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**Anderson et al.**

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(54) **VEHICULAR PEDAL ASSEMBLY**

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See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

5,233,882 A \* 8/1993 Byram ..... G01D 5/02  
123/399  
5,408,899 A 4/1995 Stewart  
5,768,946 A 6/1998 Fromer et al.  
6,089,120 A 7/2000 Lochle et al.

8,011,270 B2 9/2011 Schlabach et al.

8,240,230 B2 8/2012 Peniston et al.

10,994,707 B2 5/2021 Street et al.

(Continued)

**FOREIGN PATENT DOCUMENTS**

DE 19501680 A1 \* 8/1996 ..... B60K 23/00

DE 10058561 A1 5/2002

(Continued)

**OTHER PUBLICATIONS**

Components Direct, "Plastic Rivets—Ratchet Type," publicly available prior to Nov. 30, 2023, <https://www.components-direct.com/component-and-fastener-products/plastic-rivets-ratchet-type>.

(Continued)

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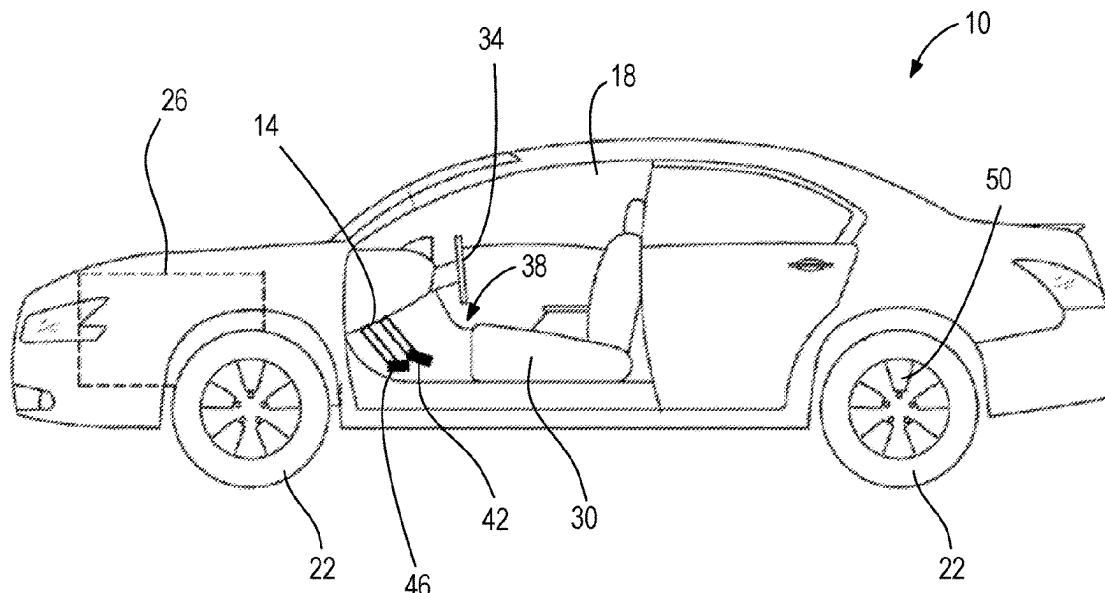
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(57)

**ABSTRACT**

A vehicular pedal assembly includes a pedal housing, a pedal shaft supported by the pedal housing for rotation about a pedal axis, a pedal arm coupled to the pedal shaft pivotable to drive the pedal shaft to rotate about the pedal axis, and a position sensor assembly coupled to the pedal shaft to determine a rotational position of the pedal shaft. The position sensor assembly includes a target element, a sensor circuit that senses the target element and generates a signal, and a sensor shaft fixed for corotation with the pedal shaft. The target element is positioned on the sensor shaft and rotates with the sensor shaft about a sensor axis to move the target element with respect to the sensor circuit and change the signal generated by the sensor circuit. The pedal shaft is movable along the pedal axis relative to the sensor shaft.

**20 Claims, 14 Drawing Sheets**



(56)

**References Cited**

## U.S. PATENT DOCUMENTS

2001/0011487 A1 \* 8/2001 Kojima ..... G05G 1/44  
74/513  
2002/0184749 A1 \* 12/2002 Burgstaler ..... B60T 7/065  
29/525.01  
2010/0064842 A1 \* 3/2010 Isono ..... B60T 8/4086  
74/512  
2016/0054752 A1 \* 2/2016 Willemsen ..... G05G 1/506  
74/512  
2022/0219659 A1 7/2022 Wagner et al.  
2023/0114657 A1 4/2023 Wagner et al.  
2023/0136473 A1 5/2023 Street et al.  
2025/0018904 A1 \* 1/2025 Matsunaga ..... B60K 26/04

## FOREIGN PATENT DOCUMENTS

DE 102010020314 A1 \* 11/2011 ..... B60K 26/02  
DE 102014202267 A1 8/2015  
EP 1857909 A2 11/2007  
JP 2007132819 A 5/2007  
WO 2022181326 A1 9/2022

## OTHER PUBLICATIONS

Hudson Supplies Inc., "Ratchet Rivet 3/4"x3/4" (20mm) White,"  
webpage available at least as early as Jul. 14, 2015, <https://www.hudson4supplies.com/ratchet-rivet-3-4-20mm-white.html>.  
International Search Report and Written Opinion for Application  
No. PCT/US2024/057640 dated Mar. 25, 2025 (14 pages).  
International Search Report and Written Opinion for Application  
No. PCT/US2024/057653 dated Mar. 10, 2025 (16 pages).

\* cited by examiner

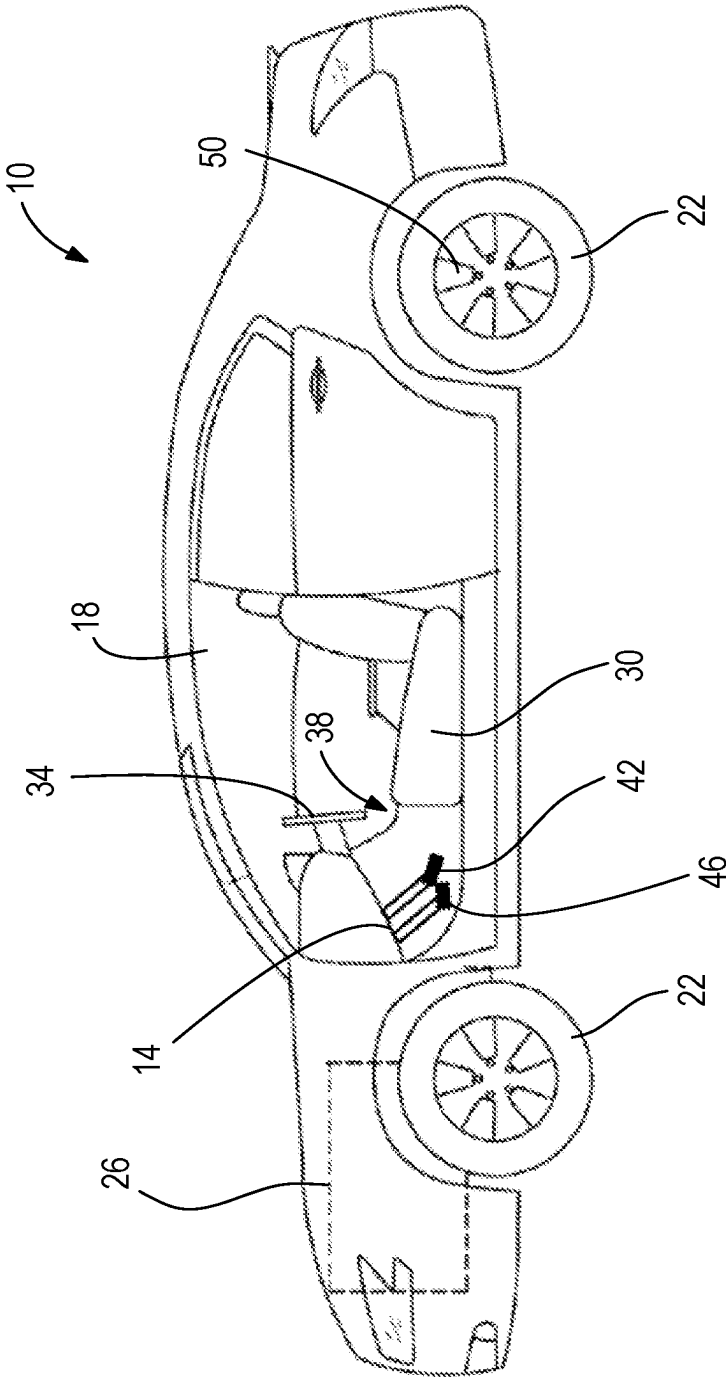
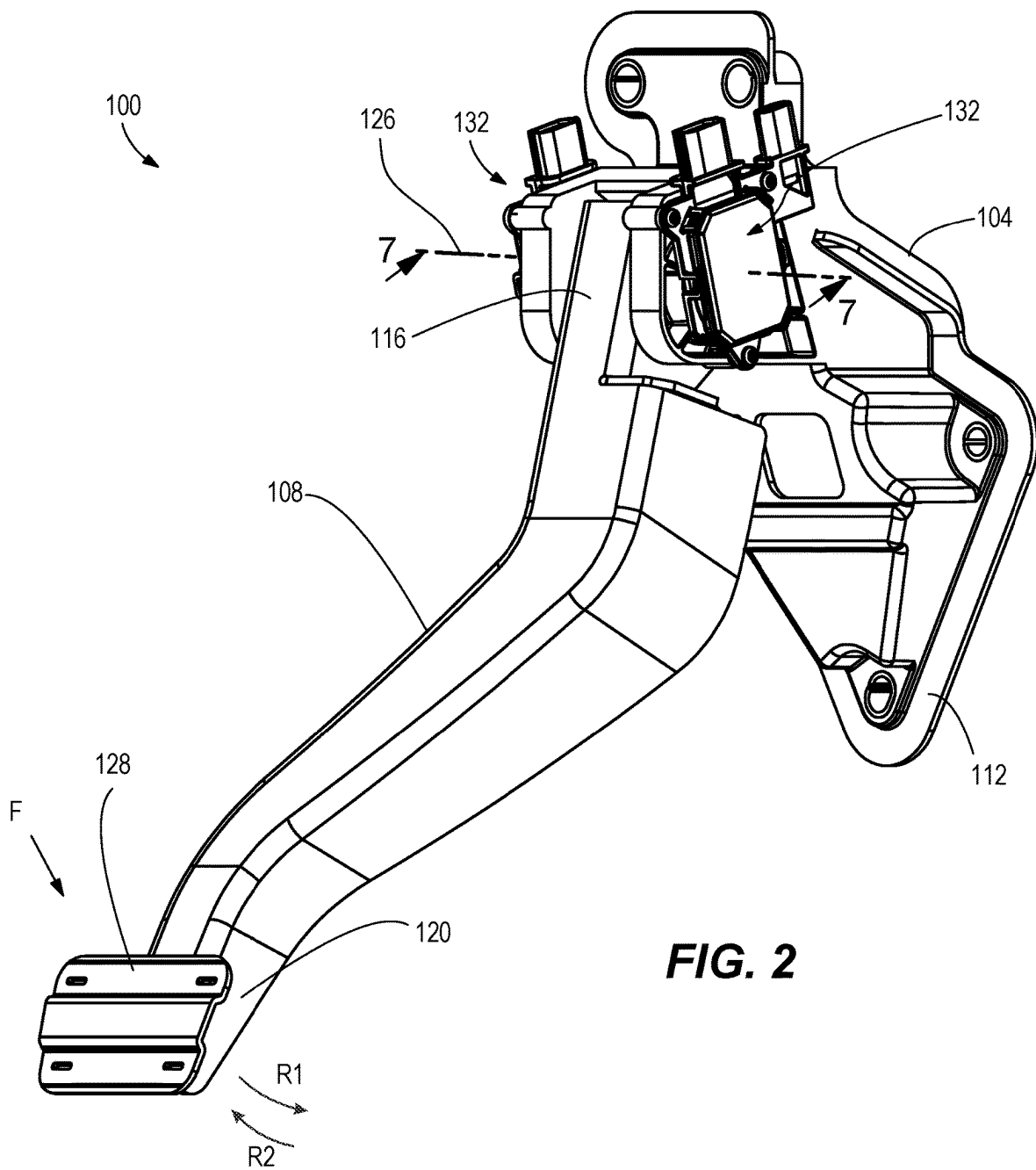


