial movement of first solenoid shaft 252 but maintains constant meshed engagement with second drive pinion 276.

[0058] FIG. 10 illustrates clutch actuation arrangement 206 with first solenoid actuator 240 operating in its Power Off state, second solenoid actuator 242 operating in its Power Off state, and motor actuator 246 operating in a “Motor Off” state. As such, first solenoid shaft 252 is located in its extended position for locating first drive component 219 and second drive component 233 in their respective first positions. Thus, first drive component 219 is disengaged from coupled engagement with second range gear 212 while second drive component 233 is in coupled engagement with second mode gear 222. Likewise, second solenoid shaft 262 is located in its extended position for locating brake component 235 in its first position such that it is also in coupled engagement with second mode gear 222. This “non-actuated” orientation of components associated with clutch actuation arrangement 200 results in range sleeve 103 being maintained in its last selected range position and mode clutch 150 being maintained in its last operating state to establish one of the available LOCK modes.

[0059] FIGS. 11 and 12 illustrate operation of clutch actuation arrangement 200 when a range shift is required as part of a range shift operation associated with selection of a different drive mode. In particular, first solenoid actuator 240 is shown shifted into its Power On state while second solenoid actuator 242 is maintained in its Power Off state. As such, first solenoid shaft 252 moves to its retracted position (as indicated by arrow 257) such that first drive component 219 is now coupled to second range gear 212 and second drive component 233 is uncoupled from second mode gear 222. Second solenoid shaft 262 is maintained in its extended position, thereby causing brake component 235 to brake second mode gear 222 and maintain the actuated state of the ballramp unit for likewise maintaining the actuated state of mode clutch 150. To complete the range shift operation, motor actuator 246 is shifted into a “Motor On” state for rotatably driving motor shaft 272. Rotation of motor shaft 272 causes first pinion gear 274 to drive first drive gear 278 which, due to coupled engagement of first drive component 219 with second range gear 212, causes second range gear to be rotated, as indicated by line 259. Such rotation of second range gear 212 results in rotation of first range gear 210 for axially translating range collar 103 via range shaft mechanism 76. As will be understood, rotation of motor shaft 272 in a first rotary direction results in axial movement of range collar 103 in a first direction from its H range position toward its L range position while rotation of motor shaft 272 in a second rotary direction results in axial movement of range collar 103 in a second direction from its L range position toward its H range position. Thus, with first solenoid actuator 242 non-energized, actuation of motor actuator 246 functions to provide the range shift function with mode clutch 150 maintained. Upon completion of the range shift operation, first solenoid actuator 240 is returned to its Power Off state.

[0060] Referring now to FIGS. 13 and 14, operation of clutch actuation arrangement 200 is shown when a mode shift (i.e., 2WD/4WD) is requested via a mode shift operation. In particular, first solenoid actuator 240 is shown maintained in its Power Off state while second solenoid actuator 242 is shifted into its Power On state. As such, first solenoid shaft 252 is maintained in its extended position (arrow

256) while second solenoid shaft 262 is moved into its retracted position (arrow 267). As such, second drive component 233 is coupled to second mode gear 222 while brake component 235 is uncoupled from second mode gear 222. Since second drive gear 280 is connected to second drive component 235, driven rotation of second pinion gear 276 (via rotation of motor shaft 272 with motor actuator 246 operating in its Motor On state) results in rotation of second mode gear 222, as indicated by line 269. As discussed, rotation of second mode gear 222 functions to cause rotation of first mode gear 220 for causing axial translation of the apply plate relative to clutch pack 156. Rotation of second mode gear 222 in a first rotary direction will result in movement of the apply plate in a first axial direction between its minimum engagement position toward its maximum engaged position while rotation of second mode gear 222 in a second rotary direction will result in movement of the apply plate in a second axial direction from its maximum engagement position toward its minimum engagement position while range collar 103 is maintained in its last selected range position.

[0061] If the 2H drive mode is selected, mode actuation mechanism 204 is operated to release engagement of mode clutch 150. In contrast, if one of the LOCK-4H or LOCK-4L drive modes is selected, mode actuation mechanism 204 is operated to fully engage mode clutch 150. Following full engagement of mode clutch 150 in either of the LOCK drive modes, second solenoid actuator 242 is returned to its Power Off state with brake component 235 acting to brake second mode gear 222 against subsequent rotation. Finally, if one of the AUTO drive modes is selected, motor actuator 246 is actively controlled to regulate the axial position of the apply plate relative to clutch pack 156 so as to automatically adjust the magnitude of the clutch engagement force and drive torque.

[0062] With particular reference now to FIGS. 16-20 of the drawings, a second non-limiting embodiment of clutch actuation arrangement 200A will now be described in detail in association with transfer case 14A. It should be noted that components of transfer case 14A that are identical (or substantially similar) in terms of structure and/or function to these components of transfer case 14 are identified in this description and the drawings using common reference numerals. Clutch actuation arrangement 200A generally includes a range clutch actuation mechanism 204A, a mode clutch actuation mechanism 204A and a power actuator mechanism 206A.

[0063] Range clutch actuation mechanism 204A is shown to generally include a range worm 300 meshed with first range gear 210 a first coupling ring 302 fixed to range worm 300, a first drive component 304 fixed to a first actuator shaft 306, and a range drive gear 308 splined to first actuator shaft 306. Range drive gear 308 is shown in constant mesh with an actuator gear 310 driven by a motor actuator 312 associated with motor actuator 246A of power actuator mechanism 206A. First coupling ring 302 has a side surface defining a continuous series of circumferentially-arranged first coupling features, shown as drive slots 320. First drive component 304 is coupled for rotation with range drive gear 308, as indicated by lines 322, and is axially moveable relative to first coupling ring 302 via movement of first actuator shaft 306. First drive component 304 includes a series of circumferentially-arranged second coupling features, shown as drive lugs 324 that can be selectively moved into and out of engagement with drive slots 320 in response to axial movement of first drive component 304. In particular, first drive component 304 is operable in a first position (FIG. 18) whereat drive lugs 324 are displaced from drive slots 320 to establish a non-driven or “disconnected” state relative to range worm 300 and is further operable in a second position (FIGS. 16 and 19) whereat drive lugs 324 are meshed with drive slots 320 to establish a driven or “connected” state with range worm 300.

[0064] Mode clutch actuation mechanism 204A is shown to generally include a mode worm 340 meshed with first mode gear 220, second and third coupling rings 342 and 344 fixed to opposite ends of mode worm 340, a second drive component 346 fixed to a second actuator shaft 348, a brake component 350, and a mode drive gear 352 splined for rotation with second actuator shaft 348. Mode drive gear 352 is shown in constant mesh with actuator gear 310. Second coupling ring 342 has a side surface defining a continuous series of circumferentially-arranged first coupling features, shown as drive slots 360. Second drive component 346 is coupled for rotation with mode drive gear 352, as indicated by lines 356. Second drive component 346 includes a continuous series of circumferentially-arranged second coupling features, shown as drive lugs 362, which can be selectively moved into and out of engagement with drive slots 360 in response to axial movement of second drive component 346. In particular, second drive component 342 is operable in a first position (FIG. 18) whereat drive lugs 362 are meshed with drive slots 360 to establish a driven or “connected” state relative to mode worm 340 and is further operable in a second position (FIGS. 16 and 19) whereat drive lugs 362 are released from drive slots 360 to establish non-driven or “disconnected” state.

[0065] Third coupling ring 344 includes a side surface having a continuous series of circumferentially-arranged brake features, shown as brake slot 370. Brake component 350 has a side surface defining a continuous series of circumferentially-arranged second brake features, shown as brake lugs 372. Brake component 350 is moveable (via operation of second solenoid actuator 242A) between a first position (FIGS. 18-19) whereat brake lugs 372 are retained within brake slots 370 to establish a non-rotary or “braked” state for mode worm 340, and a second position (FIG. 20) whereat brake lugs 372 are released from brake slots 370 so as to permit rotation of mode worm 340 and establish a “non-braked” state.

[0066] Power actuator mechanism 206A is configured to generally include first solenoid actuator 240A, second solenoid actuator 242A, motor actuator 246A, and an actuator lever assembly 380. Lever assembly 380 includes a lever arm 382 pivotally supported about a pivot point 384 and having a first end 386 and second end 388.

[0067] First end 386 of lever arm 382 engages first actuator shaft 306 while second end 388 of lever arm 382 engages second actuator shaft 348. A spring 390 is shown in FIG. 16 acting on first end 386 while first solenoid shaft 252A of first solenoid actuator 240A acts on second end 388. A slightly revised arrangement is shown in FIG. 18 with first solenoid shaft 252A acting on first end 386 of lever arm 382 while spring 390 acts on second end 388 of lever arm 382. First solenoid actuator 240A can act on either the range or mode side of these arrangements dependent on packaging and energy requirements.

[0068] FIG. 18 illustrates clutch actuation arrangement 200A with first solenoid actuator 240A operating in its Power Off state, second solenoid actuator 242A operating in its Power Off state, and motor actuator 246A operating in its Motor Off state. As such, first solenoid shaft 252A is located in a retracted position for locating first drive component in its first position and second drive component 346 in its first position via the movement of lever arm 382 to a first pivoted position. Likewise, second solenoid shaft 262A is located in its extended position for coupling brake component 350 to third coupling ring 344, thereby braking mode worm 340 from rotation.

[0069] FIG. 19 illustrates the orientation and operation of the components of clutch actuation arrangement 200A when a range shift operation is required. As seen, first solenoid actuator 240A is shifted into its Power On states such that solenoid shaft 252A moves lever arm 382 to a second pivoted position, whereby first drive component 304 is coupled to first coupling ring 302 and second drive component 346 is uncoupled from second coupling ring 342. Second solenoid actuator 242A is maintained in its Power Off state to continue to brake rotation of mode worm 340 and hold mode clutch 150 in its current state. Subsequent actuation of motor actuator 312 causes actuator gear 310 to drive range gear 308 which in turn drives range worm 310 for causing first range gear 210 to rotate. As understood, rotation of actuator gear 310 in a first direction causes a H to L range shift while rotation of actuator gear 310 in a second direction causes a L to H range shift. Upon completion of the range shift, first solenoid actuator 240A is reduced to its Power Off state.

[0070] FIG. 20 illustrates operation of clutch actuation arrangement 200A when a mode shift operation is required. As seen, first solenoid actuator 240A is in its Power Off state such that lever arm 382 is located in its first pivoted position. Thus, second drive component 346 is coupled to second coupling ring 342. I addition, second solenoid actuator 242A is now operating in its Power On state to retract brake component 350 from coupled engagement with third coupling ring 344. Upon actuation of motor actuator 312, actuator gear 310 causes mode gear 352 to rotate which, in turn, drives mode worm 340. Rotation of mode worm 340 in a first direction functions to rotate first mode gear 220 for causing increased clutch engagement of mode clutch 150. In contrast, rotation of mode worm 340 in a second direction functions to rotate first mode gear 220 for causing reduced clutch engagement of mode clutch 150.

[0071] FIGS. 21A and 21B show an alternative arrangement for clutch actuation arrangement 200B. In general, the previous embodiments employed first solenoid actuator 240 and 240A to control the mode shift operation in coordination with second solenoid actuator 242 and 242A providing a separate braking function. In contrast, FIGS. 21A and 21B illustrate a single actuator 240B configured to provide both the mode shift function and the brake function, particularly in one-speed transfer cases disclosed. Motor actuator 246 and 246A would still be employed to provide the adaptive torque transfer control.

[0072] The clutch actuation arrangement 200B includes the solenoid actuator 240B in operable connection with an actuator shaft 408. The actuator shaft 408 is axially fixed to a first drive component 404 and a second drive component 406. The first drive component 404 and the second drive component 406 are spaced from one another along actuator shaft 408. A coupling ring 402 is located about the actuator shaft 408 in the spacing between the first drive component 404 and the second drive component 406. The coupling ring 402 is axially fixed relative to the actuator shaft 408 such that axial movement of the actuator shaft 408 is relative to the coupling ring 402. The coupling ring 402 includes first drive slots 412 on a first side and second drive slots 414 on a second side that is opposite the first side. The first and second drive slots 412, 414 may be defined by apertures that extend entirely through the coupling ring 402. The first drive component 404 includes a series of circumferentially-arranged first coupling features, shown as drive lugs 410 that can be selectively moved into and out of engagement with the first drive slots 412 in response to axial movement of first drive component 404. In a similar manner, the second drive component 406 includes a series of circumferentially-arranged second coupling features, shown as drive lugs 416 that can be selectively moved into and out of engagement with the second drive slots 414 in response to axial movement of second drive component 406. In one arrangement, the first drive component 404 is located nearest the solenoid actuator 240B and is grounded to housing 405. The first drive component 404 may be similar in braking functionality to the brake component 350 and when engaged with the coupling ring 402 the clutch actuation arrangement 200B is in a braked state (FIG. 21B). The second drive component 406 may be similar in mode selection functionality to the second drive component 346 and when engaged with coupling ring 402 the clutch actuation arrangement 200B in a non-braked, mode selection state (FIG. 21A). The actuator shaft 408 may be initially biased in the braked state, wherein the solenoid actuator 240B is configured as a push solenoid. Alternatively, the actuator shaft 408 may be initially biased in the non-braked state, wherein the solenoid actuator 240B is configured as a pull solenoid. The solenoid actuator 240B may work in conjunction with the previously described first solenoid actuator 240 and 240A. In an alternate arrangement, the coupling ring 402 may be fixed to the actuator shaft 408, while the first and second drive components 404, 406 are not.

[0073] The present disclosure provides a clutch actuation arrangement that can be used in both of a single-speed active transfer case and a two-speed active transfer case by simply eliminating the range shift mechanism and planetary gearset. In addition, the clutch actuation arrangement is simplified in terms of required components relative to prior art systems used in active transfer cases and permits elimination of the conventional shift shaft, actuator (i.e., range and/or mode) cams, and the scissor-type ballramp actuator. Elimination of external position sensor is also available with sensors associated with the actuators (i.e., solenoid actuators and motor actuator) being used to provide position signals to the ECU. Furthermore, since the range shift clutch actuation mechanism and the mode shift actuation mechanism are independently operated, via ON/OFF control of first solenoid (actuator 240) the risk of the transfer case unintentionally shifting into Neutral is significantly reduced.

[0074] The present disclosure can be generally summarized to provide an improved clutch actuation arrangement for two-speed active transfer cases configured to include a solenoid-driven range/mode selection device (i.e., first solenoid actuator) in combination with solenoid-driven brake device (i.e., second solenoid actuator). A single motor-driven shifting device (i.e., motor actuator is only operated after selection of a range shift or mode shift operation via the solenoid-driven range/mode selection device. Control of the motor-driven shifting device function in its range shift state to control translational movement of a range clutch component between distinct range positions, and further functions in its mode shift state to control the magnitude of a clutch engagement force exerted on a multi-plate mode clutch.

[0075] The foregoing description of the embodiments has been provided for purposes of illustration and description. 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 varied 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 the disclosure.

CLAIMS

1. A transfer case for use in a four-wheel drive motor vehicle having a powertrain and first and second drivelines, comprising:

an input shaft adapted to receive drive torque from the powertrain and aligned for rotation about a first axis;

a first output shaft adapted to be interconnected to the first driveline and aligned for rotation about said first axis;

a second output shaft adapted to be interconnected to the second driveline and aligned for rotation about a second axis;

a transfer mechanism having a first transfer component rotatably supported on said first output shaft for rotation about said first axis, and a second transfer component fixed to said second output shaft for rotation about said second axis, said second transfer component being driven by said first transfer component;

a range mechanism including a reduction unit and a range clutch, said reduction unit being driven at a reduced speed relative to said input shaft, said range clutch being operable in a first range position to establish a drive connection between said input shaft and said first output shaft and being further operable in a second position to establish a drive connection between said reduction unit and said first output shaft;

a range shift mechanism controlling movement of said range clutch between said first and second range positions;

a mode mechanism disposed between said first transfer component and said first output shaft, said mode mechanism including a mode clutch having a first clutch member coupled to said first transfer component, a second clutch member coupled to said first output shaft, a multi-plate clutch pack disposed between said first and second clutch members, and an apply member moveable into and out of engagement with said clutch pack;

a mode shift mechanism for controlling movement of said apply member relative to said clutch pack so as to control the magnitude of a clutch engagement force applied to said clutch pack and concurrently control the amount of drive torque transferred from said first output shaft through said transfer mechanism and said mode clutch to said second output shaft; and

a clutch actuation arrangement having a range clutch actuation mechanism for controlling actuation of said range shift mechanism, a mode clutch actuation mechanism for controlling actuation of said mode shift mechanism, and a power actuator mechanism for controlling actuation of said range clutch actuation mechanism and said mode clutch actuation mechanism.

2. The transfer case of Claim 1, wherein said range shift mechanism includes a first rotary-to-linear conversion device, wherein said range clutch actuation mechanism includes a first range gear, wherein rotation of said first range gear in a first rotary direction causes said first conversion device to move said range clutch from its first range position to its second range position, wherein rotation of said first range gear in a second rotary direction causes said first conversion device to move said range clutch from its second range position to its first range position, and wherein said power actuator mechanism controls rotation of said first range gear.

3. The transfer case of Claim 2, wherein said mode shift mechanism includes a second rotary-to-linear conversion device, wherein said mode clutch actuation mechanism includes a first mode gear, wherein rotation of said first mode gear in a first rotary direction causes said second conversion device to move said

apply plate in a first direction to increase the clutch engagement force applied to said clutch pack, wherein rotation of said first mode gear in a second rotary directions causes said second conversion device to move said apply plate in a second direction to decrease the clutch engagement force applied to said clutch pack, and wherein said power actuator mechanism controls rotation of said first mode gear.

4. The transfer case of Claim 3, wherein said range clutch actuation mechanism includes a second range gear meshed with said first range gear, wherein said mode clutch actuation mechanism includes a second mode gear meshed with said first mode gear, wherein said power actuator mechanism includes a range drive gear, a mode drive gear, a two-position linear actuator and a rotary actuator, said linear actuator is operable in a first position to couple said range drive gear to said second range gear and to uncouple said mode drive gear from said second mode gear and is further operable in a second position to uncouple said range drive gear from said second range gear and to couple said mode drive gear to said second mode gear, and wherein actuation of said rotary actuator with said linear actuator in its first position functions to drive said range drive gear and actuation of said rotary actuator with said linear actuator in its second position functions to drive said mode drive gear.

5. The transfer case of Claim 4, wherein said power actuator mechanism further includes a second two-position linear actuator, said second linear actuator is operable in a first position to brake rotation of said second mode gear and in a second position to permit rotation of said second mode gear.

6. The transfer case of Claim 5, wherein said second linear actuator is located in its first position when said first linear actuator is located in its first position,

and wherein said second linear actuator is located in its second position when said first linear actuator is located in its second position.

7. The transfer case of Claim 5, wherein said first range gear and said second range gear define a range spur gearset, wherein said first mode gear and said second mode gear define a mode spur gearset, wherein said first linear actuator is a first solenoid actuator having a first energizable coil, a first linearly-moveable solenoid shaft moveable between said first and second positions, and a first biasing device for biasing said first solenoid shaft toward its second position, said range drive gear and said mode drive gear being fixed for rotation with said first solenoid shaft, said first solenoid shaft is operable in its first position to couple said range drive gear to said second range gear via a range coupling arrangement, and said first solenoid shaft is operable in its second position to couple said mode drive gear to said second mode gear via a mode coupling arrangement.

8. The transfer case of Claim 7, when said rotary actuator includes an electric motor having a motor shaft, a range pinion fixed to said motor shaft and which is meshed with said range drive gear, and a mode pinion fixed to said motor shaft and which is meshed with said mode drive gear, wherein actuation of said electric motor when said first solenoid shaft is located in its first position causes said range pinion to drive said range spur gearset for moving said range clutch via said first conversion device, and wherein actuation of said electric motor when said first solenoid shaft is located in its second position causes said mode pinion to drive said mode spur gearset for moving said apply plate via said second conversion device.

9. The transfer case of Claim 5, wherein said second range gear is a range worm meshed with said first range gear and said second mode gear is a mode worm meshed with said first mode gear, wherein said first linear actuator includes a

first solenoid actuator and a lever arm, wherein said first solenoid actuator is operable in its first position to pivot said lever arm to a range position to couple said range drive gear to said range worm via a range coupling arrangement, and wherein said first solenoid actuator is operable in its second position to pivot said lever arm to a mode position to couple said mode drive gear to said mode worm via a mode coupling arrangement.

10. The transfer case of Claim 9, wherein said range coupling arrangement includes a first coupling ring fixed to said range worm, wherein said first coupling ring includes a plurality of coupling features, wherein a first drive component fixed to a first actuator shaft and is selectively coupled for rotation with said range drive gear and is axially moveable relative to said first coupling ring via movement of said first actuator shaft by said first solenoid actuator.

11. The transfer case of Claim 10, wherein said mode coupling arrangement includes a first mode coupling ring fixed to one end of said mode worm and a second mode coupling ring fixed to an opposite end of said mode worm, wherein a second drive component is fixed to a second actuator shaft and is selectively coupled for rotation with said first mode gear via movement of said second actuator shaft by said second solenoid actuator.

12. The transfer case of Claim 11, wherein said mode coupling arrangement further includes a brake component selectively coupled to said second mode coupling ring via movement of said second solenoid actuator between a braked state and a non-braked state, wherein in said braked state said brake component is rotationally connected to said second mode coupling ring and said mode worm is prevented from rotating, wherein in said non-braked state said brake

component is rotationally unpaired from said second mode coupling ring to permit said mode worm to rotate.

13. A transfer case for use in a four-wheel drive motor vehicle having a powertrain and first and second drivelines, comprising:

an input shaft adapted to receive drive torque from the powertrain and aligned for rotation about a first axis;

a first output shaft adapted to be interconnected to the first driveline and aligned for rotation about said first axis;

a second output shaft adapted to be interconnected to the second driveline and aligned for rotation about a second axis;

a transfer mechanism having a first transfer component rotatably supported on said first output shaft for rotation about said first axis, and a second transfer component fixed to said second output shaft for rotation about said second axis, said second transfer component being driven by said first transfer component;

a mode mechanism disposed between said first transfer component and said first output shaft, said mode mechanism including a mode clutch having a first clutch member coupled to said first transfer component, a second clutch member coupled to said first output shaft, a multi-plate clutch pack disposed between said first and second clutch members, and an apply member moveable into and out of engagement with said clutch pack;

a mode shift mechanism for controlling movement of said apply member relative to said clutch pack so as to control the magnitude of a clutch engagement force applied to said clutch pack and concurrently control the amount of drive torque transferred from said first output shaft through said transfer mechanism and said mode clutch to said second output shaft; and a mode clutch actuation mechanism for controlling actuation of said mode shift mechanism, and a power actuator mechanism for controlling actuation of said mode clutch actuation mechanism.

14. The transfer case of Claim 13, wherein said mode shift mechanism includes a rotary-to-linear conversion device, wherein said mode clutch actuation mechanism includes a first mode gear, wherein rotation of said first mode gear in a first rotary direction causes said second conversion device to move said apply plate in a first direction to increase the clutch engagement force applied to said clutch pack, wherein rotation of said first mode gear in a second rotary directions causes said second conversion device to move said apply plate in a second direction to decrease the clutch engagement force applied to said clutch pack, wherein said power actuator mechanism controls rotation of said first mode gear, and wherein said power actuator mechanism further includes a two-position linear actuator, said two-position linear actuator is operable in a first position to brake rotation of said mode gear and in a second position to permit rotation of said mode gear.

15. The transfer case of Claim 14, wherein said linear actuator includes a solenoid in operable connection to an actuator shaft, wherein a mode component and a brake component are axially fixed to said actuator shaft and spaced apart from one another, wherein a coupling ring is located between said mode component and said brake component, wherein said solenoid moves said mode component via said actuator shaft in a first axial direction and into meshed engagement with said coupling ring in a non-braked and mode selection state, and wherein said solenoid moves said brake component via said actuator shaft in a second axial direction and into meshed engagement with said coupling ring in a braked state.