FIG. 1



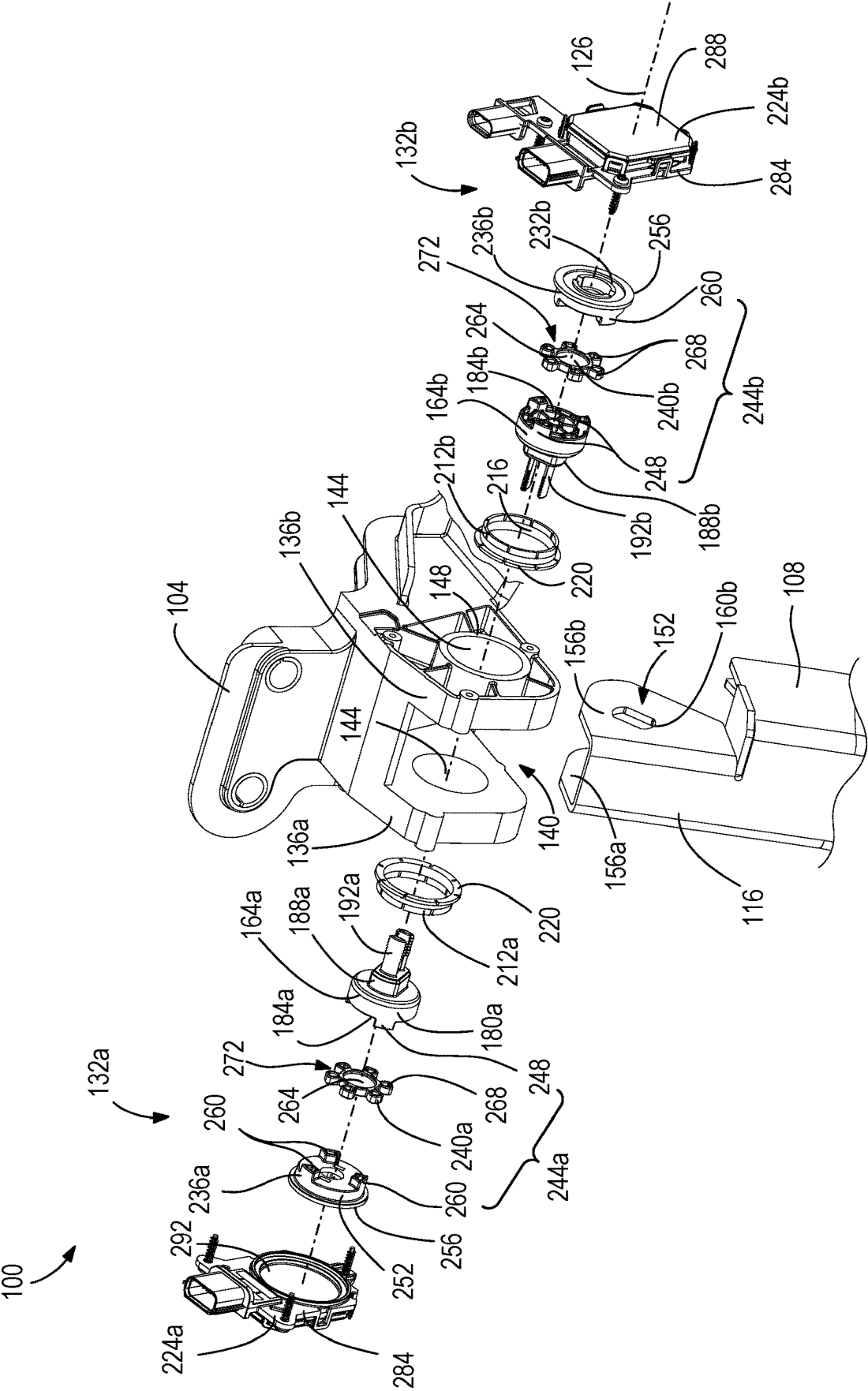
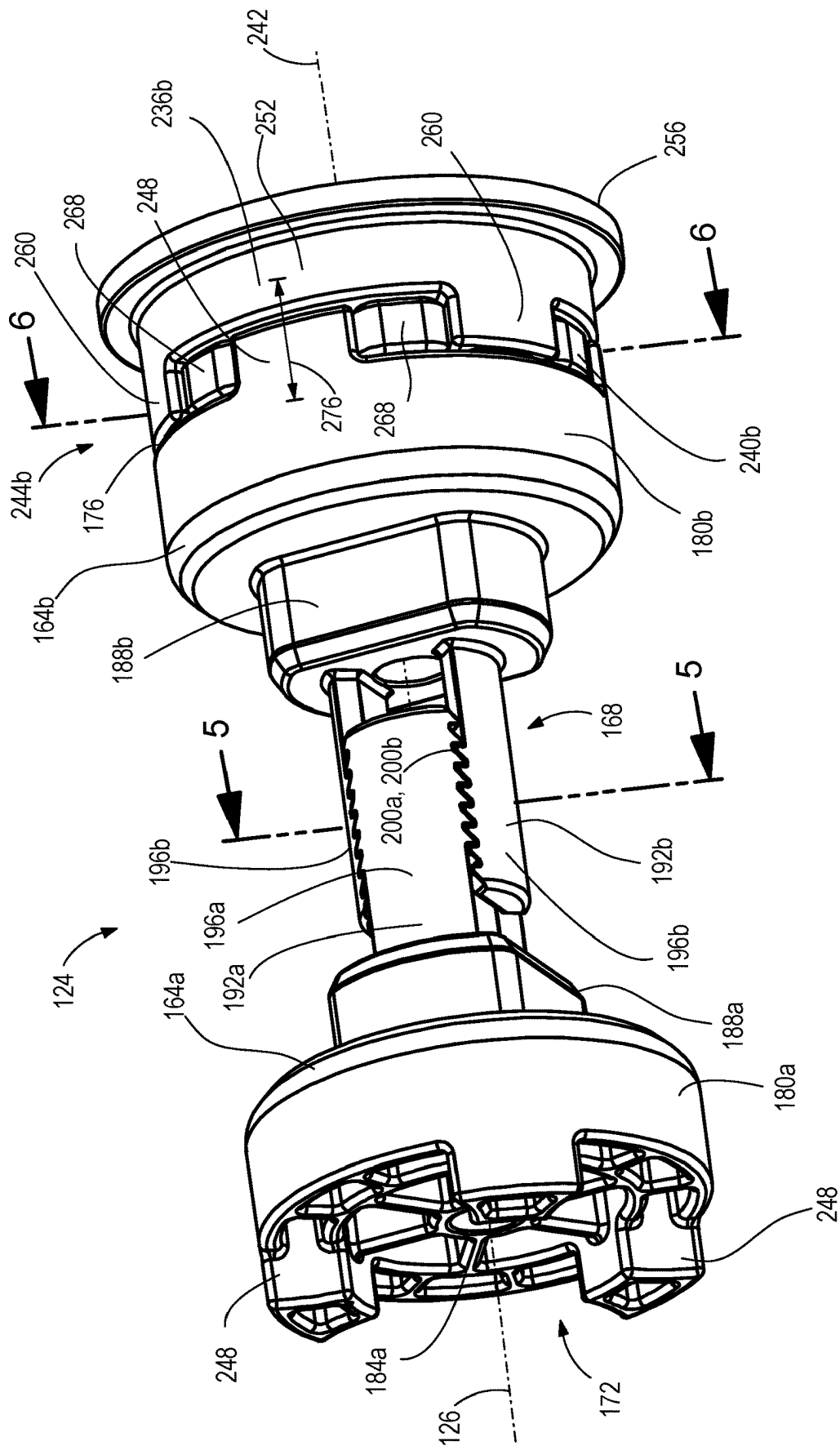
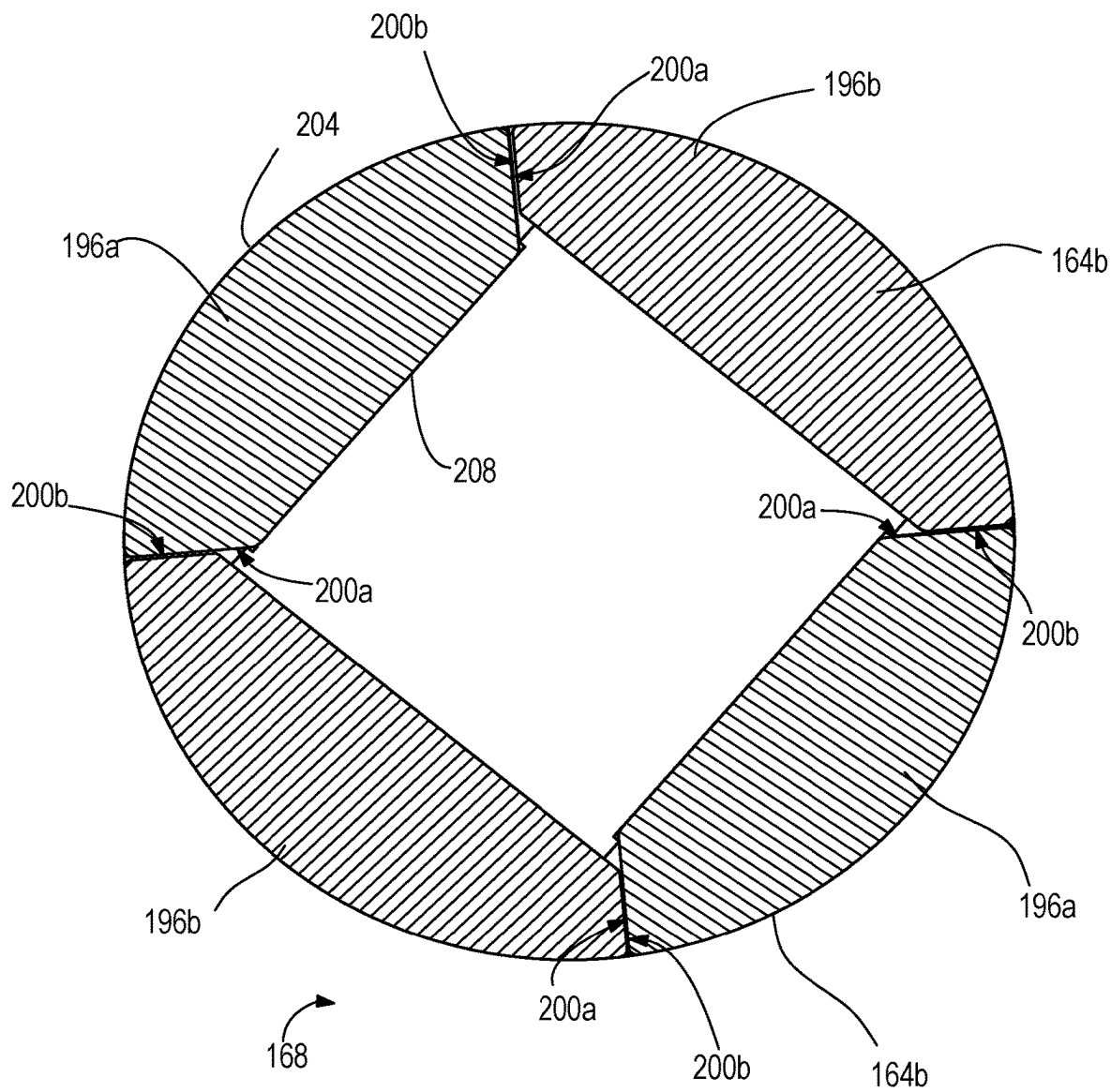