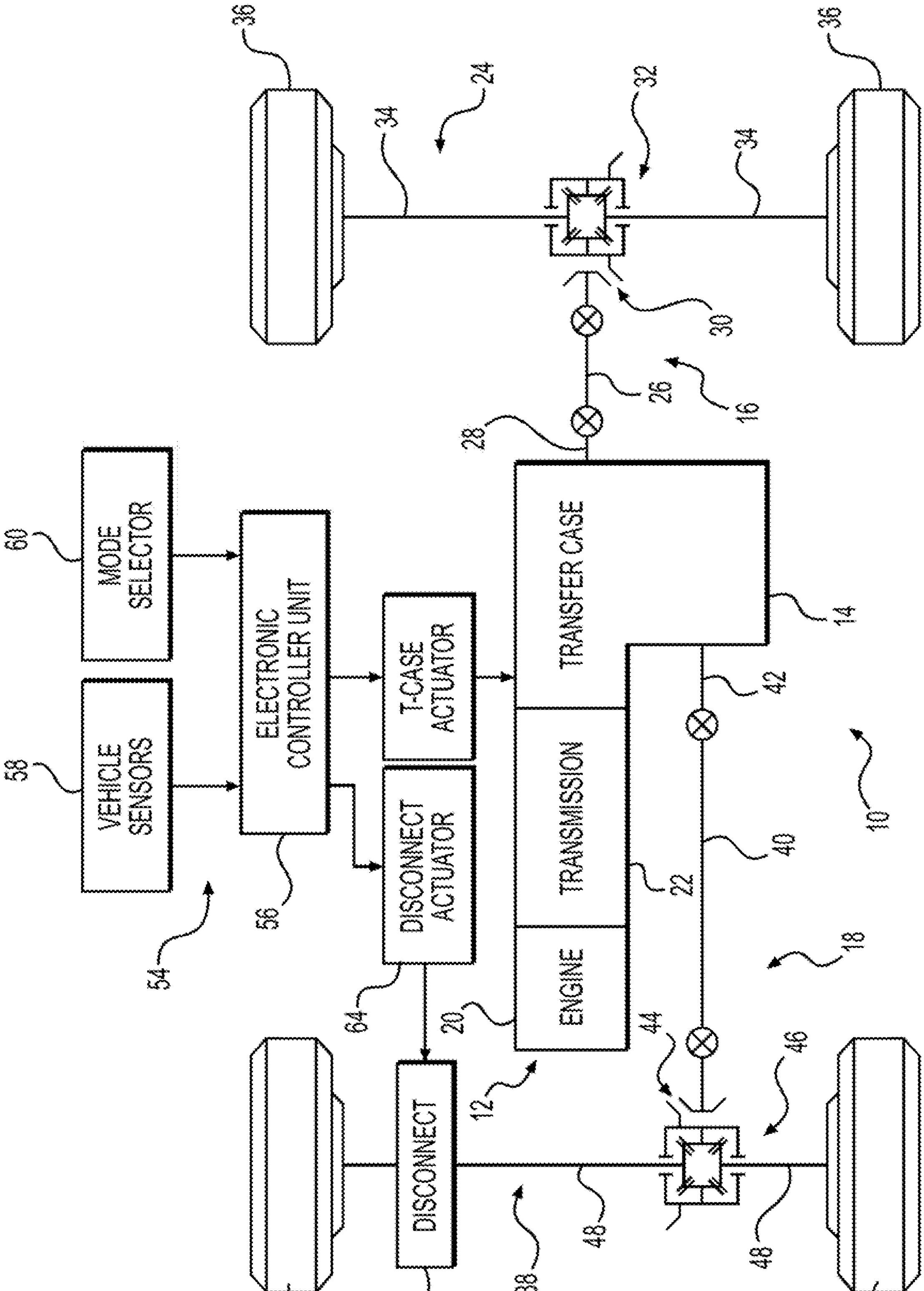
MODE SELECTOR
VEHICLE SENSORS
ELECTRONIC CONTROLLER UNIT
T-CASE ACTUATOR
DISCONNECT ACTUATOR
TRANSFER CASE
TRANSMISSION
ENGINE
DISCONNECT
10
12
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FIG. 1

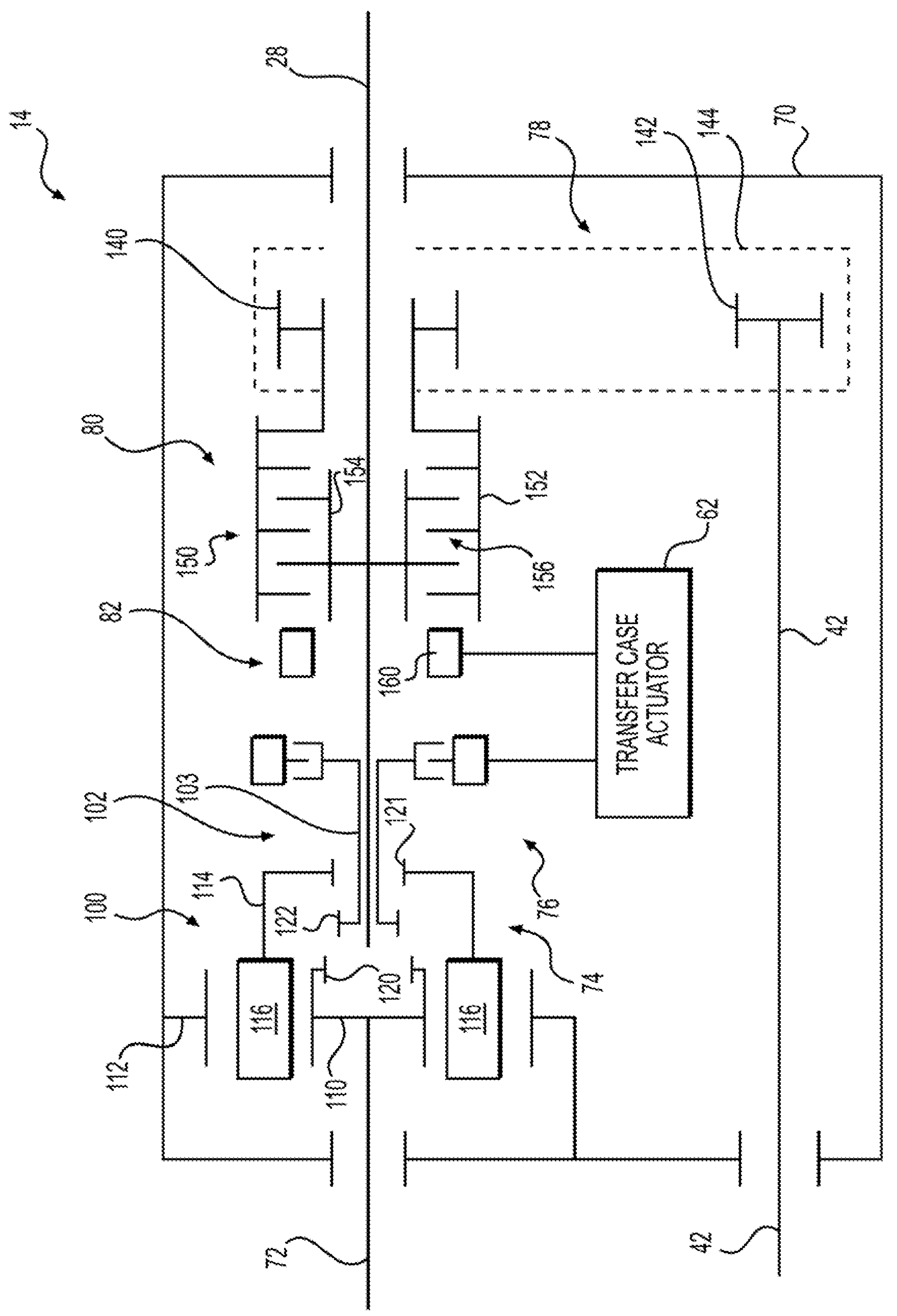
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FIG. 2

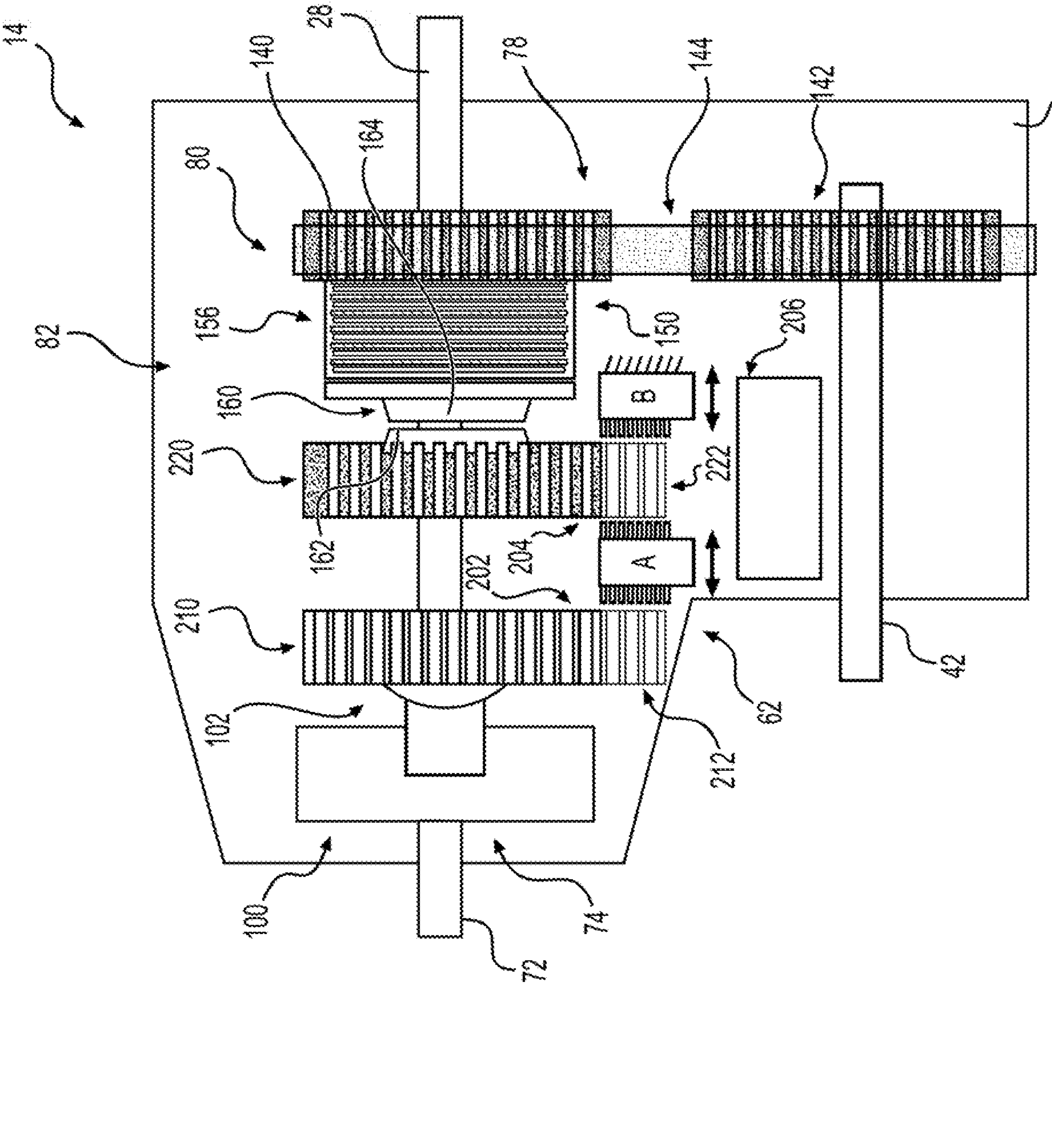
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FIG. 3

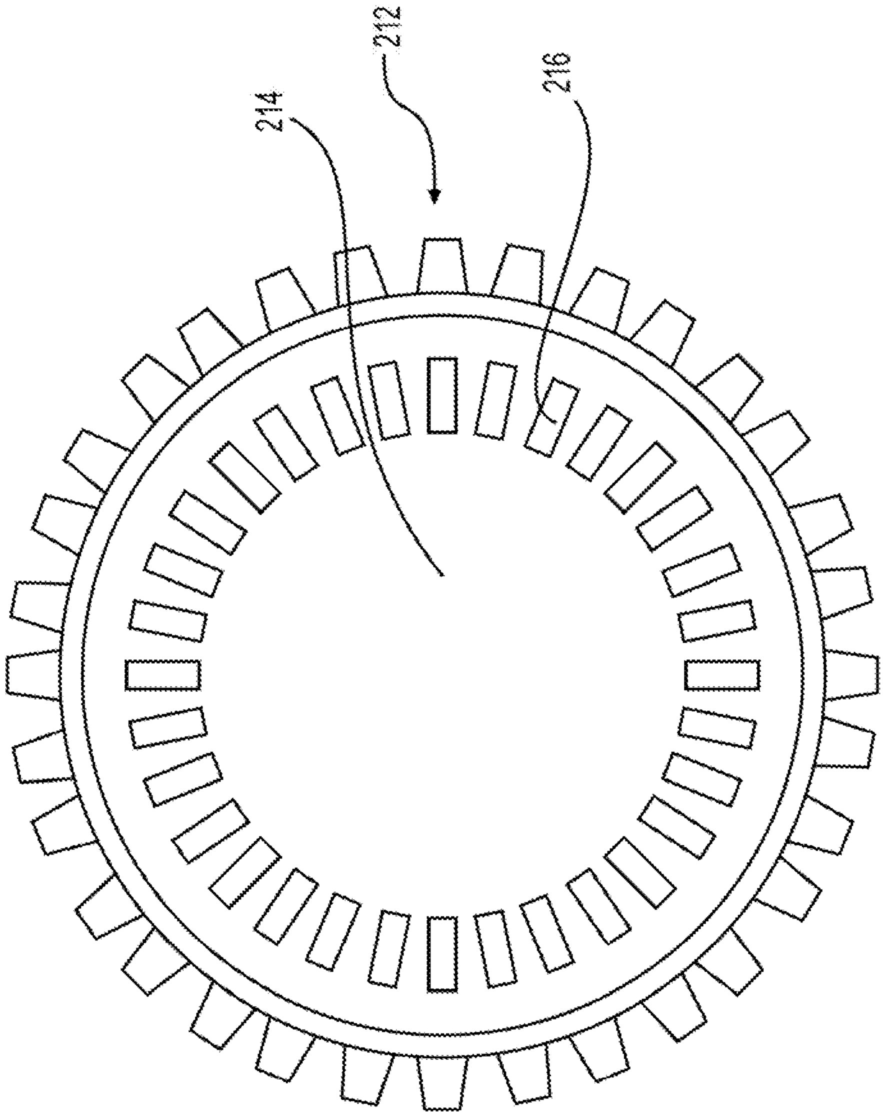

FIG. 4

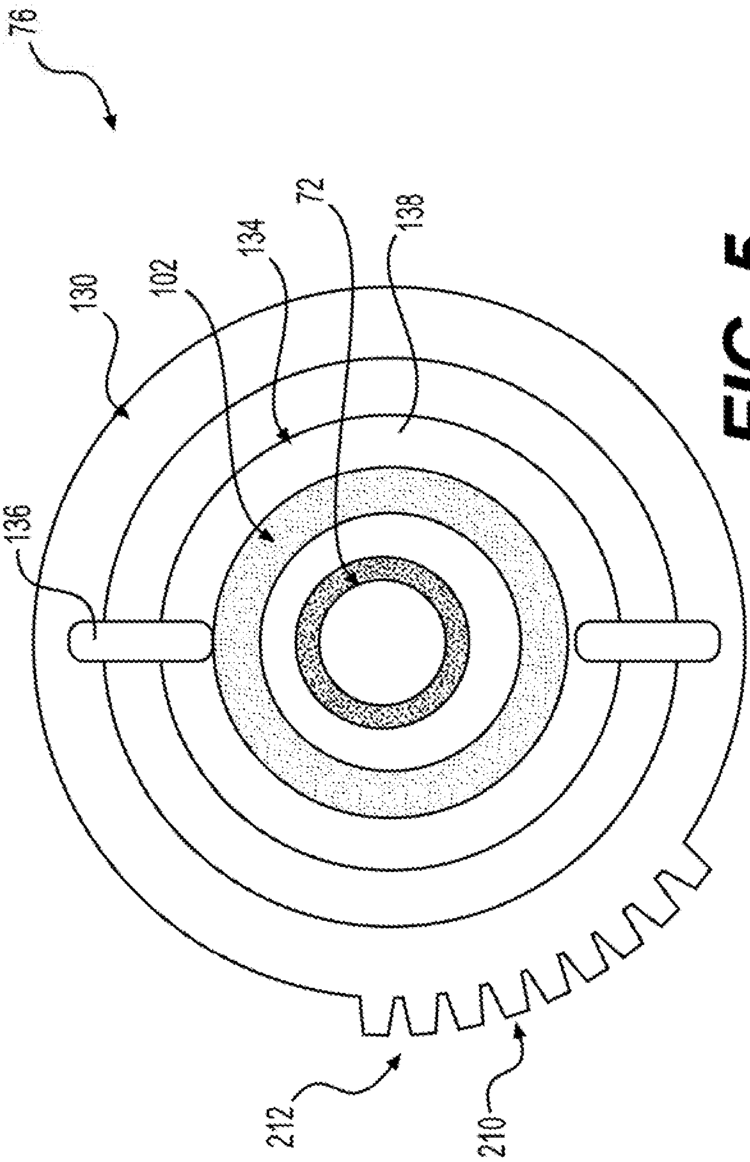

FIG. 5

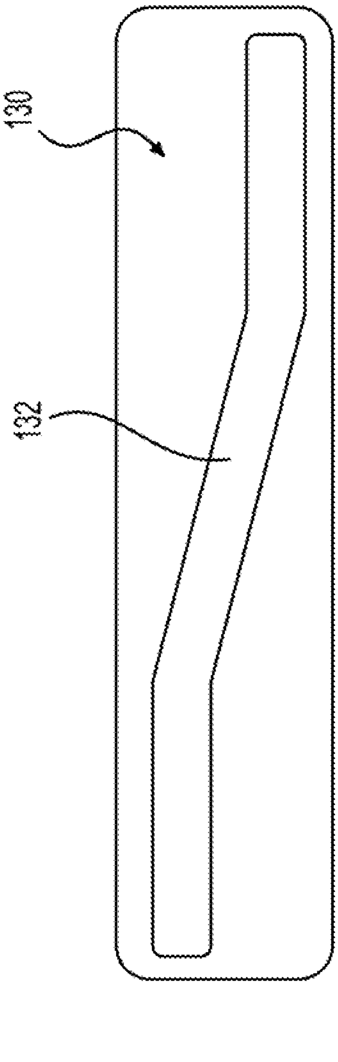

FIG. 6

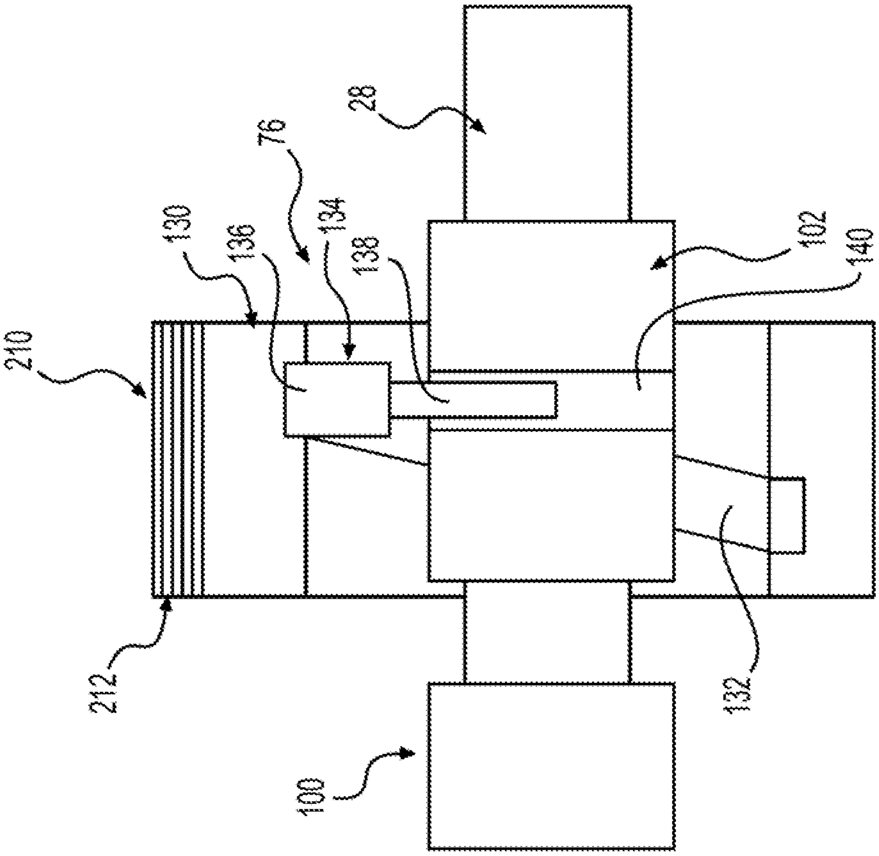
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FIG. 7B

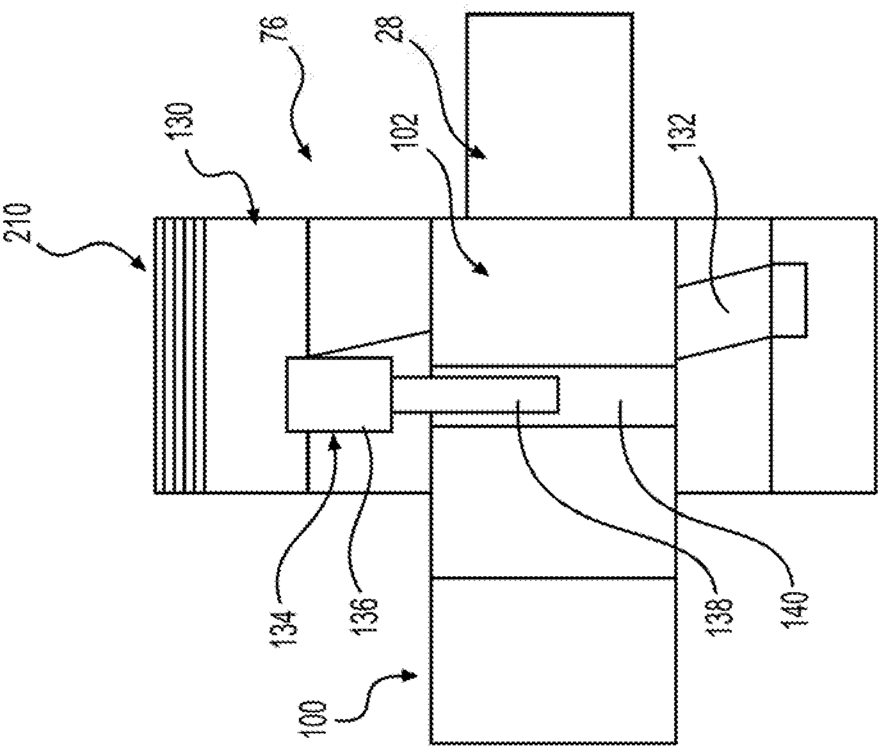
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FIG. 7A