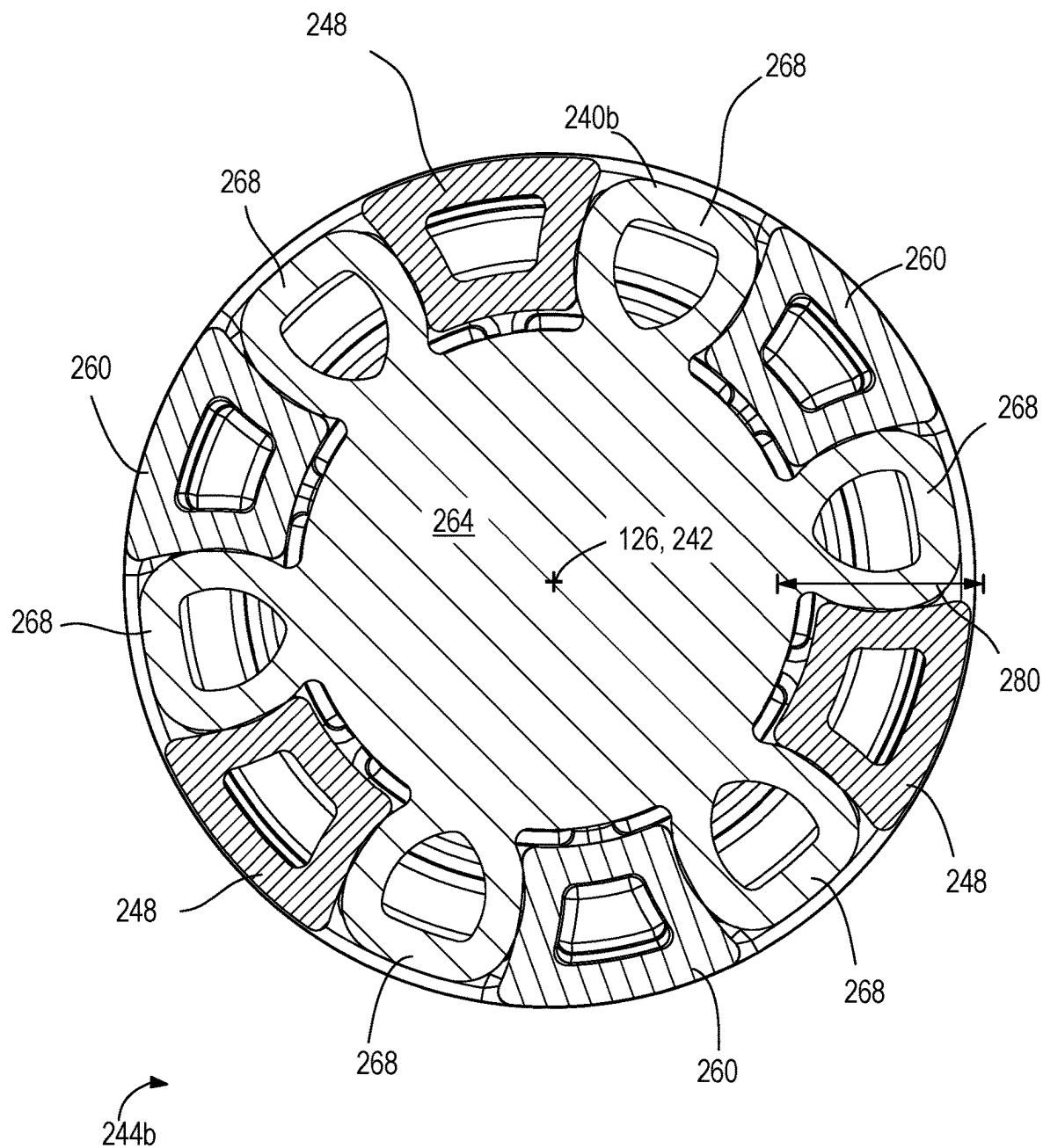
FIG. 3



**FIG. 4**

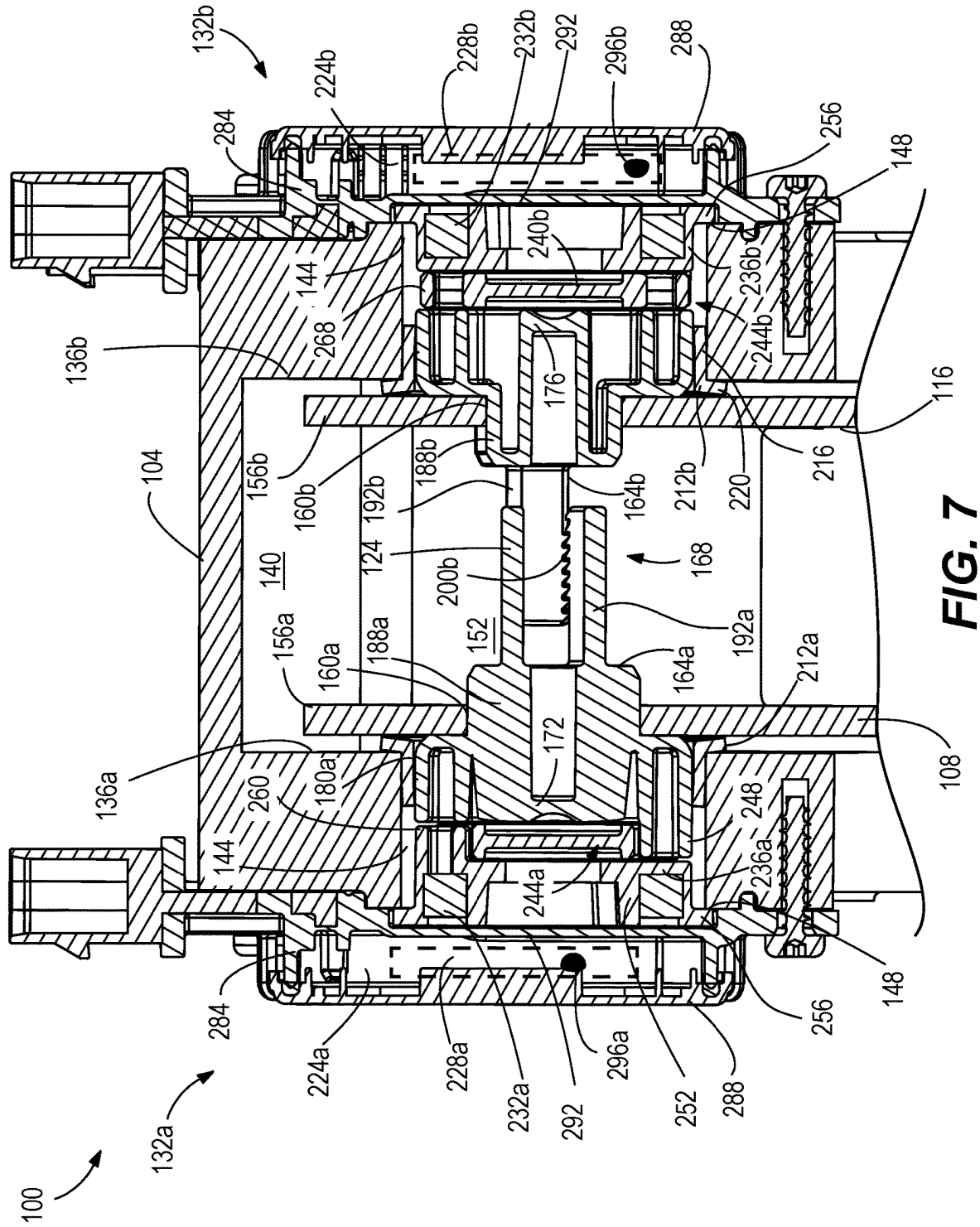


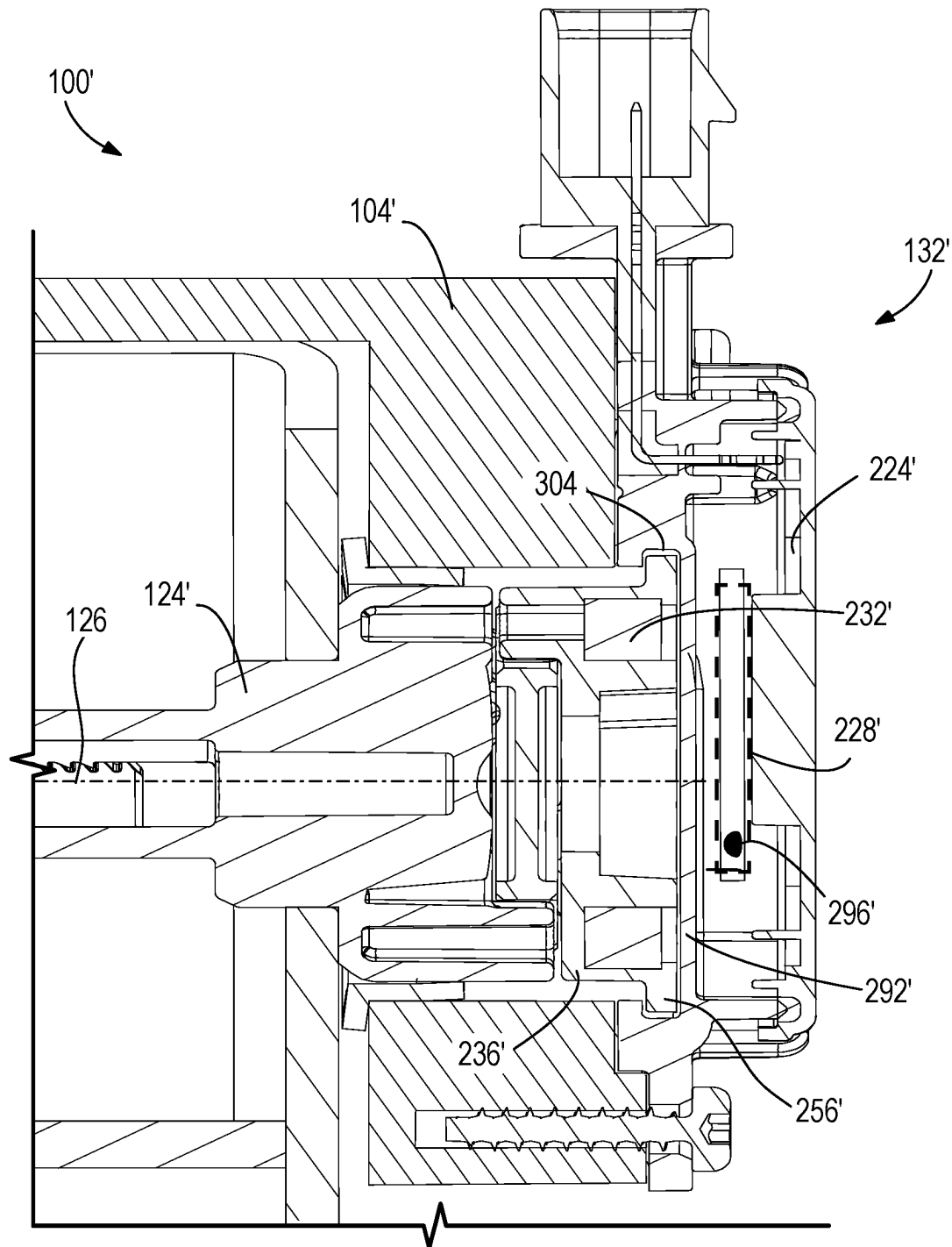
**FIG. 5**

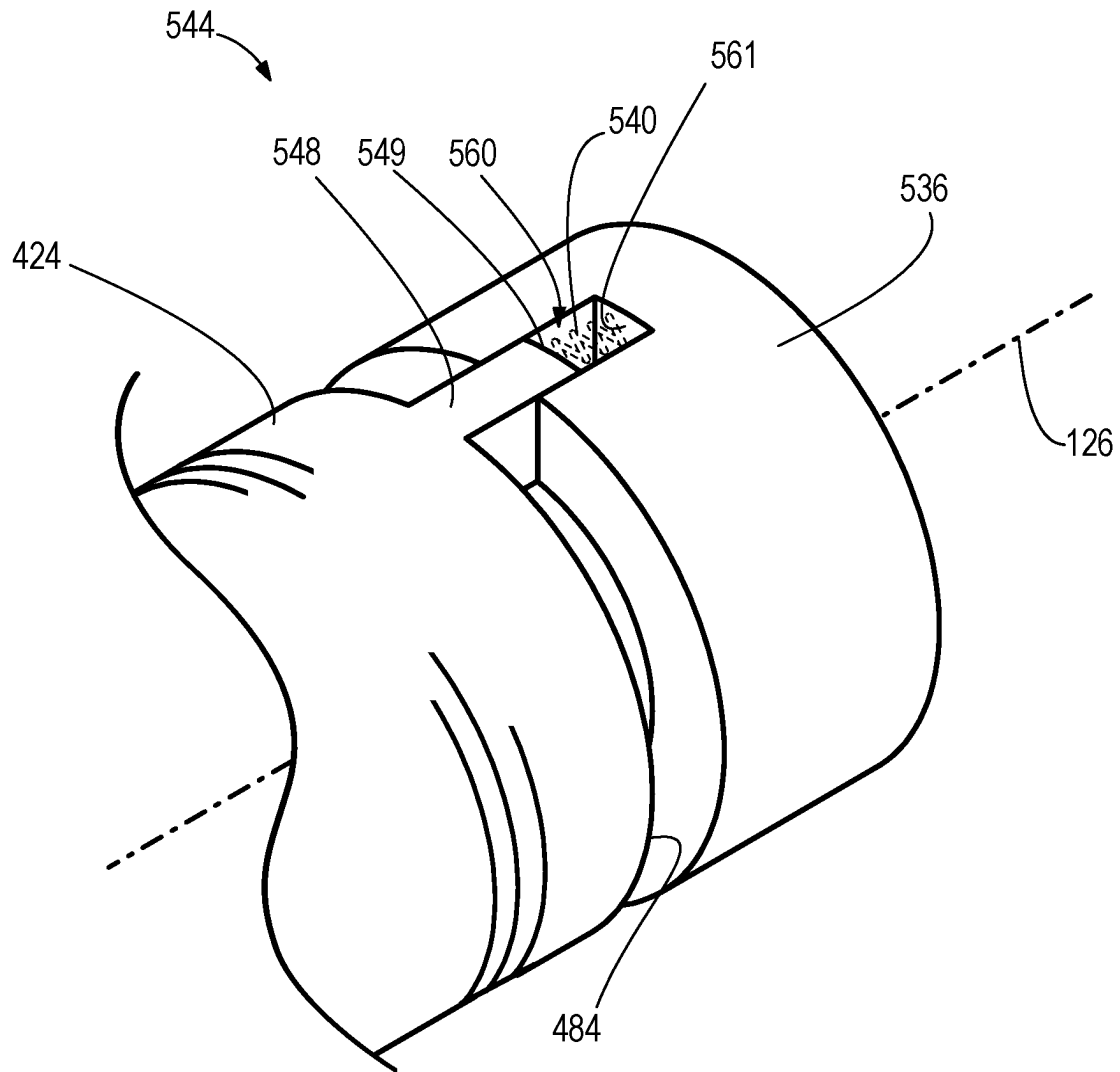


**FIG. 6**

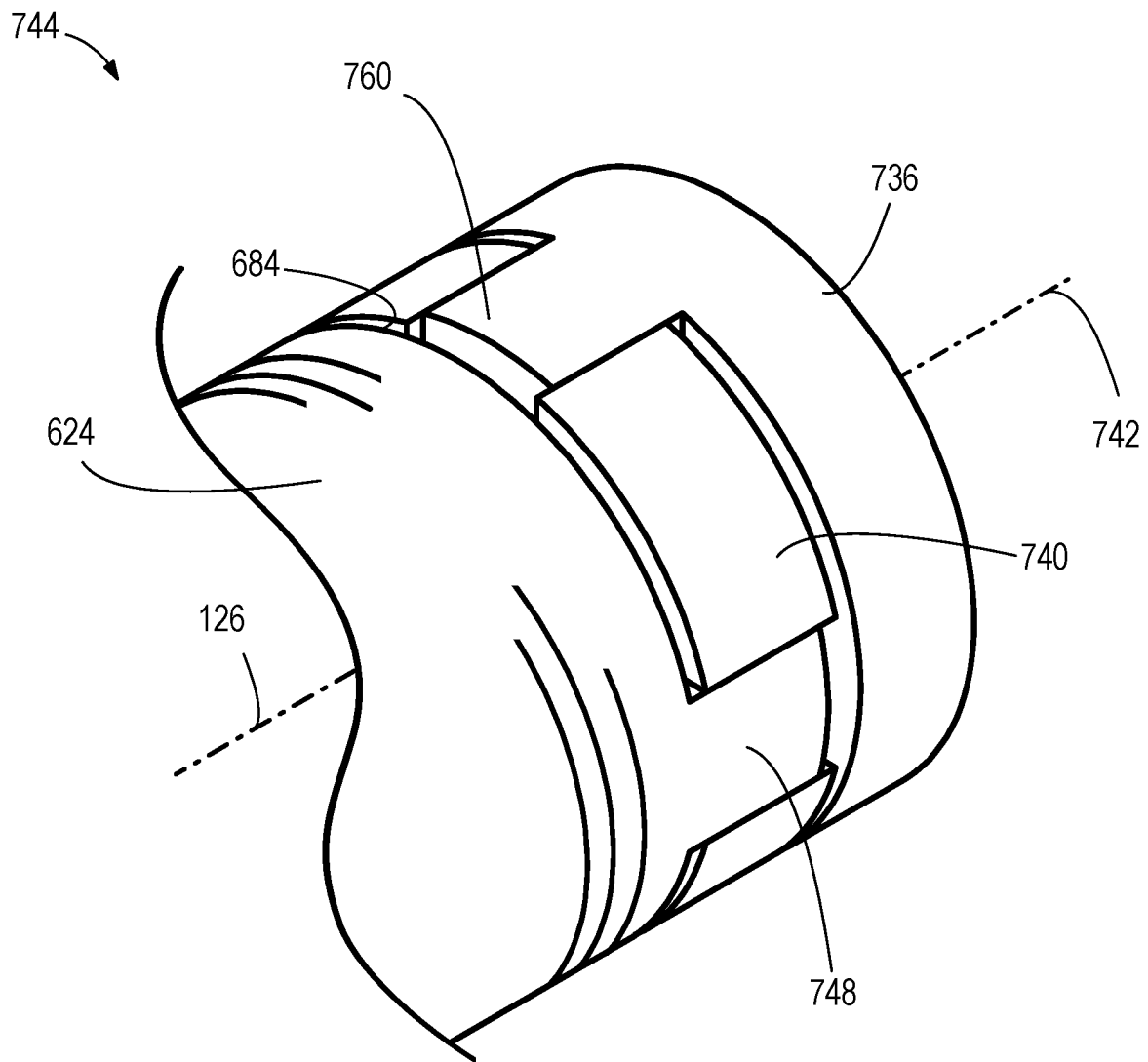


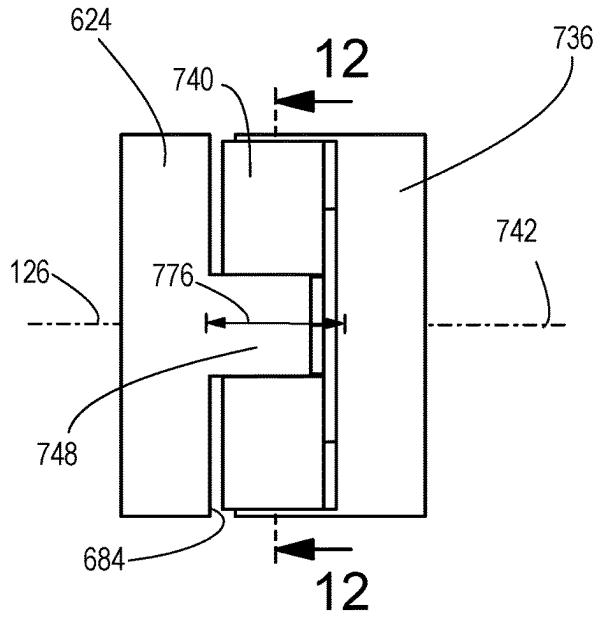


**FIG. 8**

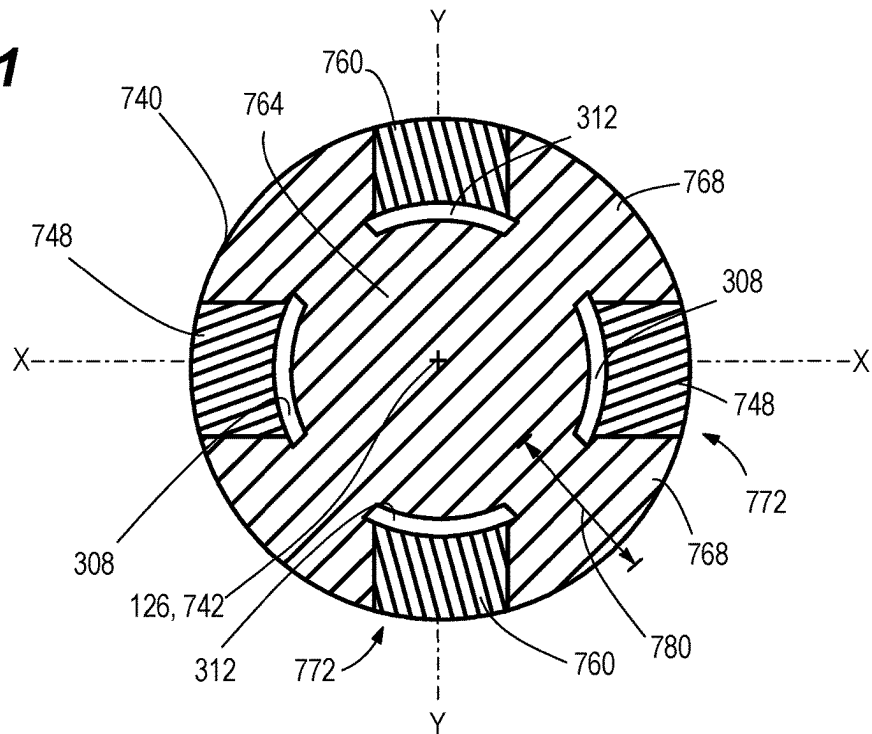


**FIG. 9**

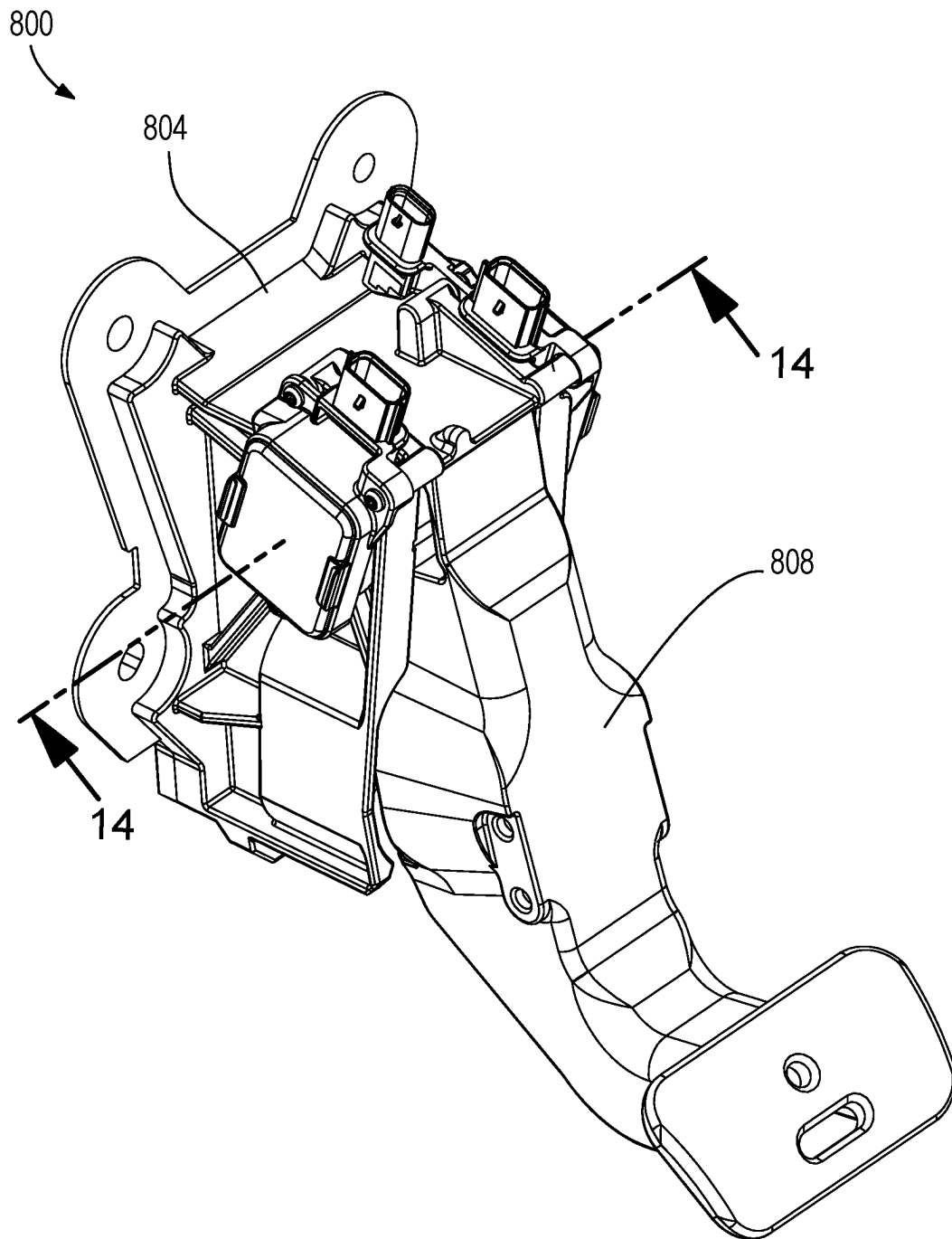
**FIG. 10**



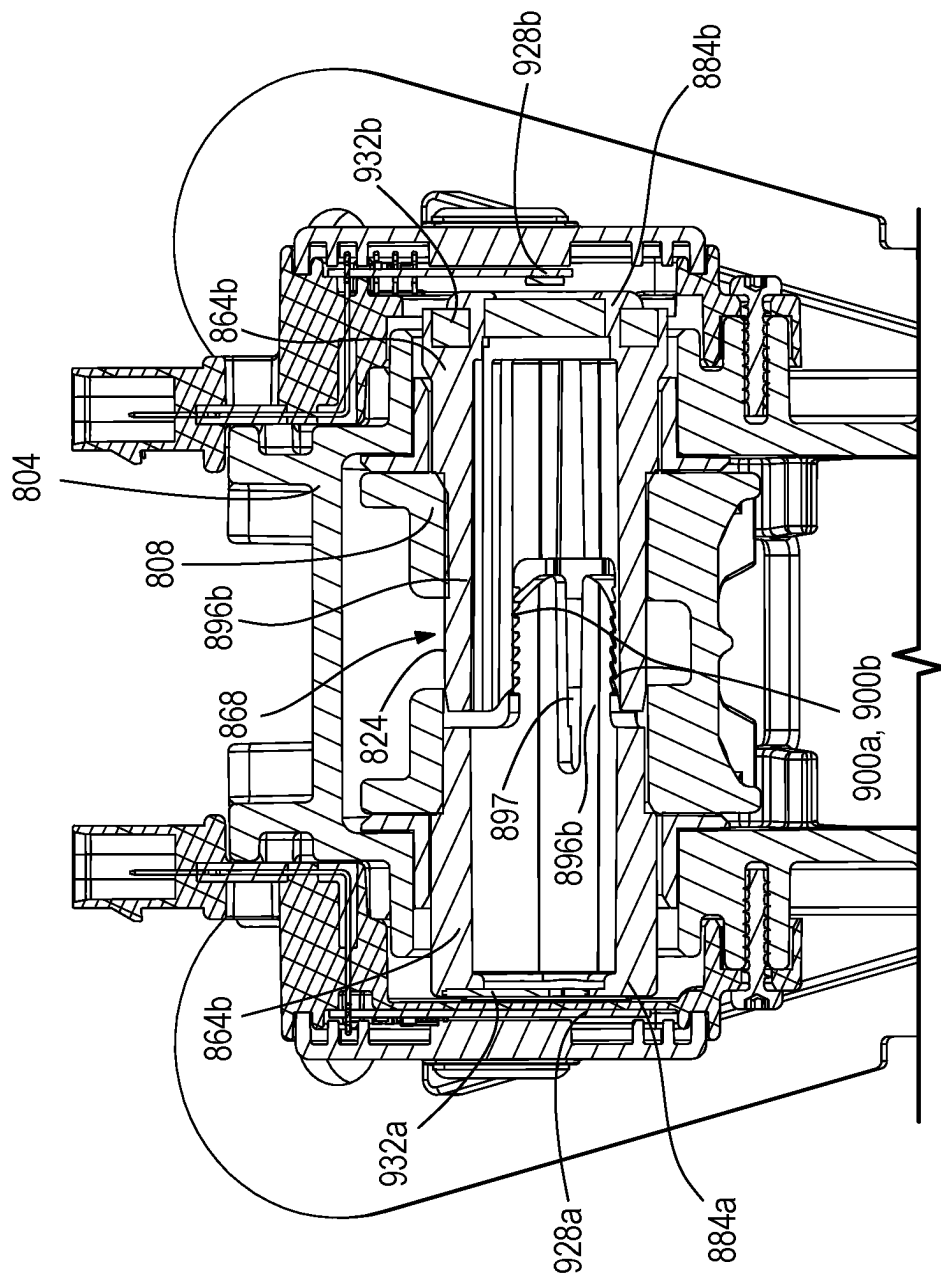
**FIG. 11**



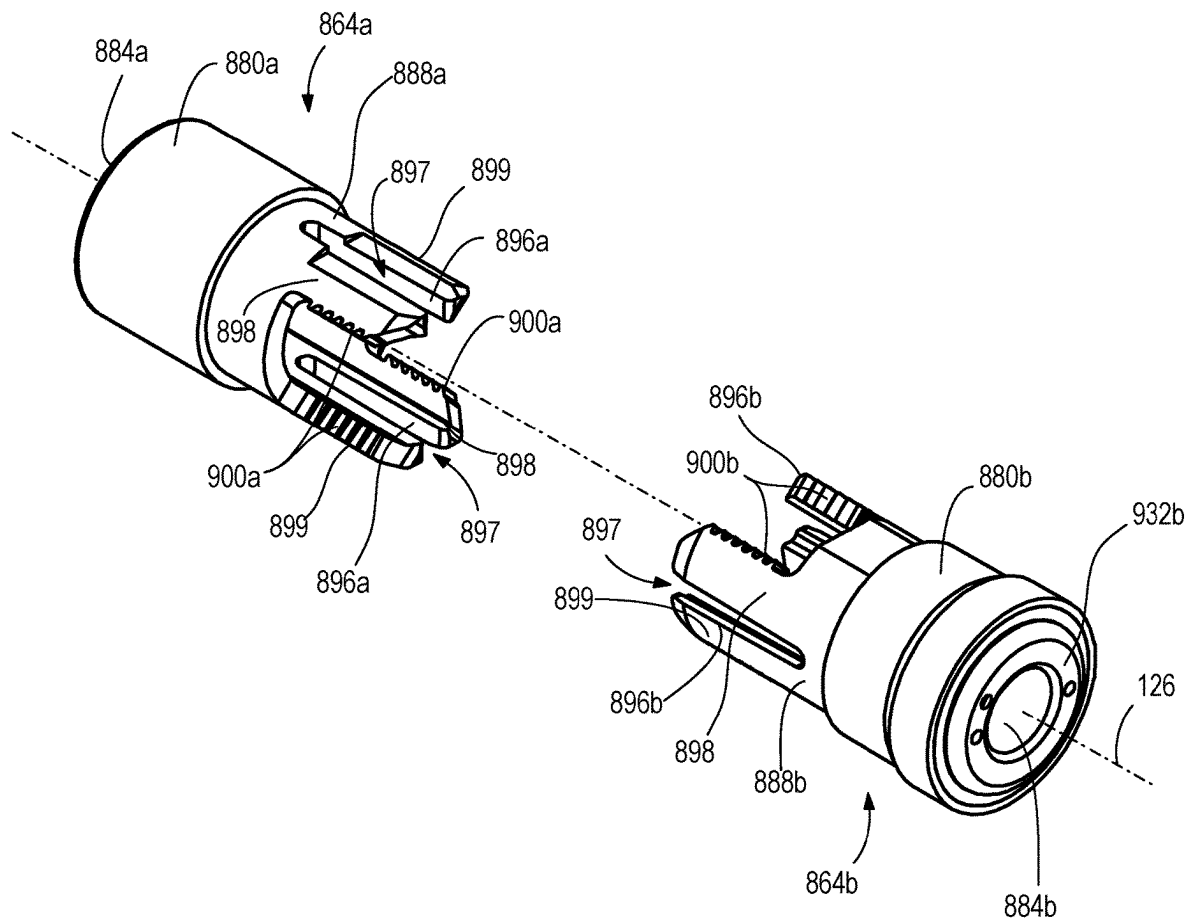
**FIG. 12**



**FIG. 13**



**FIG. 14**



**FIG. 15**



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**VEHICULAR PEDAL ASSEMBLY****BACKGROUND**

The present invention relates to vehicle pedal assemblies and, more specifically, to sensors for determining a position of a pedal.

**SUMMARY**

Control-by-wire vehicle pedals use sensors that determine the position of the pedal for the purpose of controlling the vehicle. For example, brake-by-wire pedals determine the position of the pedal for the purpose of electro-mechanically applying and releasing the brakes of the vehicle via an actuator not mechanically coupled to the pedal.

In one aspect, the invention provides a vehicular pedal assembly including a pedal housing configured for mounting within a vehicle, a pedal shaft supported by the pedal housing for rotation about a pedal axis, a pedal arm coupled to the pedal shaft and configured to pivot in response to input from a driver to drive the pedal shaft to rotate about the pedal axis, and a position sensor assembly coupled to the pedal shaft to determine a rotational position of the pedal shaft and generate a signal based on the rotational position. The position sensor assembly includes a target element, a sensor circuit configured to sense the target element and generate the signal, and a sensor shaft configured to rotate about a sensor axis and fixed for corotation with the pedal shaft. The target element is positioned on the sensor shaft and is configured to rotate with the sensor shaft about the sensor axis to move the target element with respect to the sensor circuit and change the signal generated by the sensor circuit. The pedal shaft is movable along the pedal axis relative to the sensor shaft.

In another aspect, the invention provides a vehicular pedal assembly for a vehicle, the vehicular pedal assembly including a pedal housing configured for mounting in the vehicle, a pedal shaft supported by the pedal housing for rotation about a pedal axis, a pedal arm drivably engaged with the pedal shaft, and a position sensor assembly coupled to the pedal shaft and configured to determine a rotational position of the pedal shaft and generate a signal based on the rotational position. The pedal shaft extends along the pedal axis between a first end and a second end, and the position sensor assembly is coupled to the first end of the pedal shaft. The pedal arm includes a footpad configured to be engaged by a driver to pivot the pedal arm and rotate the pedal shaft about the pedal axis. The position sensor assembly includes a sensor housing coupled to the pedal housing and containing a sensor circuit, a sensor shaft configured to rotate about a sensor axis and fixed for corotation with the pedal shaft, and a target element positioned on the sensor shaft, wherein the sensor circuit is configured to sense the target element and generate the signal. The vehicular pedal assembly further includes a spacer positioned between the sensor shaft and the first end of the pedal shaft to transmit rotation from the pedal shaft to the sensor shaft. The spacer is configured to absorb movement of the pedal shaft along the pedal axis to axially isolate the sensor shaft.

Other aspects of the invention will become apparent by consideration of the detailed description and accompanying drawings.

**BRIEF DESCRIPTION OF THE DRAWINGS**

The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout

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the separate views, together with the detailed description below, are incorporated in and form part of the specification, and serve to further illustrate examples, instances, and/or aspects of concepts that include the claimed subject matter, and explain various principles and advantages of examples, instances, and/or aspects.

FIG. 1 is a schematic side view of a vehicle with portions of the driver's side removed, the vehicle including a brake pedal and an accelerator pedal.

FIG. 2 is a perspective view of a pedal assembly according to one embodiment for use with the vehicle of FIG. 1.