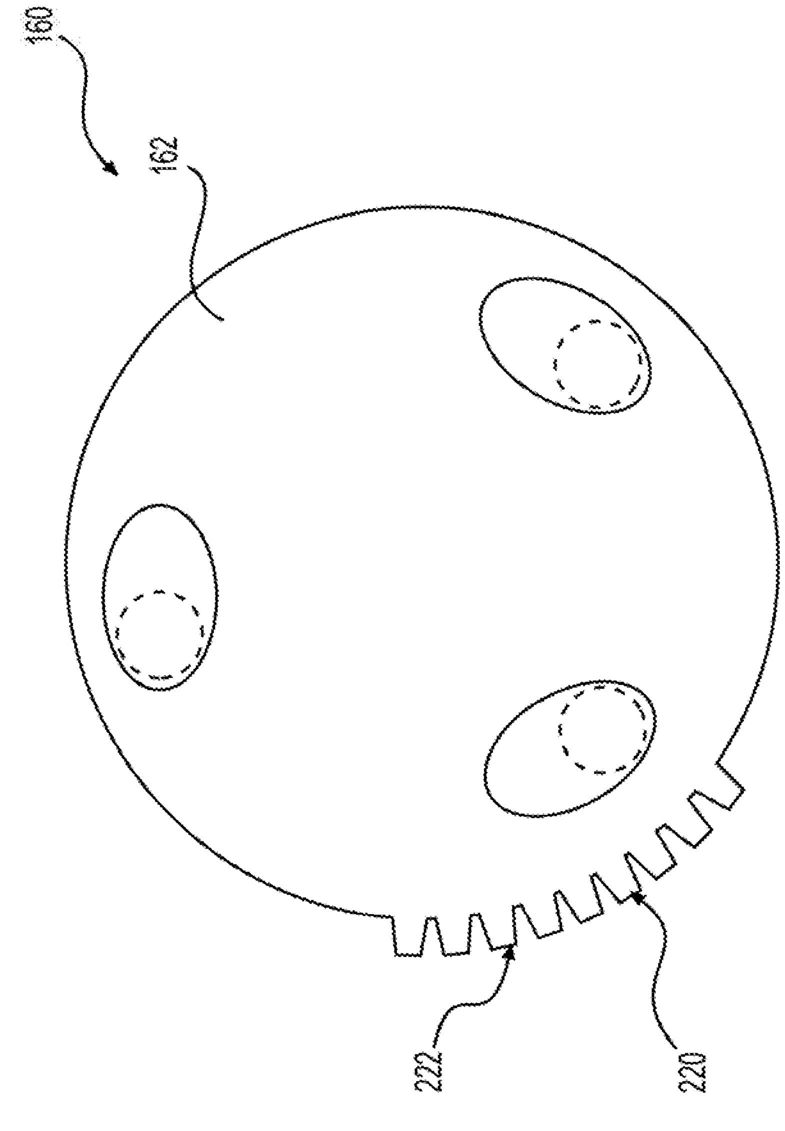

FIG. 8

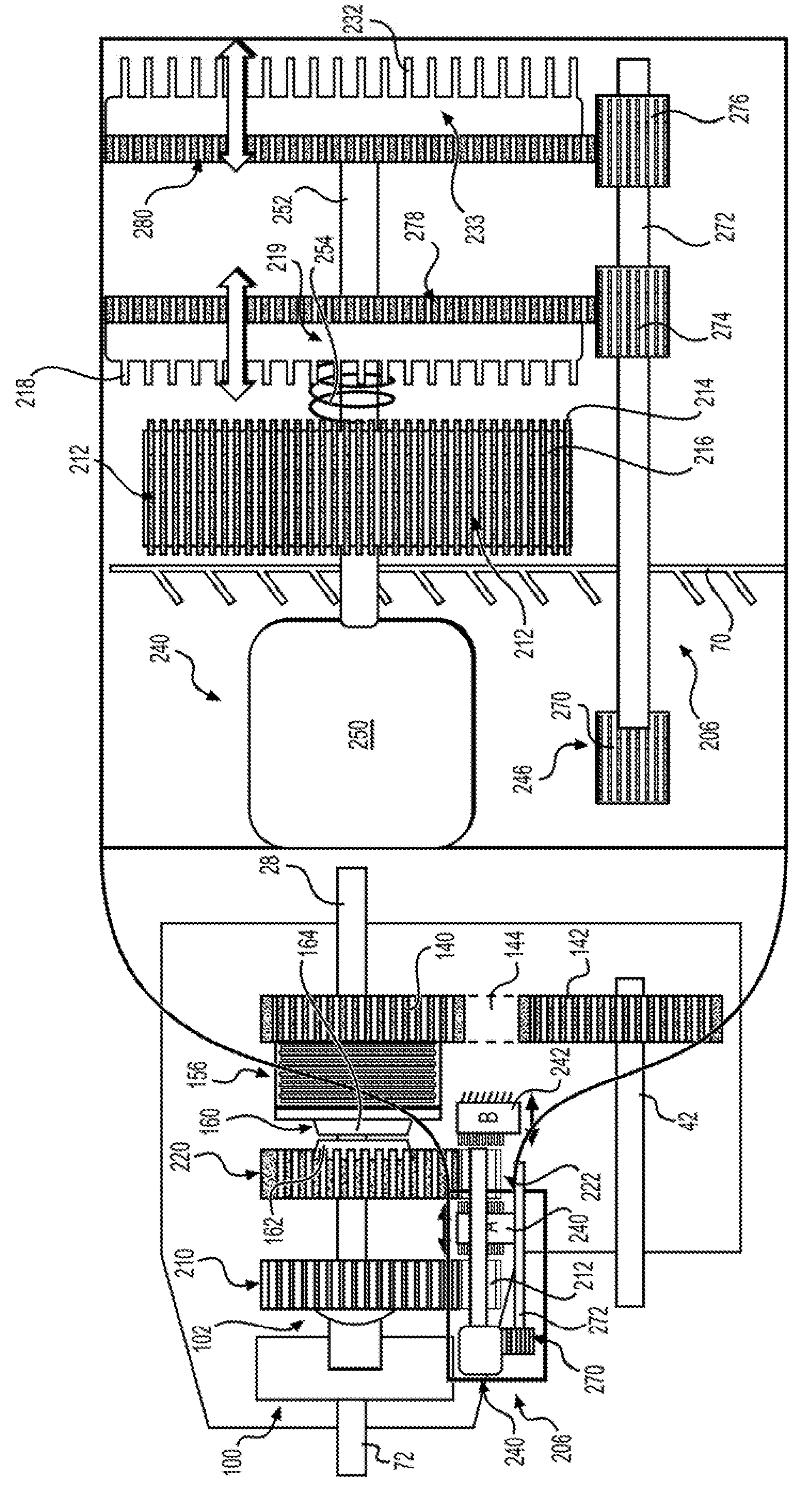
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FIG. 9

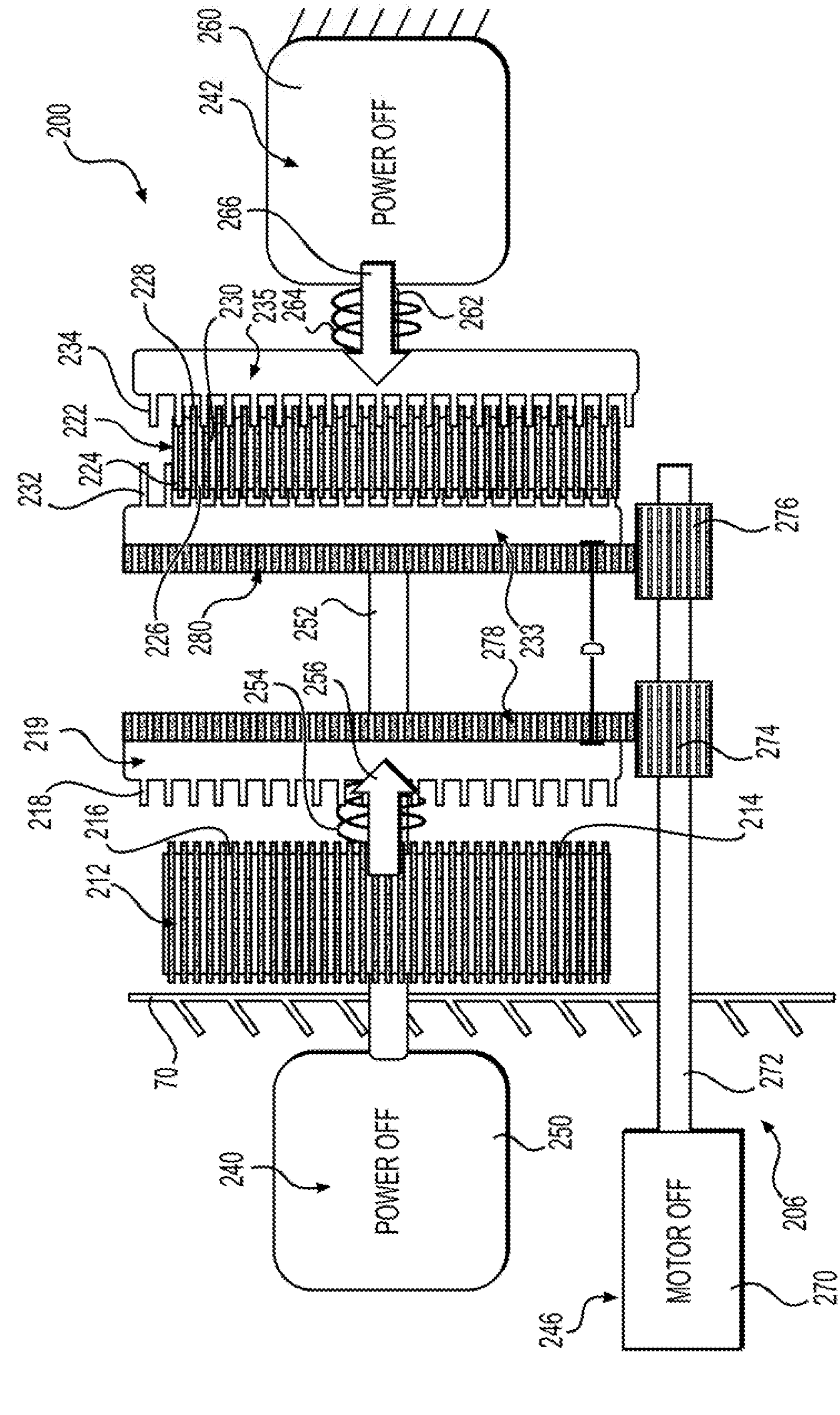

FIG. 10

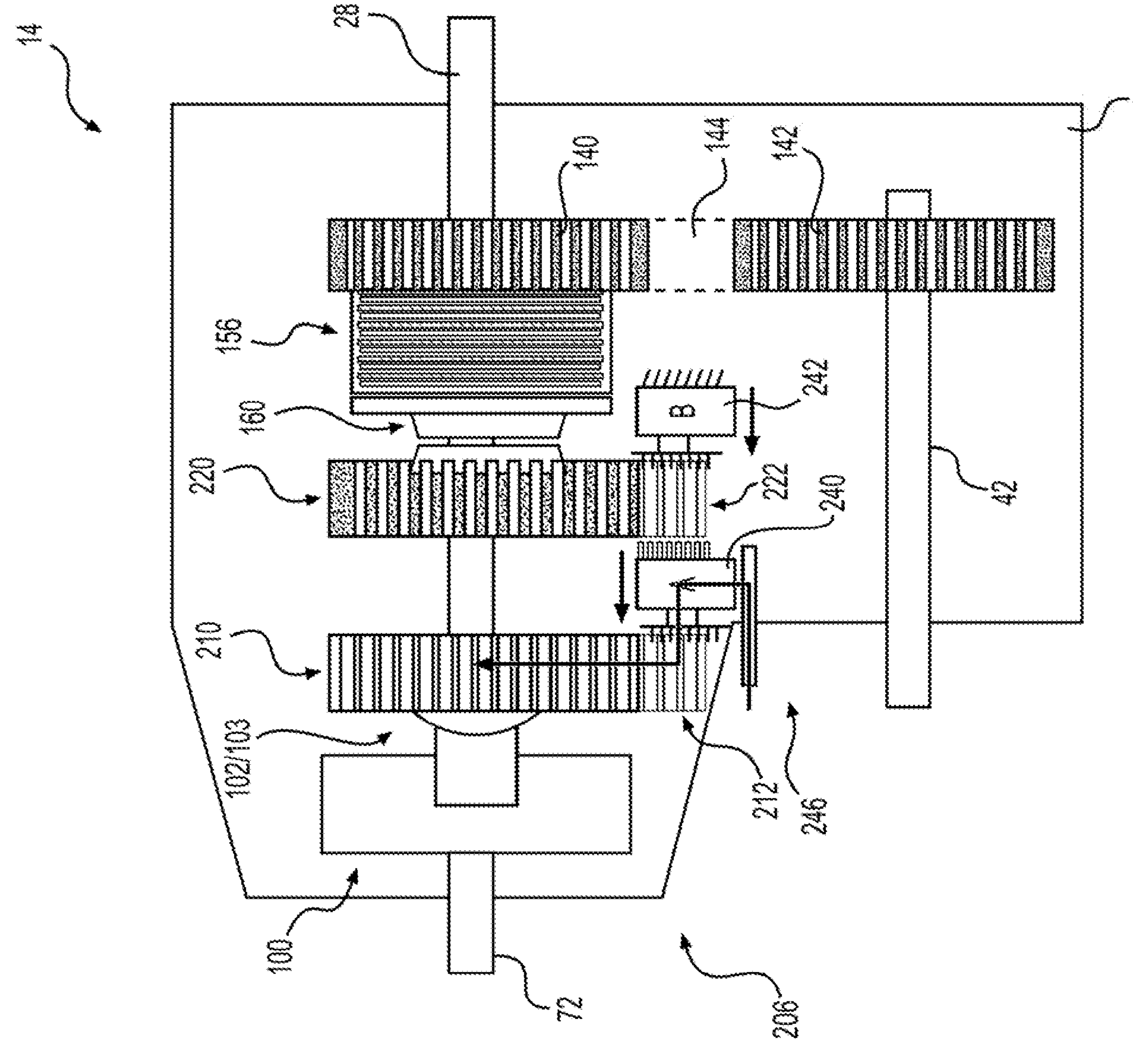
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FIG. 11

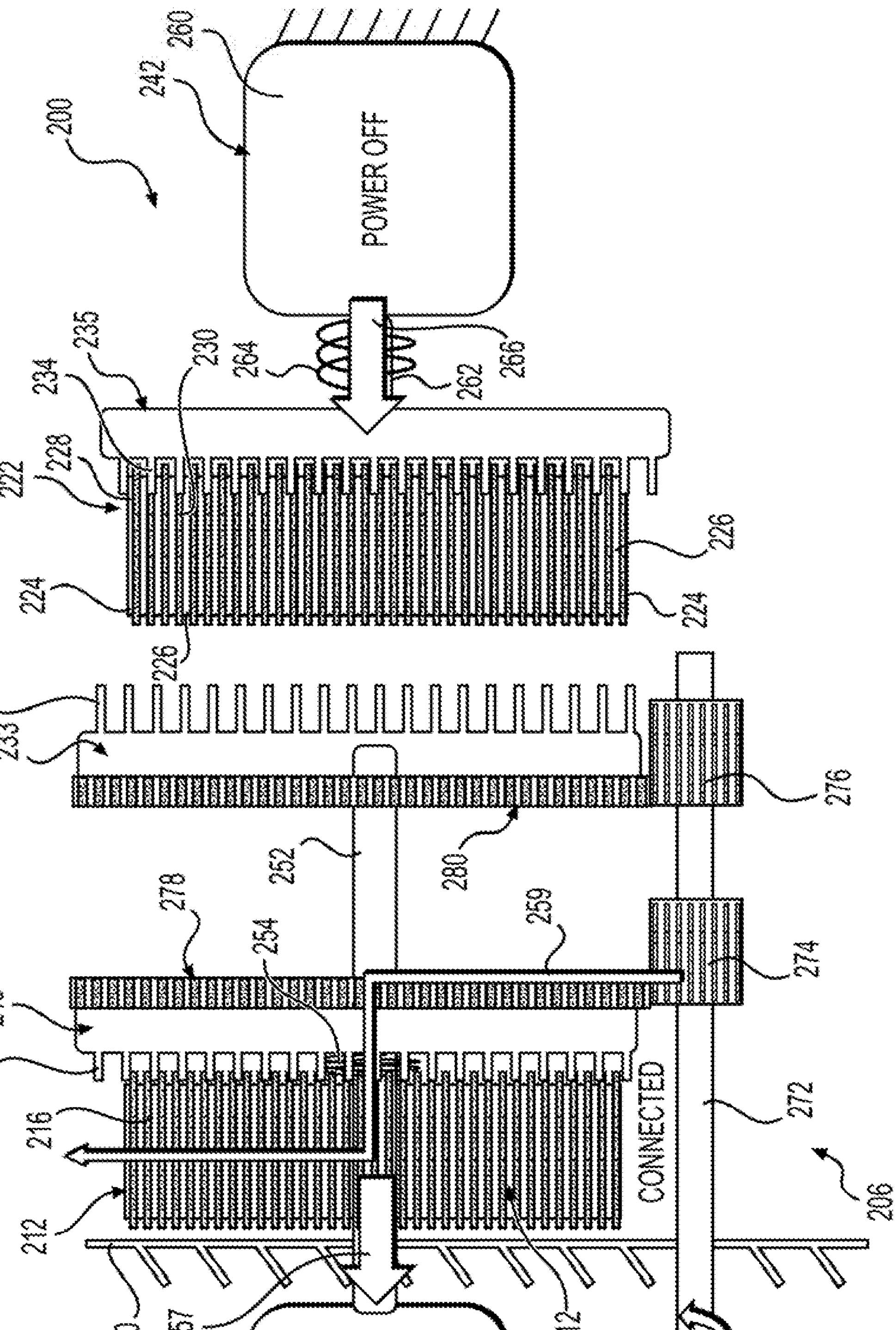
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FIG. 12

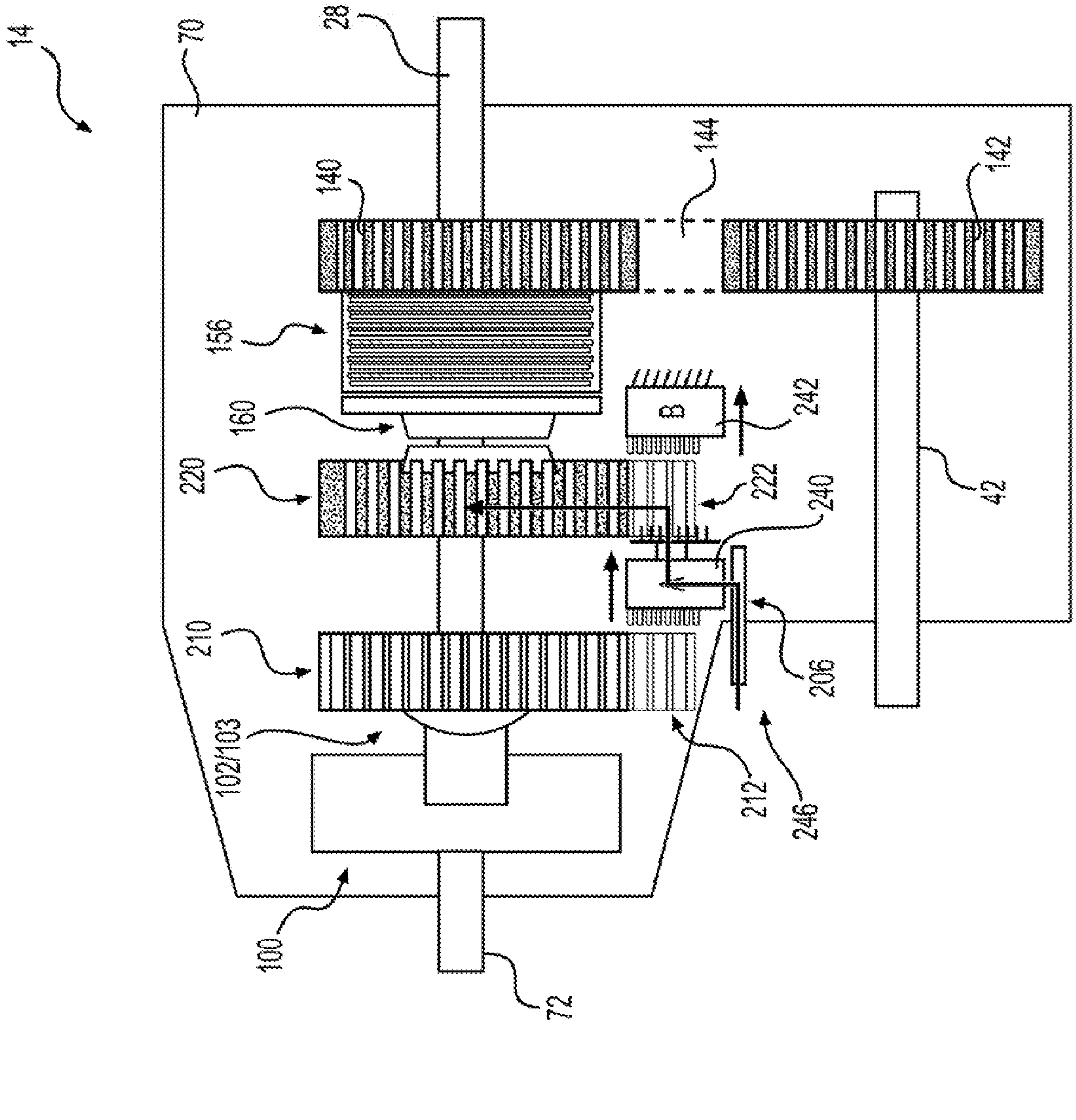
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FIG. 13

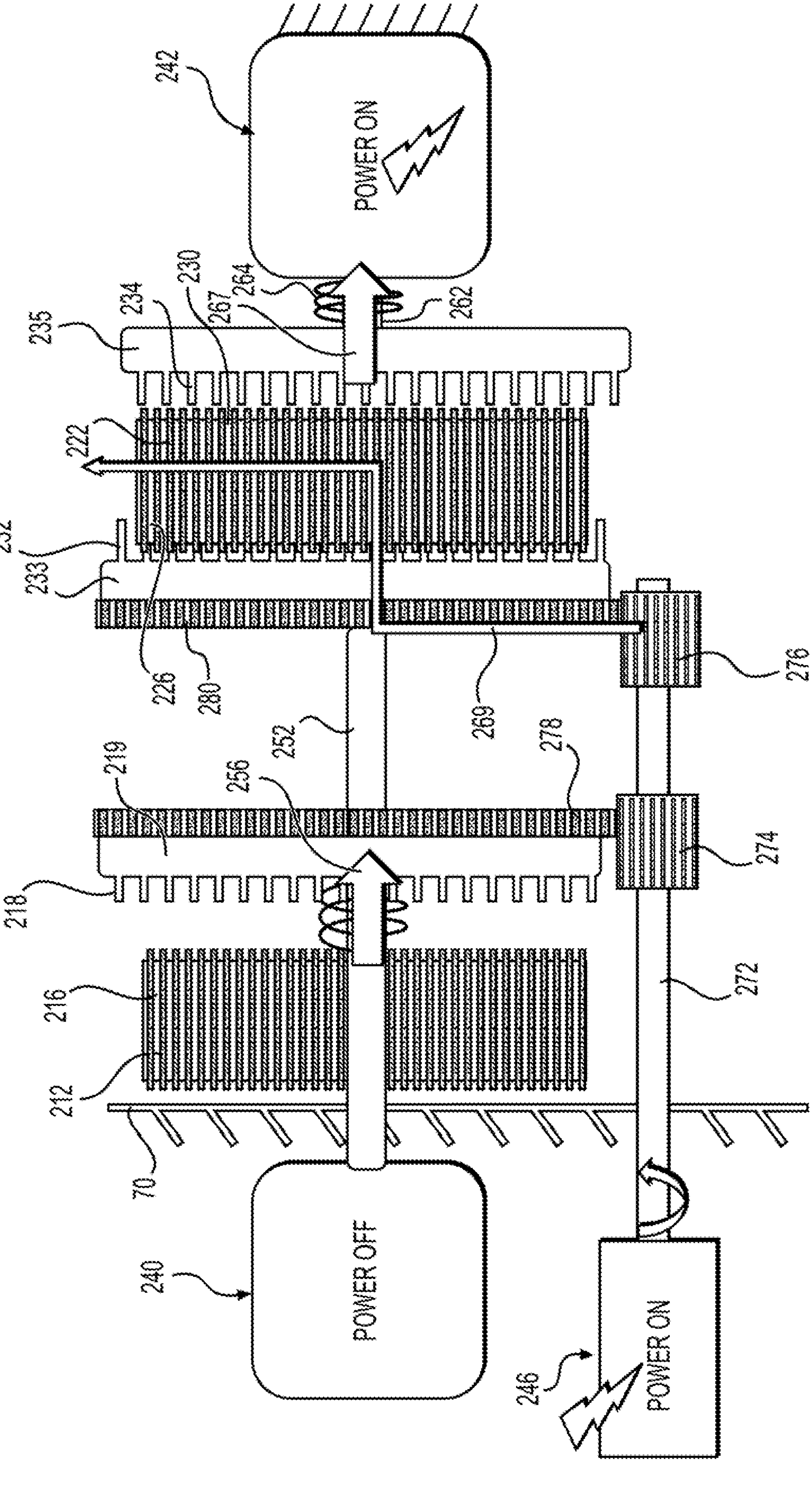
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FIG. 14