FIG. 3 is an exploded view of the pedal assembly of FIG. 2 including a pedal shaft.

FIG. 4 is a perspective view of a joint of the pedal shaft of FIG. 3, and a coupling between the pedal shaft and a sensor shaft.

FIG. 5 is a cross-sectional view of the joint of the pedal shaft of FIG. 4, taken along line 5-5 of FIG. 4.

FIG. 6 is a cross-sectional view of the coupling of FIG. 4, taken along the line 6-6 of FIG. 4.

FIG. 7 is a cross-sectional view of the pedal assembly of FIG. 2 taken along the line 7-7, including the pedal shaft and the sensor shaft.

FIG. 8 is a cross-sectional view of an alternate embodiment of a position sensor assembly for use in the pedal assembly of FIG. 2.

FIG. 9 is a perspective view of an alternative coupling between the pedal shaft and the sensor shaft of the pedal assembly of FIG. 2 according to a first embodiment.

FIG. 10 is a perspective view of an alternative coupling between the pedal shaft and the sensor shaft of the pedal assembly of FIG. 2 according to a second embodiment.

FIG. 11 is a side view of the coupling of FIG. 10.

FIG. 12 is a cross-sectional view of the coupling of FIG. 10 taken along line 12-12 of FIG. 11.

FIG. 13 is a perspective view of a pedal assembly according to another embodiment for use with the vehicle of FIG. 1.

FIG. 14 is a cross-sectional view of the pedal assembly of FIG. 13 taken along line 14-14 of FIG. 13.

FIG. 15 is an exploded view of the pedal shaft of the pedal assembly of FIG. 13.

**DETAILED DESCRIPTION OF THE DRAWINGS**

Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the accompanying drawings. It should be understood that the description of specific embodiments is not intended to limit the disclosure from covering all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The invention is capable of other embodiments and of being practiced or of being carried out in various ways.

Unless the context of their usage unambiguously indicates otherwise, the articles "a," "an," and "the" should not be interpreted as meaning "one" or "only one." Rather these articles should be interpreted as meaning "at least one" or "one or more." Likewise, when the terms "the" or "said" are used to refer to a noun previously introduced by the indefi-

nite article “a” or “an,” “the” and “said” mean “at least one” or “one or more” unless the usage unambiguously indicates otherwise.

FIG. 1 illustrates a motor vehicle 10, such as a car, including a body 14 defining an interior compartment 18, a set of wheels 22 coupled to the body 14, and an engine 26 operably coupled to at least one of the front or rear sets of wheels 22 to propel the vehicle 10 to move. The vehicle 10 is controlled by a driver located in a driver's seat 30 in the interior compartment 18. A set of controls is positioned around the driver on a dashboard and in a footwell 38. The controls include, among other things, a steering wheel 34 for steering the direction of the front wheels 22, an accelerator pedal 42 located in the footwell 38, and a brake pedal 46 located adjacent the accelerator pedal 42 in the footwell 38. In a typical vehicle configuration, the accelerator pedal 42 may be positioned to the driver's right of the brake pedal 46. The driver alternately presses the accelerator pedal 42 and the brake pedal 46 to control motion of the car. The accelerator pedal 42 communicates with the engine 26 to provide more torque to the wheels 22. The brake pedal 46 communicates with one or more braking elements 50 (e.g., brake calipers) positioned adjacent one or more of the wheels 22. Each braking element 50 selectively engages a rotor rotatable with the wheel 22 to slow the rotation of the wheel 22 and thus slow the movement of the vehicle 10. In the illustrated embodiment, at least one of the accelerator pedal 42 or the brake pedal 46 includes a control-by-wire system. In the illustrated embodiment, the brake pedal 46 may be brake-by-wire control. Brake-by-wire brake pedals do not mechanically actuate a hydraulic system for braking. Instead, the movement of the brake pedal 46 caused by the driver is measured by a sensor assembly and electronically communicated to a brake controller and one or more remote actuators in control of the braking elements 50 on or adjacent the wheels 22 of the vehicle 10.

FIGS. 2-7 illustrate a vehicular pedal assembly 100 according to a first embodiment. The pedal assembly 100 is a brake-by-wire pedal assembly that may be coupled to the vehicle 10 as the brake pedal 46. In the illustrated embodiment, the pedal assembly 100 is mounted to the body 14 of the vehicle 10 in the footwell 38 in front of the driver's seat 30. In some embodiments, the pedal assembly 100 may additionally or alternatively be used as the accelerator pedal 42 of the vehicle 10. In some embodiments, the pedal assembly 100 may be coupled to the vehicle 10 in different locations based on the type of vehicle 10.