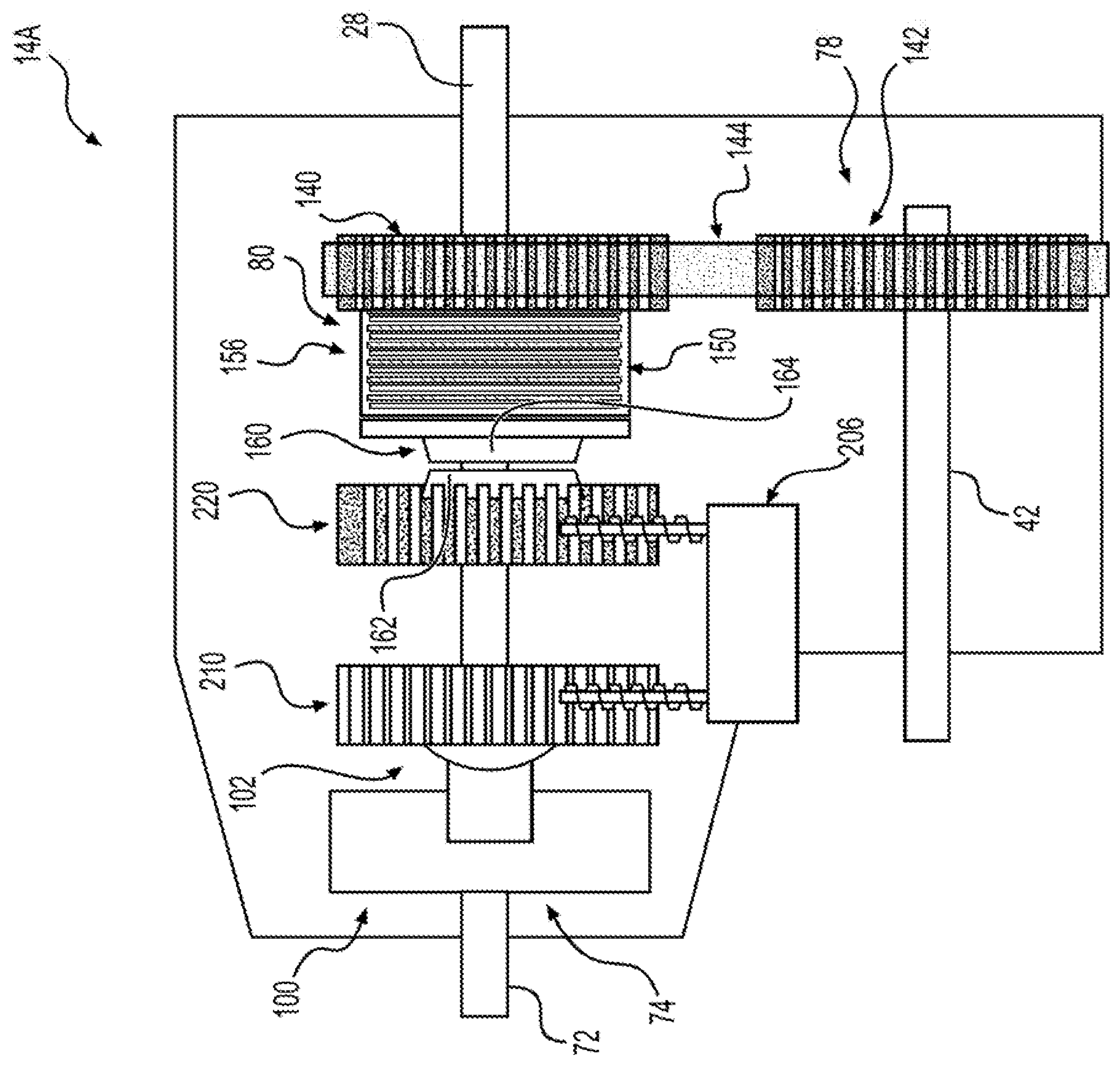
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FIG. 15

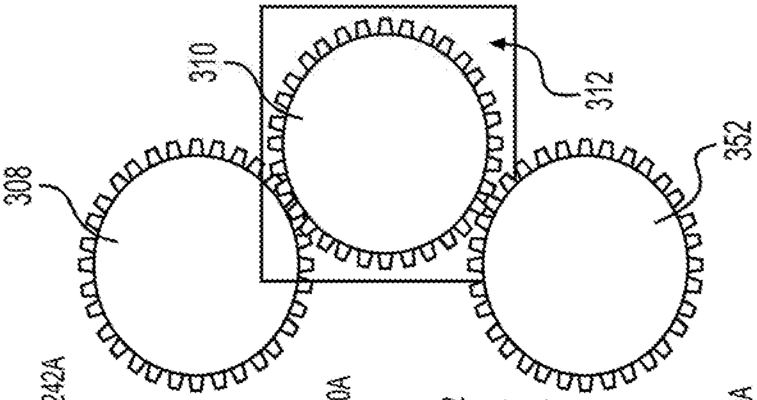
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FIG. 17

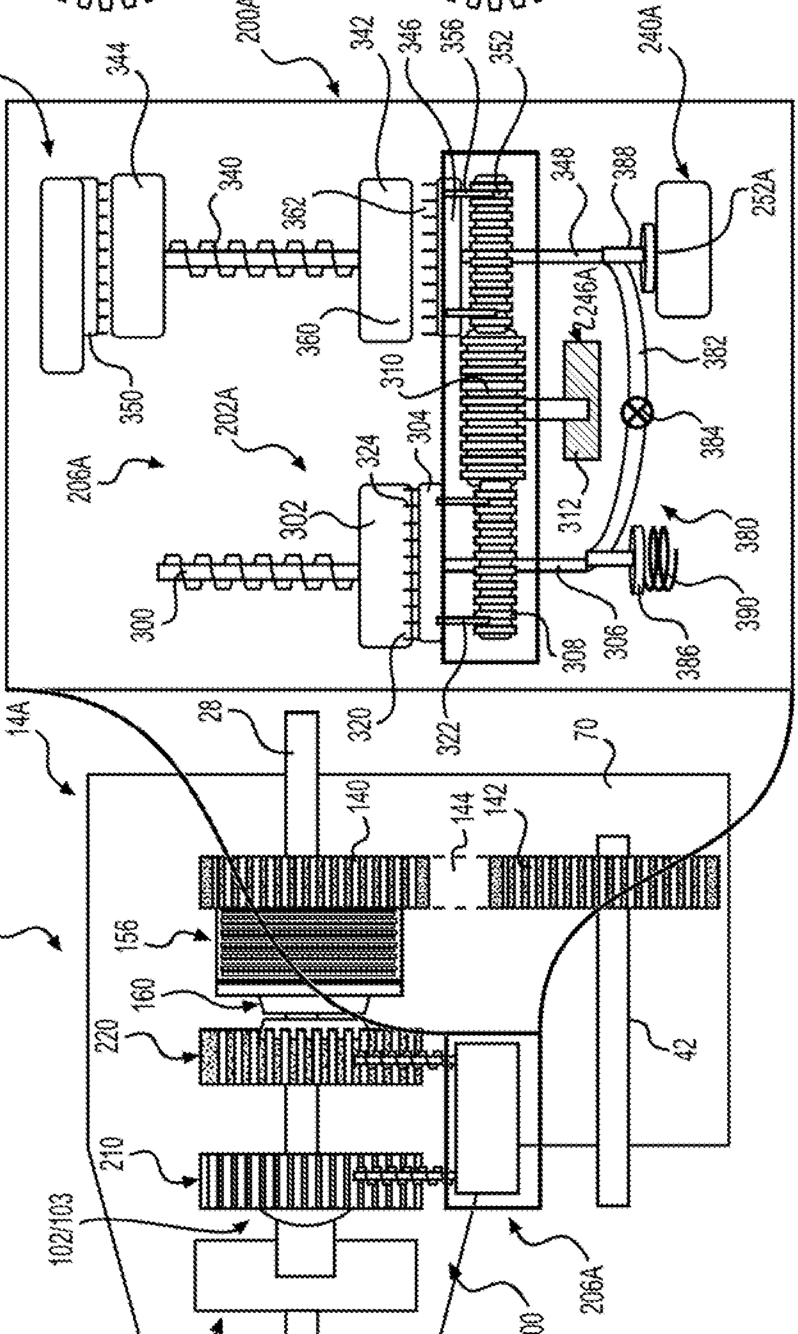
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FIG. 16

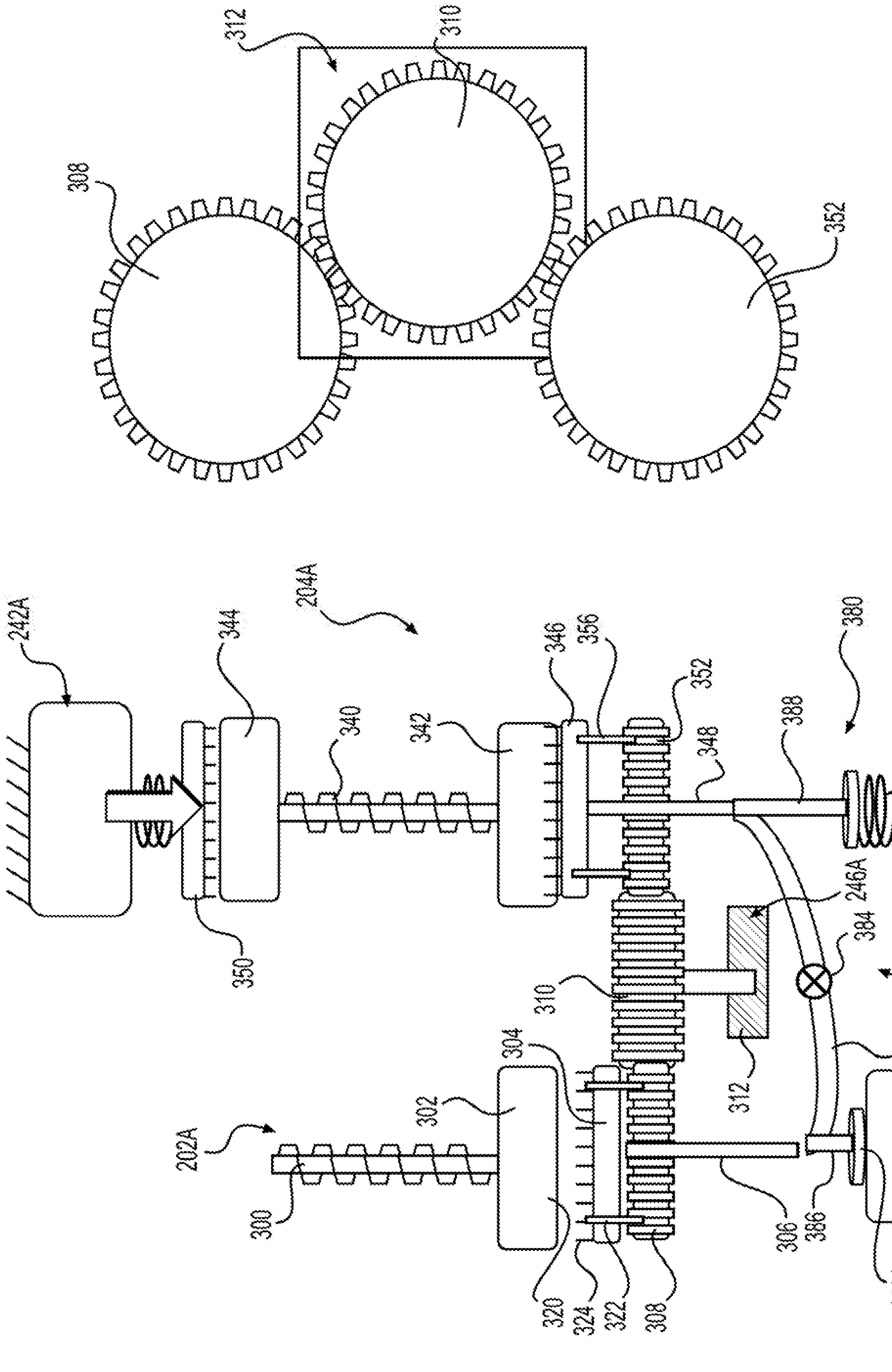
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FIG. 18

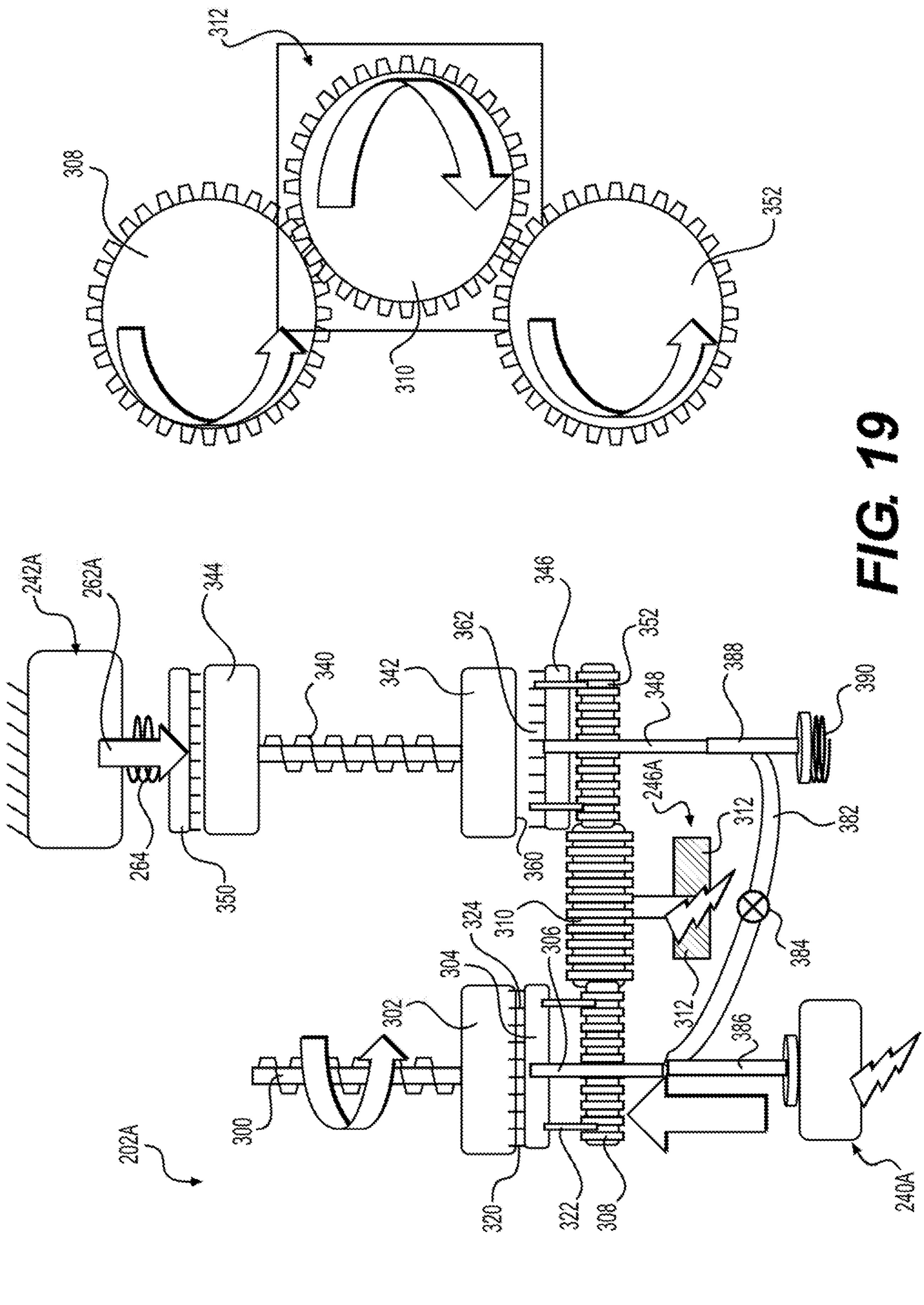
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FIG. 19

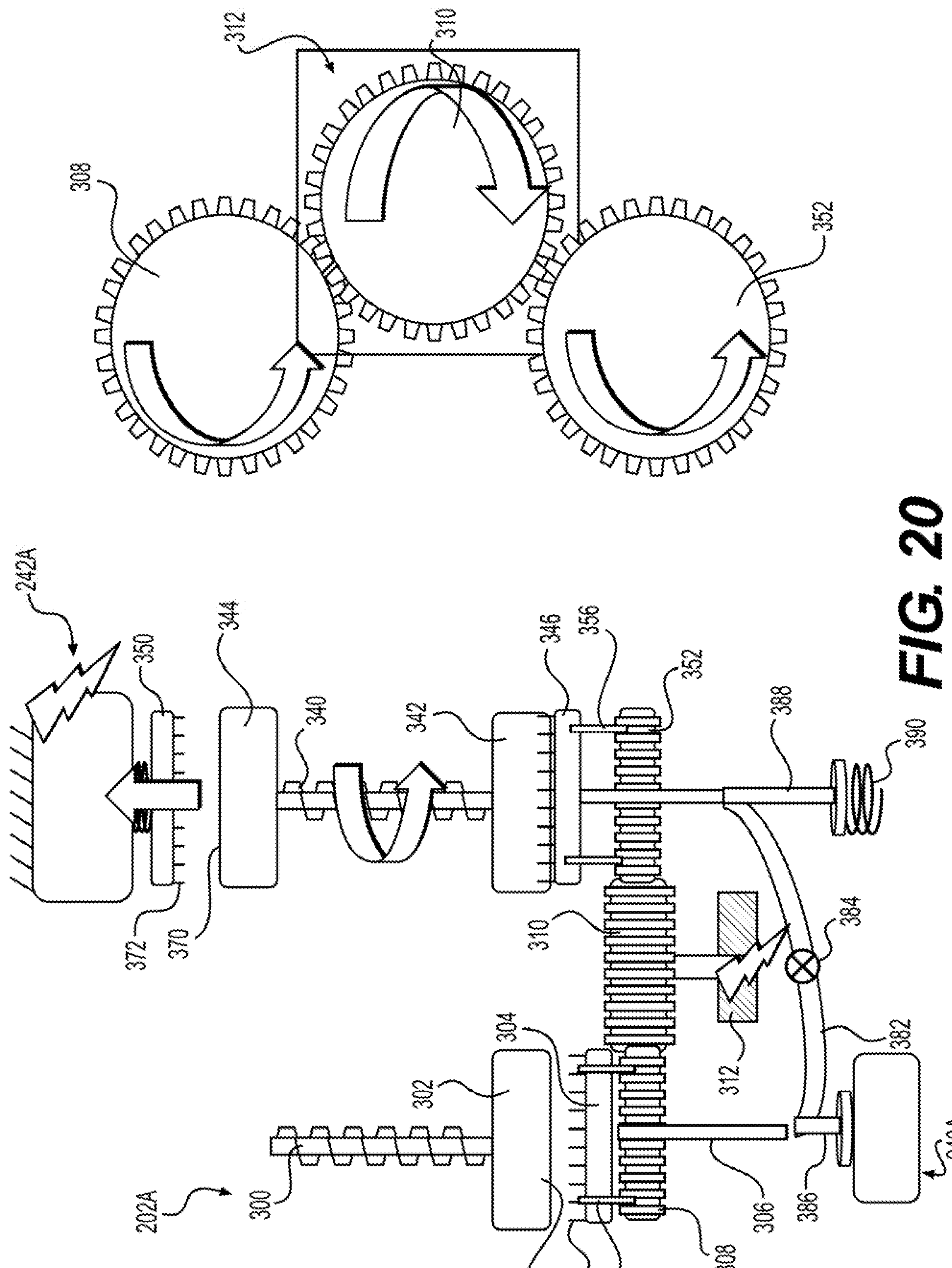
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FIG. 20

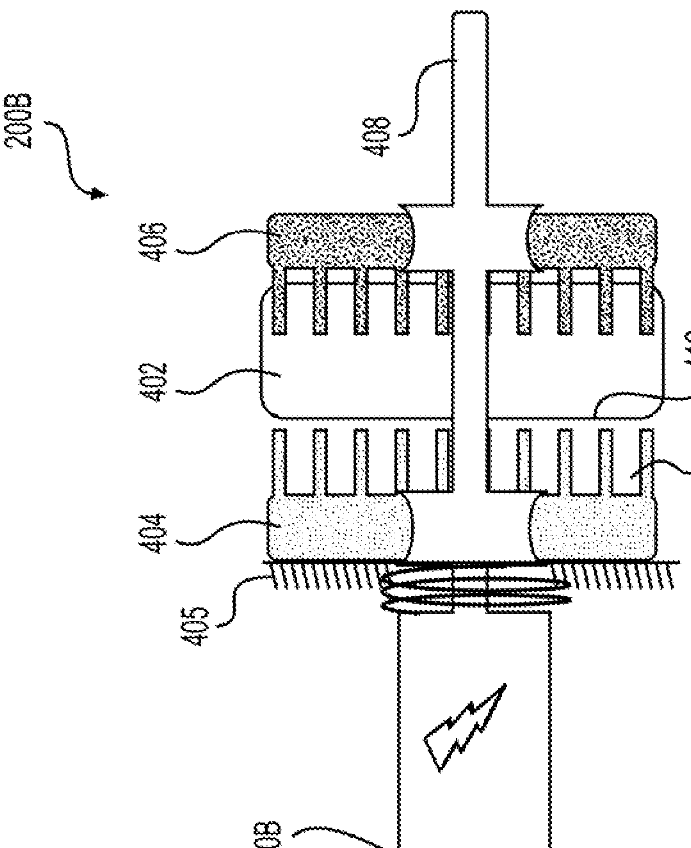

FIG. 21A

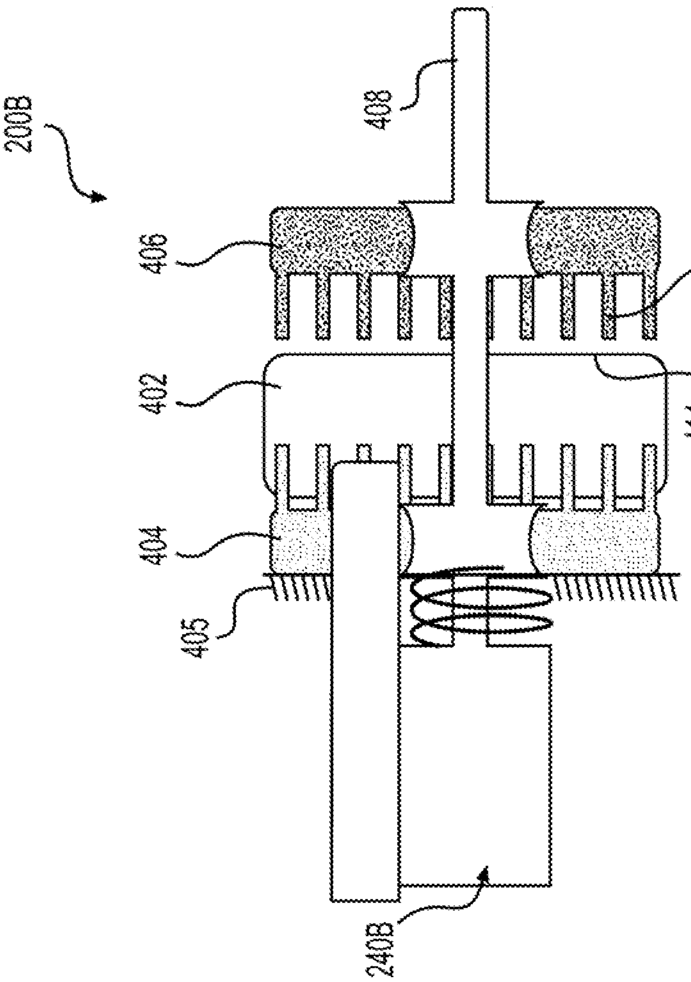

FIG. 21B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/054915

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60K17/344 B60K17/02 B60K17/346
ADD.

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)
B60K

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	EP 0 925 986 A2 (NEW VENTURE GEAR INC [US]) 30 June 1999 (1999-06-30) abstract; figures 1-5 paragraph [0004] - paragraph [0011] paragraph [0013] - paragraph [0028] -----	1-6,9, 13-15 7,8, 10-12
X A	US 2006/128515 A1 (MUELLER JOSEPH G [US] ET AL) 15 June 2006 (2006-06-15) abstract; figures 1-13 paragraph [0022] - paragraph [0053] -----	1-6,9, 13-15 7,8, 10-12
A	US 2016/377156 A1 (ROBLES ENRIQUE [US]) 29 December 2016 (2016-12-29) abstract; figures 1-17 paragraph [0037] - paragraph [0077] ----- -/--	1-15

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

[X] See patent family annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

"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

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 January 2021	04/02/2021

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Ozdemir, Anil

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International application No
PCT/US2020/054915

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2006/058146 A1 (BRISSENDEN JAMES S [US] ET AL) 16 March 2006 (2006-03-16) abstract; figures 1-25 paragraph [0014] - paragraph [0017] paragraph [0038] - paragraph [0115] -----	1-15

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2020/054915

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0925986 A2	30-06-1999	CA 2255438 A1	15-06-1999
		DE 69812055 T2	08-01-2004
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US 2016377156 A1	29-12-2016	NONE	
US 2006058146 A1	16-03-2006	NONE	