As seen in FIG. 2, the pedal assembly 100 includes a pedal housing 104 and a pedal arm 108 extending from the pedal housing 104. The pedal housing 104 may include one or more bracket portions 112 including mounting features for securing the pedal housing 104 in the vehicle 10. For example, the bracket portion(s) 112 may be used to secure the pedal assembly 100 to the body 14 of the vehicle 10 (e.g., at the front bulkhead between the engine bay and the interior compartment 18). The pedal arm 108 extends between an upper end 116 (or first end 116), and a lower end 120 (or second end 120), opposite the upper end 116. The upper end 116 of the pedal arm 108 is coupled to the pedal housing 104 by a pedal shaft 124 (FIG. 4). The pedal shaft 124 is rotatable about a pedal axis 126 and the pedal arm 108 is pivotable relative to the pedal housing 104 between a fully depressed position and a rest position. A biasing member (not shown) may be coupled between the pedal housing 104 and the pedal arm 108 to bias the pedal arm 108 toward the rest position.

A footpad 128 (e.g., a brake footpad), is coupled to the lower end 120 of the pedal arm 108. In some embodiments, the footpad 128 may be integrally formed with the lower end 120 of the pedal arm 108. In other embodiments, the footpad 128 may be a separate component affixed to the lower end 120. The footpad 128 is fixed for movement with the lower end 120 of the pedal arm 108. A driver input force (F) may be applied to the footpad 128, causing the pedal arm 108 to rotate about the pedal axis 126 in a first direction R1, toward the fully depressed position. In other words, the pedal arm 108 pivots in response to an input of the driver on the footpad 128. As discussed, upon removal of the force (F) the biasing member may rotate the pedal arm 108 in a second direction (R2) opposite the first direction. In some embodiments the pedal arm 108 may include at least one curved portion creating an offset in one or multiple directions to increase access to the footpad 128 by the driver. The pedal arm 108 is rotatably fixed to the pedal shaft 124 so that movement of the pedal arm 108 in response to the input force F drives the pedal shaft 124 to rotate about the pedal axis 126.

The pedal assembly 100 includes at least one position sensor assembly (PSA) 132 coupled to the pedal housing 104. The PSA 132 determines the travel of the pedal arm 108 between the rest position and the fully depressed position by determining the rotational position of the pedal shaft 124. The PSA 132 generates a signal corresponding to the sensed rotational position of the pedal shaft 124. In some embodiments, the signal generated by the PSA 132 is a preliminary signal that is communicated to a controller which generates a further braking signal to be sent to the braking elements 50. The controller may perform comparisons or calculations on the preliminary signal in order to generate the further braking signal. For example, the controller may compare the current value of the preliminary signal to stored information (e.g., values that correspond to the signals generated by the PSA 132 when the pedal arm 108 is in the rest position and the fully depressed position, respectively). In another example, the controller may compare a current value of the preliminary signal to a prior value of the preliminary signal. As seen in FIG. 3, in the illustrated embodiment, the pedal assembly 100 includes a first PSA 132a and a second PSA 132b coupled to the pedal housing 104 on either side of the pedal arm 108. In some embodiments, the controller may perform comparisons or calculations on the preliminary signal from the first PSA 132a and the preliminary signal from the second PSA 132b to generate the further braking signal. In other embodiments, the controller may be configured to process data from the PSA(s) 132 in other ways.

As mentioned above, the illustrated embodiment includes a pair of PSAs including the first PSA 132a and the second PSA 132b. In some embodiments, the pair of PSAs 132a, 132b are structurally mirror images of each other and may include similar or the same components in a sensor circuit. In some embodiments, the pair of PSAs 132a, 132b are mirror images but include different components in each sensor circuit. In other embodiments, the pair of PSAs 132a, 132b may be both structurally and electronically different.

As seen best in FIG. 3, the pedal assembly 100, with the exception of the bracket portion 112 of the pedal housing 104 and the pedal arm 108, is generally symmetrical such that one side is a mirror image of the other side. Like components use like reference numbers. The instances of the components on the first side of the pedal assembly 100 are labeled with the reference number followed by an ‘a’ (e.g., 132a) and on the second side of the pedal assembly 100 with the reference number followed by an ‘b’ (e.g., 132b). Fea-

tures described with reference to one side of the assembly can generally be assumed to apply to the other side of the assembly unless otherwise specified. Generally, when describing the assembly, “inward” refers to a direction toward the symmetrical center and “outward” refers to a direction toward the edges.

With reference to FIG. 3, the pedal housing 104 includes a pair of sidewalls 136a, 136b extending parallel to each other and defining a recess 140 therebetween. The pair of sidewalls 136a, 136b (also referred to herein as supports 136a, 136b) are spaced apart by a sufficient distance such that the recess 140 is wider than the upper end 116 of the pedal arm 108. Each sidewall 136a, 136b includes a shaft bore 144 extending from the recess 140 through the sidewall 136a, 136b to a reference surface 148 on the outer side of the sidewall 136a, 136b. The shaft bore 144 of the first sidewall 136a and the shaft bore 144 of the second sidewall 136b extend along and are generally aligned with the pedal axis 126.

The upper end 116 of the pedal arm 108 includes a through bore 152 extending along the pedal axis 126 and having a non-circular profile. In the illustrated embodiment, the upper end 116 includes a pair of flanges 156a, 156b each having a noncircular opening 160a, 160b defining the through bore 152 therebetween. In some embodiments, the upper end 116 of the pedal arm 108 may be solid and the openings 160a, 160b may be positioned at either end of the through bore 152. In the illustrated embodiment, each opening 160a, 160b includes a “double D-shaped” profile (i.e., a circle or oval with parallel flattened edges). In other embodiments, other non-circular profiles may be used (e.g., D-shape, star, keyway, notched circle, square, etc.). In some embodiments, the openings 160a, 160b are identical in shape and orientation. In other embodiments, the opening 160a may have a different profile or different orientation from the opening 160b.

With continued reference to FIG. 3, the pedal assembly 100 includes the pedal shaft 124 supported for rotation about the pedal axis 126. In the illustrated embodiment the pedal shaft 124 is formed from a pair of shaft portions including a first shaft portion 164a and a second shaft portion 164b. In the illustrated embodiment, the first shaft portion 164a and the second shaft portion 164b are first and second halves of the pedal shaft 124 having identical constructions. In other embodiments, the first shaft portion 164a and the second shaft portion 164b have unique constructions. The shaft portions 164a, 164b are coupled by a joint 168 (FIG. 4) to form the pedal shaft 124.

FIG. 4 illustrates the pedal shaft 124 in more detail. The pedal shaft 124 extends between a first end 172 and a second end 176 along the pedal axis 126. The first shaft portion 164a includes a bearing hub 180a having an outer end 184a, a mounting hub 188a extending inwardly from the bearing hub 180a, and a ratchet portion 192a (or a joint portion 192a) extending inwardly from the mounting hub 188a. The second shaft portion 164b similarly includes a bearing hub 180b having an outer end 184b, a mounting hub 188b extending inwardly from the bearing hub 180b, and a ratchet portion 192b extending inwardly from the mounting hub 188b. When assembled, the outer end 184a of the first shaft portion 164a corresponds to the first end 172 of the pedal shaft 124 and the outer end 184b of the second shaft portion 164b corresponds to the second end 176 of the pedal shaft 124. As seen in FIG. 4, the first shaft portion 164a is coupled to the second shaft portion 164b by the joint 168 (also referred to herein as the shaft coupling 168). In the illustrated embodiment, the joint 168 is a snap connection, and

more specifically, a ratchet rivet connection. Each ratchet portion 192a, 192b includes a set of ratchet fingers 196a, 196b extending from the mounting hub 188a, 188b. In the illustrated embodiment, the first shaft portion 164a is identical to the second shaft portion 164b and may be rotationally offset to allow the ratchet portion 192a to engage the ratchet portion 192b. For example, in the illustrated embodiment, the second shaft portion 164b is rotated about 90 degrees with respect to the first shaft portion 164a.

With reference to FIG. 5, in the illustrated embodiment, the ratchet fingers 196a of the first shaft portion 164a are evenly spaced circumferentially about the ratchet portion 192a. In other words, the pair of ratchet fingers 196a are spaced apart by 180 degrees about the pedal axis 126. Each ratchet finger 196a includes a pair of toothed surfaces 200a (also referred to herein as ratchet surfaces) extending lengthwise along the ratchet finger 196a, generally along the pedal axis 126, as seen in FIG. 4. As seen in FIG. 5, looking down the length of the ratchet finger 196a (or at the cross-section of the ratchet portion 192a), each toothed surface 200a is oriented radially with respect to the pedal axis 126. In some embodiments, the ratchet portion 192a may include three or more ratchet fingers 196a. In some embodiments, the toothed surfaces 200a of each ratchet finger 196a may be angularly spaced by approximately 360 degrees divided by twice the number of ratchet fingers 196a, 196b on the ratchet portions 192a, 192b. For example, in the illustrated embodiment, the toothed surfaces 200a of each ratchet finger 196a are spaced by approximately 90 degrees, which is 360 degrees divided by four. In the illustrated embodiment, each ratchet finger 196a includes an arcuate outer surface 204 and a flat lower surface 208 extending between the pair of toothed surfaces 200a. In other embodiments, the upper and lower surfaces of the ratchet fingers 196a may be shaped differently. The ratchet fingers 196b of the second shaft portion 164b are similarly constructed and each of the ratchet fingers 196b includes a pair of toothed surfaces 200b in the same arrangement as the toothed surfaces 200a.

With continued reference to FIG. 5, the joint 168 is formed by engaging the ratchet fingers 196a of the first shaft portion 164a with the ratchet fingers 196b of the second shaft portion 164b. The first ratchet fingers 196a are positioned between the second ratchet fingers 196b, such that each toothed surface 200a is engaged with the toothed surface 200b of the second ratchet finger 196b directly adjacent. As seen best in FIG. 4, the teeth on the toothed surfaces 200a, 200b are shaped to allow axial joining of the shaft portions 164a, 164b (e.g., movement of the shaft portions 164a, 164b along the pedal axis 126 in an inward direction and toward each other), but inhibit axial separation of the shaft portions 164a, 164b (e.g., movement of the shaft portions 164a, 164b along the pedal axis 126 in an outward direction and away from each other). The joint 168 axially secures the first shaft portion 164a and the second shaft portion 164b against separation or uncoupling by the engagement of the toothed surfaces 200a, 200b along the pedal axis 126. Additionally, the joint 168 rotationally couples the first shaft portion 164a and the second shaft portion 164b through the circumferential engagement of the ratchet fingers 196a, 196b seen in FIG. 5. Thus, the first shaft portion 164a and the second shaft portion 164b may be coupled together by the joint 168 to form the pedal shaft 124 that rotates about the pedal axis 126.

With reference to FIG. 4, the mounting hub 188a, 188b of each shaft portion 164a, 164b has a cross-sectional profile that corresponds to the profile of the openings 160a, 160b to the through bore 152 in the pedal arm 108. In the illustrated

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embodiment, each mounting hub **188a**, **188b** includes a “double D-shaped” profile corresponding to the “double D-shaped” profile of the openings **160a**, **160b**. In embodiments where the openings **160a**, **160b** have different profiles, the mounting hubs **188a**, **188b** may each have a matching profile with the associated opening **160a**, **160b**. As seen in FIG. 4, each shaft portion **164a**, **164b** has a generally stepped configuration. With reference to the first shaft portion **164a**, the bearing hub **180a** has a generally cylindrical surface and a width (e.g., the largest dimension measured perpendicular to the axis **126**) of the bearing hub **180a** generally corresponds to a diameter of the surface. The width of the bearing hub **180a** is larger than a width (e.g., the largest dimension measured perpendicular to the axis **126**) of the mounting hub **188a**. Finally, the width of the mounting hub **188a** is larger than a width (e.g., the largest dimension measured perpendicular to the axis **126**) of the ratchet portion **192a**. In embodiments where each ratchet finger **196a**, **196b** includes the arcuate outer surface **204**, the width of the ratchet portion **192a** may generally correspond to a diameter of the resulting outer profile (FIG. 5). When assembled, the shaft **124** therefore has an overall ‘V’ shape or ‘hourglass’ shape, where the first end **172** and the second end **176** have generally similar widths, which are larger than a width near a center or a middle portion of the shaft **124**, adjacent the joint **168**.

Returning to FIG. 3, the pedal shaft **124** is supported in the pedal housing **104** for rotation by a pair of bearings **212a**, **212b** that engage the bearing hubs **180a**, **180b** of the pedal shaft **124**. Each bearing **212a**, **212b** includes an insert ring **216** for engaging the shaft bore **144** of the respective sidewall **136a**, **136b**, and a bearing flange **220** that abuts an inner side of the sidewall **136a**, **136b** to locate the bearing **212a**, **212b** within the respective shaft bore **144** adjacent the recess **140**. As discussed above, the first and second PSAs **132a**, **132b** have similar or identical constructions in the illustrated embodiment. The first PSA **132a** includes a sensor housing **224a**, a sensor circuit **228a** (FIG. 7) for sensing a target element **232a** and generating the preliminary signal, a sensor shaft **236a**, and a spacer **240a** positioned between the sensor shaft **236a** and the pedal shaft **124**. The sensor shaft **236a** is rotatable with respect to the sensor housing **224a** about a sensor axis **242** (FIG. 4). In the illustrated embodiment, the sensor axis **242** is coaxial with the pedal axis **126** when the pedal assembly **100** is assembled (see FIG. 7). In other embodiments, the sensor axis **242** may be offset from and parallel to the pedal axis **126**. Similarly, the second PSA **132b** includes a sensor housing **224b**, a sensor circuit **228b** (FIG. 7) that senses a target element **232b**, a sensor shaft **236b** configured to rotate about a sensor axis **242**, and a spacer **240b**. The first PSA **132a** is coupled to the first end **172** of the pedal shaft **124** (i.e., the outer end **184a** of the first shaft portion **164a**) to determine a rotational position of the pedal shaft **124** and generate a first preliminary signal based on the sensed position. The second PSA **132b** is coupled to the second end **176** of the pedal shaft **124** (i.e., the outer end **184b** of the second shaft portion **164b**) to determine a rotational position of the pedal shaft **124** and generate a second preliminary signal based on the sensed position. In some embodiments, the PSAs **132a**, **132b** are both used to add redundancy to the system. In some embodiments, one of the PSAs **132a**, **132b** may be used as a primary sensing unit and the other of the PSAs **132a**, **132b** may be used as a backup sensing unit.

The sensor shaft **236a**, **236b** of each PSA **132a**, **132b** is fixed for corotation with the pedal shaft **124** by a coupling **244a**, **244b** formed between the pedal shaft **124** and the

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sensor shaft **236a**, **236b**. Each coupling **244a**, **244b** transmits rotation from the pedal shaft **124** to the respective sensor shaft **236a**, **236b** to fix the shafts for corotation. Additionally, each coupling **244a**, **244b** axially isolates the sensor shaft **236a**, **236b** from movement of the pedal shaft **124** along the pedal axis **126**. In other words, each sensor shaft **236a**, **236b** is translationally decoupled from the pedal shaft **124** by the coupling **244a**, **244b** formed between the pedal shaft **124** and the sensor shaft **236a**, **236b**. The axial isolation of the sensor shafts **236a**, **236b** from the pedal shaft **124** increases the accuracy of the sensor circuits **228a**, **228b** as described in more detail further below.

Turning to FIG. 4, the coupling **244b** between the pedal shaft **124** and the sensor shaft **236b** is isolated and illustrated in more detail. While not described in detail, the coupling **244a** is substantially the same as the coupling **244b** and includes the same components and interactions. Each shaft portion **164a**, **164b** includes a set of first projections **248** (also referred to herein as drive projections **248**) extending axially outward from the outer end **184a**, **184b**. In the illustrated embodiment, each shaft portion **164a**, **164b** includes three of the drive projections **248** circumferentially spaced evenly about the pedal axis **126**. With reference to FIG. 4, the sensor shaft **236b** includes a main hub **252** having a cylindrical outer surface, a flange **256** extending from an outer side of the main hub **252**, and a set of second projections **260** (also referred to herein as driven projections **260**) axially extending from an inner end of the main hub **252**. In the illustrated embodiment, the sensor shaft **236b** includes three of the driven projections **260** circumferentially spaced evenly about the sensor axis **242**.

As seen in FIG. 6, a cross section of the coupling **244b** illustrates the spacer **240b** including an inner hub **264** and a set of spurs **268** extending radially outward from the inner hub **264**. The spurs **268** are circumferentially spaced evenly about the inner hub **264**. A window **272** (FIG. 3) is formed by the space between each adjacent pair of the spurs **268**. In the illustrated embodiment, the spacer **240b** includes six of the spurs **268** and six of the windows **272**. The spacer **240b** is positioned between the sensor shaft **236b** and the pedal shaft **124** such that the driven projections **260**, the drive projections **248**, and the spurs **268** axially overlap. In other words, the driven projections **260**, the drive projections **248**, and the spurs **268** occupy a common axial span **276** (FIG. 4) along the pedal axis **126** and engage each other to form the coupling **244b**. This means that when viewed perpendicular to the pedal axis **126**, the drive projections **248**, the driven projections **260**, and spurs **268** overlap each other in an axial direction along the pedal axis **126** and are visible in a cross-section taken through the common axial span **276**, as seen in FIG. 6.

With continued reference to FIG. 6, the cross section of the coupling **244b** through the common axial span **276** shows that, when coupled, the drive projections **248** are received in alternating windows **272** of the spacer **240b** and the driven projections **260** are received in the remaining windows **272** between the spurs **268**. When the coupling **244b** is viewed in cross-section, the outer end **184b** of the pedal shaft **124**, the sensor shaft **236b**, and the spacer **240b** all have similar sizes and outer diameters such that the drive projections **248**, the driven projections **260**, and the spurs **268** all radially overlap (i.e., occupy a common radial span **280**). The radial overlap and the axial overlap of the drive projections **248**, the driven projections **260**, and the spurs **268** causes circumferential engagement during rotation and couples the sensor shaft **236b** to rotate with the pedal shaft **124**. In other words, the coupling **244b** between the drive

projections **248** and the driven projections **260** transmits rotation from the pedal shaft **124** to the sensor shaft **236b** through the spacer **240b**. The sensor shaft **236b** is driven to corotate with the pedal shaft **124**, so that rotation of the sensor shaft **236b** is simultaneous with and the same amount as the pedal shaft **124**. While specific amounts and spacings of projections and spurs are disclosed, in other embodiments, different amounts or configurations of drive projections **248**, driven projections **260**, and spurs **268** may be used to form the couplings **244a**, **244b**. For example, the drive projections **248**, the driven projections **260**, and the spurs **268** may be unevenly circumferentially spaced with complementary configurations. In another example, the outer end **184b** includes only two of the drive projections **248**, the sensor shaft **236b** includes only two of the driven projections **260**, and the spacer **240b** includes four of the spurs **268**.

In the illustrated embodiment, the spacer **240b** is formed from a compliant material that has a low stiffness in the axial direction and is axially deformable (e.g., along the pedal axis **126**). The compliant material may also have a high resilience such that the spacer **240b** is biased to return to its original shape. In some embodiments, the spacer **240b** is formed and shaped so that the rotational stiffness is higher than the axial stiffness. For example, during forming of the spacer **240b** the structure of the material may be oriented so the lowest stiffness is in the axial direction, or the spacer **240b** may have increased thicknesses at certain spots to increase the rotational stiffness, or the spacer **240b** may be assembled in a certain way to increase the rotational stiffness. In some embodiments, the spacer **240a** may be generally rigid and may not be axially deformable. In some embodiments the coupling **244a** may be configured differently from the coupling **244b**. Additional variations may exist and may be incorporated into the design.

Returning again to FIG. 3, each sensor shaft **236a**, **236b** is fixed for corotation with the pedal shaft **124** by the couplings **244a**, **244b**. Each sensor shaft **236a**, **236b** includes the target element **232a**, **232b** positioned at an outer side of each main hub **252** and positioned for use with the sensor circuits **228a**, **228b**. The target elements **232a**, **232b** each rotate with the respective sensor shaft **236a**, **236b** to move relative to the adjacent sensor housing **224a**, **224b**. In some embodiments, the target elements **232a**, **232b** is embedded in the sensor shafts **236a**, **236b**. For example, the sensor shaft **236a**, **236b** may be formed through a molding process, and the target element **232a**, **232b** may be embedded in the main hub **252** during the forming process. In some embodiments, a recess is positioned on the outer side of the main hub **252** and the target element **232a**, **232b** is positioned within the recess and carried by the sensor shaft **236a**, **236b** to rotate therewith. In other embodiments, the target element **232a**, **232b** is otherwise coupled to the main hub **252** of the sensor shaft **236a**, **236b**. Each sensor housing **224a**, **224b** includes an inner housing **284** and a cover **288** removably coupled to the inner housing **284**. The inner housing **284** includes a bearing surface **292** facing inward when assembled.

Turning to FIG. 7, the sensor circuits **228a**, **228b** each have a sensor **296a**, **296b** positioned within the respective inner housing **284**. As seen with respect to the first PSA **132a**, at least a portion of the sensor circuit **228a** is positioned in the sensor housing **224a**. For example, a portion of the sensor circuit **228a** may be positioned on a printed circuit board (PCB) mounted in the inner housing **284**. In some embodiments, the sensor circuit **228a** may include components electrically connected to the PCB but external to the sensor housing **224a**, such as a vehicle controller, the

braking elements **50**, etc. The PCB and the sensor **296a** may be accessible by removing the cover **288** from the inner housing **284**. The sensor circuit **228a** uses the sensor **296a** to sense the associated target element **232a** and generate the preliminary signal. The signal varies based on the movement of the target elements **232a** about the sensor axis **242**, as determined by the rotational position of the pedal shaft **124**. In the illustrated embodiment, the sensor **296a** includes a proximity sensor such as a Hall sensor or an inductive sensor. The sensor **296a** may utilize magnetic or electric fields to determine a position of the target element **232a**. In embodiments where the sensor **296a** includes a Hall sensor, the target element **232a** may include a magnet with rotationally varying flux patterns. In embodiments where the sensor **296a** includes an inductive sensor, the target element **232a** may include a metallic element configured to interact with a magnetic field generated by the sensor **296a**. In other embodiments, the sensor **296a** may include another type of proximity sensor or a different type of rotational position sensor. The sensor **296a** may be positioned on the PCB and may be positioned adjacent a side of the bearing surface **292** opposite the target element **232a** on the sensor shaft **236a**. In some embodiments the sensor **296a** may be a dual die sensor and may include multiple sensing elements configured to sense the target element **232a**. In some embodiments, the sensor shaft **236a** may include multiple target elements **232a** and the sensor circuit **228a** may include multiple sensors **296a** each associated with one of the multiple target elements **232a**. The sensor circuit **228b** of the second PSA **132b** is generally similar to the sensor circuit **228a**.

As discussed above, in the illustrated embodiment the first PSA **132a** and the second PSA **132b** are structurally mirror images. In some embodiments, the PSAs **132a**, **132b** are electronically identical and the sensor **296a** of the first PSA **132a** and the sensor **296b** of the second PSA **132b** are the same type of sensor. For example, in one embodiment, the first PSA **132a** and the second PSA **132b** both include Hall sensors. In other embodiments, the PSAs **132a**, **132b** are electronically different and the first PSA **132a** includes a first type of sensor and the second PSA **132b** includes a second type of sensor, different from the first type of sensor. For example, in one embodiment, the first PSA **132a** includes a Hall sensor, and the second PSA **132b** includes an inductive sensor.

FIG. 7 illustrates a cross section of the pedal assembly **100** with the pedal arm **108**, the pedal shaft **124**, and the PSAs **132a**, **132b** assembled to the pedal housing **104**. To assemble the pedal assembly **100**, the bearings **212a**, **212b** are each coupled to the pedal housing **104** by press-fitting the insert ring **216** into the shaft bore **144** on the respective sidewall **136a**, **136b** until the bearing flange **220** abuts the sidewall **136a**, **136b**. The upper end **116** of the pedal arm **108** is received in the recess **140** defined between the sidewalls **136a**, **136b** such that the through bore **152** (and the openings **160a**, **160b**) are generally aligned with the shaft bores **144** along the pedal axis **126**.

As discussed above, the pedal shaft **124** is formed by the pair of shaft portions **164a**, **164b** coupled by the joint **168**. In some embodiments, the shaft portions **164a**, **164b** may be part of a set of shaft portions having different features and the shaft portions **164a**, **164b** may each be selected based on the needs of the respective side of the assembly (e.g., the diameter of the shaft bore, the type of sensor assembly, the type of coupling between the pedal shaft and sensor shaft, etc.). For example, the first shaft portion **164a** may be selected based on the situation of the first side of the pedal assembly **100** and the first PSA **132a**, and the second shaft

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portion **164b** may be selected based on the situation of the second side of the pedal assembly **100** and the second PSA **132b**. The joint **168** allows for greater adaptability of the pedal shaft **124** as compared to a unitary pedal shaft.

Once selected, the first shaft portion **164a** is inserted into the shaft bore **144** of the first sidewall **136a** from the outside, adjacent the reference surface **148**. The first shaft portion **164a** is moved along the pedal axis **126** toward the recess **140**. As the first shaft portion **164a** translates, the ratchet portion **192a** passes through the opening **160a** and into the through bore **152** of the pedal arm **108**. If needed, the first shaft portion **164a** is rotated to align the mounting hub **188a** with the opening **160a** in the pedal arm **108**. The mounting hub **188a** is press fit into the through bore **152** of the pedal arm **108** to couple the first shaft portion **164a** to the pedal arm **108**. The press fit (or interference fit) between the mounting hub **188a** and the opening **160a** axially and rotationally couples the first shaft portion **164a** to the pedal arm **108**. The bearing hub **180a** of the first shaft portion **164a** is supported in shaft bore **144** extending through the sidewall **136a** of the pedal housing **104**. The bearing hub **180a** is supported for rotation about the pedal axis **126** through contact with the insert ring **216** of the bearing **212a**.

Similar to the first shaft portion **164a**, the second shaft portion **164b** is inserted into the shaft bore **144** of the sidewall **136b** and moved along the pedal axis **126** until the ratchet portion **192b** passes into the through bore **152** of the pedal arm **108**. The mounting hub **188b** is aligned with the opening **160b** and press fit therein. In the illustrated embodiment, the “double D-shape” of the first opening **160a** is oriented differently from the “double D-shape” of the second opening **160b**. Specifically, the first opening **160a** is offset by 90 degrees from the second opening **160b**. Therefore, when the mounting hub **188b** is aligned with the opening **160b**, the ratchet portion **192b** is also aligned with the ratchet portion **192a**. More specifically, the ratchet fingers **196a** are positioned between the ratchet fingers **196b** and the toothed surfaces **200a**, **200b** of each are engaged, as seen in FIG. 6. As the second shaft portion **164b** is press fit and travels toward the first shaft portion **164a**, the teeth on the toothed surfaces **200a**, **200b** ramp against each other causing the ratchet fingers **196a**, **196b** to deflect slightly radially outward from the pedal axis **126**, allowing the second shaft portion **164b** to continue axially joining with the first shaft portion **164a** and translating along the pedal axis **126**. Thus, the joint **168** is coupled at the same time and by the same motion as the press fit between the shaft portion **164b** and the pedal arm **108**. Once the joint **168** is connected, the teeth on the toothed surfaces **200a**, **200b** lock against each other to prevent axial separating of the shaft portions **164a**, **164b** (e.g., movement of the shaft portions **164a**, **164b** away from each other along the pedal axis **126**). The toothed surfaces **200a**, **200b** extend along the ratchet fingers **196a**, **196b** of each shaft portion **164a**, **164b** such that the joint **168** is formed once the shaft portions **164a**, **164b** are a first distance apart from each other (e.g., when three teeth of each toothed surface **200a**, **200b** are engaged). Once the joint **168** is formed, axial separation is inhibited by the toothed surfaces **200a**, **200b**. The toothed surfaces **200a**, **200b** extend along the ratchet fingers **196a**, **196b** in the direction of the pedal axis **126** such that the shaft portions **164a**, **164b** may continue to travel toward each other, engaging more teeth, until the resulting pedal shaft **124** is the correct length, or the remaining components are correctly positioned. For example, the shaft portions **164a**, **164b** may be moved toward each other until an end of the bearing hubs **180a**, **180b** from which the mounting hubs **188a**, **188b** extend

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abuts the flanges **156a**, **156b** of the pedal arm **108**. The joint **168** therefore allows the pedal shaft **124** to be used with pedal arms **108** having different spacing between the flanges **156a**, **156b** or in pedal housings **104** with different spacing between the sidewalls **136a**, **136b**, which increases the adaptability of the pedal shaft **124** compared to a unitary pedal shaft.

The pedal shaft **124** is therefore coupled to the pedal arm **108** and to the pedal housing **104** in order to support the pedal arm **108** for rotation about the pedal axis **126** relative to the pedal housing **104**. The pedal arm **108** is drivably engaged with the pedal shaft **124** and the openings **160a**, **160b** cooperate with the mounting hubs **188a**, **188b** to transmit rotation therebetween. The bearing flange **220** of each of the bearings **212a**, **212b** may contact the upper end **116** of the pedal arm **108** to decrease wear as the pedal arm **108** rotates. The pedal shaft **124** is supported with the drive projections **248** at the first end **172** extending within the shaft bore **144** in the first sidewall **136a**, and the drive projections **248** at the second end **176** extending within the shaft bore **144** in the second sidewall **136b**. In the illustrated embodiment, the first PSA **132a** is coupled to first end **172** of the pedal shaft **124** and the second PSA **132b** is coupled to the second end **176** of the pedal shaft **124**.

To assemble the first PSA **132a** to the pedal housing **104**, the spacer **240a** is positioned adjacent the outer end **184a** of the first shaft portion **164a** of the pedal shaft **124**, and the drive projections **248** are press fit into alternating windows **272** between the spurs **268**, so that the drive projections **248** and the spurs **268** occupy the common axial span **276** along the pedal axis **126**. The sensor shaft **236a** is then positioned in the shaft bore **144** of the first sidewall **136a**, with the driven projections **260** extending toward the first end **172** of the pedal shaft **124**. The sensor shaft **236a** is moved within the shaft bore **144** toward the first end **172** of the pedal shaft **124** until the driven projections **260** axially overlap with the spurs **268** and the drive projections **248**. The driven projections **260** are press fit into the remaining windows **272** between the spurs **268**. The drive projections **248**, driven projections **260** and spurs **268** are positioned within the common axial span **276** (FIG. 4) of the pedal axis **126**. The sensor axis **242** is aligned with the pedal axis **126**. The spacer **240a** is positioned axially between the pedal shaft **124** and the sensor shaft **236a** and circumferentially between the drive projections **248** and the driven projections **260**. The spacer **240a** transmits rotation between the pedal shaft **124** and the sensor shaft **236a** and axially isolates the sensor shaft **236a** from axial movement of the pedal shaft **124**.

The sensor shaft **236a** is inserted into the shaft bore **144** until the flange **256** of the sensor shaft **236a** abuts the reference surface **148** of the first sidewall **136a** of the pedal housing **104**, limiting axial movement of the sensor shaft **236a** in the direction toward the pedal arm **108**. A small gap is left between the inner ends of the driven projections **260** and the outer end **184a** of the shaft portion **164a**. The target element **232a** is coupled to the outer end of the sensor shaft **236a**, if not already provided therein. The sensor housing **224a** is then mounted to the pedal housing **104**, for example, by threaded fasteners. The sensor housing **224a** secures the flange **256** of the sensor shaft **236a** between the reference surface **148** and the bearing surface **292** of the inner housing **284**, limiting axial movement of the sensor shaft **236a** in the direction away from the pedal arm **108**. The sensor shaft **236a** is therefore axially constrained against the reference surface **148** by the sensor housing **224a** to axially fix the sensor shaft **236a** (and thus the target element **232a**) with respect to the sensor **296a** of the sensor circuit **228a**. In the

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context of this disclosure, axially fixed means that the sensor shaft 236a is inhibited from any excess movement along the pedal axis 126 relative to the sensor housing 224a. In other words, a small amount of axial clearance may exist between the flange 256 and the pedal housing 104 and/or the sensor housing 224a due to manufacturing and assembly tolerances that allow for rotation of the sensor shaft 236a with respect to the sensor housing 224a, however, this axial clearance is minimized. The sensor shaft 236a is therefore axially limited with respect to the pedal housing 104 and the sensor housing 224a. Any movement of the sensor shaft 236a along the pedal axis 126 occurs within a range of axial motion that is smaller than the range of axial motion of the pedal shaft 124 along the pedal axis 126. The sensor 296a and a portion of the sensor circuit 228a (e.g., the PCB) are positioned within the sensor housing 224a. The cover 288 is coupled to the inner housing 284 to enclose the electronic components in the sensor housing 224a. The sensor 296a is supported in the sensor housing 224a adjacent the bearing surface 292, and therefore adjacent the target element 232a.

The second PSA 132b is assembled to the pedal housing 104 in the same way as the first PSA 132a, and the details are not repeated for the sake of brevity. The order in which the assembly steps are disclosed is not intended to limit a method of assembling the pedal assembly 100. The order in which the components are coupled together can be altered without departing from the scope of the disclosure.

During operation of the pedal assembly 100, a driver applies an input force F (FIG. 2) to the footpad 128. The pedal arm 108 is pivoted by the force F and drives the pedal shaft 124 to rotate about the pedal axis 126. Specifically, the press-fit connection between the mounting hubs 188a, 188b and the openings 160a, 160b in the pedal arm 108 transmits the rotation from the pedal arm 108 to the pedal shaft 124. Rotation of the pedal shaft 124 about the pedal axis 126 is transmitted to the sensor shafts 236a, 236b by the couplings 244a, 244b. For the sake of brevity, operation is described with reference to the first side of the assembly 100, however, the second side operates similarly and simultaneously with the first side. The pedal shaft 124 is driven to rotate the drive projections 248 of the first shaft portion 164a about the pedal axis 126. The drive projections 248 are circumferentially engaged with the spurs 268 of the spacer 240a, which are in turn circumferentially engaged with the driven projections 260 on the sensor shaft 236a. The spurs 268 transmit the rotation from the drive projections 248 to the driven projections 260. As discussed above, the spacer 240a has a high rotational stiffness. In the illustrated embodiment, the press-fit between the drive projections 248, the driven projections 260, and the spurs 268 may deform the spurs 268 near the elastic deformation limit. Thus, rotation is transmitted through the spurs 268 without loss due to rotational deformation of the spacer 240a, and the sensor shaft 236a co-rotates with the pedal shaft 124. In other words, the sensor shaft 236a rotates the same amount and at the same time as the pedal shaft 124 so that the rotational position of the sensor shaft 236a is indicative of the rotational position of the pedal shaft 124. The sensor shaft 236a rotates about the sensor axis 242. In the illustrated embodiment, the pedal axis 126 and the sensor axis 242 are co-axial. The rotation of the sensor shaft 236a about the sensor axis 242 causes the target element 232a to rotate with respect to the sensor circuit 228a in the sensor housing 224a. The sensor circuit 228a varies the preliminary signal based on the rotational position of the target element 232a, and by extension the position of the pedal arm 108. A controller processes the preliminary signal from the sensor circuits 228a, 228b and

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instructs associated elements of the vehicle 10 (e.g., braking elements 50) to activate in response to the movement of the pedal arm 108.

As discussed above, the couplings 244a, 244b axially isolate the PSAs 132a, 132b from the pedal shaft 124, which increases accuracy of the sensor circuits 228a, 228b. For example, sometimes, during operation, the force F applied to the pedal arm 108 may cause the pedal arm 108 to shift laterally (e.g., from side to side) in the recess 140. This translation or lateral displacement of the pedal arm 108 is transmitted to the pedal shaft 124 by the press fit connections between the mounting hubs 188a, 188b and the openings 160a, 160b of the through bore 152. In one example, the pedal shaft 124 is translated along the pedal axis 126 toward the first PSA 132a. The translation of the pedal shaft 124 moves the first end 172 of the pedal shaft 124 toward the sensor shaft 236a. The pedal shaft 124 applies a force along the pedal axis 126 to the spacer 240a, and the spacer 240a deforms (i.e., compresses) in response to absorb the movement of the pedal shaft 124 along the pedal axis 126, axially isolating the sensor shaft 236a. Therefore, the pedal shaft 124 moves along the pedal axis 126 relative to the sensor shaft 236a. In some embodiments, instead of relying on axial deformation of the spacer 240a, the drive projections 248 and/or the driven projections 260 may be slidably coupled to the spacer 240a and configured to slide within the windows 272 such that the pedal shaft 126a is axially translatable with respect to the sensor shaft 236a. Those embodiments may include embodiments where the spacer 240a is generally rigid or embodiments where the spacer 240a is axially deformable. The sensor shaft 236a is isolated from the translation of the pedal shaft 126a. The sensor shaft 236a is further inhibited from moving along the pedal axis 126 and is axially limited by the pedal housing 104 and the sensor housing 224a. The flange 256 of the sensor shaft 236a is axially constrained against the reference surface 148 of the pedal housing 104 by the bearing surface 292 of the sensor housing 224a to axially fix the sensor shaft 236a with respect to the sensor housing 224a. Any axial force applied to the sensor shaft by the spacer 240a is transmitted through the flange 256 and absorbed by the connection between the pedal housing 104 and the sensor housing 224a. Therefore, the sensor shaft 236a (and the target element 232a carried thereon) is axially limited with respect to the sensor housing 224a and the sensor 296a therein, inhibiting any decrease in accuracy of the sensor 296a that would occur if the translation of the pedal shaft 124 were transmitted to the sensor shaft 236a.

Thus, the pedal assembly 100 described herein provides greater precision and accuracy of position sensing. The precision and accuracy of the sensor circuits 228a, 228b in determining the rotational position of the pedal shaft 124 is greatly improved if the proximity of the target element 232a, 232b to the sensor 296a, 296b is only varied by the rotation of the shaft 124 and not by any translational movement. In other words, axial movement of the target elements 232a, 232b (e.g., along the pedal axis 126) can decrease the accuracy of the PSAs 132a, 132b. Therefore, the pedal assembly 100 described herein axially fixes the target element 232a, 232b with respect to the sensor circuit 228a, 228b in the sensor housing 224a, 224b by axially constraining the sensor shaft 236a, 236b with respect to the sensor housing 224a, 224b and the pedal housing 104, and by translationally decoupling (i.e., axially isolating) the sensor shafts 236a, 236b with respect to the pedal shaft 124. Each spacer 240a, 240b, and more broadly each coupling 244a, 244b, is designed to simultaneously i) maintain a connection



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for corotation and transmit rotation between the pedal shaft 124 and the sensor shaft 236a, 236b, and ii) axially isolate the sensor shaft 236a, 236b by allowing the pedal shaft 124 to move along the pedal axis 126 with respect to the sensor shaft 236a, 236b. Therefore, the proposed design offers improved accuracy and precision in determining the rotational position of the pedal shaft 124.

In the embodiment illustrated in FIGS. 2-7, the sensor shafts 236a, 236b are each axially constrained with respect to the sensor circuits 228a, 228b by constraining the flange 256 of each sensor shaft 236a, 236b against the pedal housing 104 and mounting the sensor housing 224a, 224b to the pedal housing 104 to pin or sandwich the flange 256 between the bearing surface 292 of the adjacent sensor housing 224a, 224b and the reference surface 148 of the respective sidewall 136a, 136b of the pedal housing 104. In other embodiments, the sensor shafts 236a, 236b may be axially constrained or fixed using different means.

For example, FIG. 8 illustrates an alternative embodiment of the pedal assembly 100' including a position sensor assembly 132' in which the sensor shaft 236' (including the target element 232') is axially constrained directly by the sensor housing 224'. The flange 256' of the sensor shaft 236' is rotatably received in a groove 304 (or track) formed partly or entirely by the sensor housing 224' adjacent the bearing surface 292'. The sensor shaft 236' is therefore supported adjacent the sensor circuit 228' and is axially constrained with respect to the sensor circuit 228' and the sensor 296'. The sensor housing 224' is then secured to the pedal housing 104', and the sensor shaft 236' is coupled to the pedal shaft 124' for corotation therewith. The target element 232' is axially fixed with respect to the sensor housing 224' and thus is rotated relative to the sensor circuit 228' without translating axially with respect to the sensor circuit 228'. The sensor circuit 228' generates a signal indicative of the position of the pedal shaft 124' as indicated by the position of the target element 232'. Other embodiments may include still further methods of axially constraining the sensor shaft(s) 236a, 236b and target element(s) 232a, 232b with respect to the sensor circuit(s) 228a, 228b.

With reference back to the pedal assembly 100 of FIGS. 2-7, and as discussed above, the jointed shaft design allows for greater adaptability and modularity, allowing the pedal shaft 124 to be easily customized based on the specific requirements of the situation. Additionally, the pedal shaft 124 of the pedal assembly 100 illustrated in FIGS. 2-7 offers increased ease of installation compared to previous pedal assembly designs. Previous designs included a single unitary shaft (often carrying one or more sensor targets) for mounting the pedal arm to the housing, however, such designs often required difficult or complex press fits through multiple components in order to properly support the pedal arm in the housing. One common issue results from the differing widths of the various bores. For example, a press fit may be more secure when made with a smaller opening, however, rotational support of a shaft may be easier when made with a larger opening, meaning that the portions of the shaft configured to be supported in the housing is often wider than the portion between the supports which is configured to couple (e.g., via press fit) to the pedal shaft. Complex geometry or press-fits may be required to properly support and couple the pedal arm to the housing when using a standard unitary pedal shaft design.

In the embodiment illustrated in FIGS. 2-7, the joint 168 in the pedal assembly 100 allows each of the shaft portions 164a, 164b of the pedal shaft 124 to be separately coupled through the outside of the pedal housing 104 and press fit

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into the openings 160a, 160b of the through bore 152. The bearing portions 180a, 180b, which are the wider portions of the shaft, are supported in the housing 104 on both sides of the pedal arm 108, and the mounting hubs 188a, 188b, which are narrower than the bearing portions 180a, 180b, are press fit in the openings 160a, 160b and coupled to the pedal arm 108. The joint 168 is easily connected within the through bore 152 without additional tools, components, or actions. The axial movement needed to join the shaft portions 164a, 164b and couple the joint 168 occurs as part of the process of press fitting the shaft portions 164a, 164b to the pedal arm 108. Therefore, the shaft 124 is formed from the shaft portions 164a, 164b during assembly without adding a separate motion or step to the process. The ratchet rivet style of the joint 168 allows each shaft portion 164a, 164b to be formed as a single piece and the joint 168 does not require additional components or pre-assembly of any parts. The joint 168 of the illustrated embodiment offers additional simplicity since the first shaft portion 164a and the second shaft portion 164b are identical, meaning the number of distinct components in the pedal assembly 100 is not increased by replacing the unitary shaft with the pedal shaft 124 with the joint 168.

In addition to the ease of assembly, the joint 168 provides secondary or backup locating features that axially and rotationally fix the first shaft portion 164a with respect to the second shaft portion 164b. In the pedal assembly 100 described herein, the shaft portions 164a, 164b are each separately press fit to the pedal arm 108, and therefore the shaft portions 164a, 164b are each axially fixed with respect to the pedal arm 108 and therefore to each other. Additionally, each shaft portion 164a, 164b is separately driven to rotate about the pedal axis 126 by the engagement between the openings 160a, 160b and the mounting hubs 188a, 188b, resulting in simultaneous rotation of the shaft portions 164a, 164b. The press fits may serve as the primary system for locating (e.g., fixing the location of) the shaft portions 164a, 164b with respect to the pedal arm 108 and to each other. However, even without the press fit between the shaft portions 164a, 164b and the pedal arm 108, the joint 168 acts as a backup locating system for maintaining the shaft portions 164a, 164b with respect to each other. Therefore, in assemblies where only one shaft portion 164a, 164b is press fit (or otherwise axially and rotationally fixed) with the pedal arm 108, both shaft portions 164a, 164b are still rotated and translated simultaneously. Rotationally locating the shaft portions 164a, 164b with respect to each other allows the shaft portions 164a, 164b to act together as the pedal shaft 124 so that in embodiments with both the first PSA 132a and the second PSA 132b, the sensor shafts 236a, 236b are driven to rotate by the pedal shaft at the same time and to the same degree, resulting in consistent measuring between the first PSA 132a and the second PSA 132b.

For example, if during operation, only the first shaft portion 164a is axially fixed to the pedal arm 108 (e.g., by the press fit between the mounting hub 188a and the opening 160a), and the second shaft portion 164b attempts to axially separate from (i.e., move axially outward with respect to) the first shaft portion 164a, the joint 168 would inhibit axial separation. Specifically, the toothed surfaces 200a of the ratchet fingers 196a would engage the toothed surfaces 200b of the ratchet fingers 196b and would lock against each other, stopping movement of the toothed surfaces 200a, 200b relative to each other, and thereby inhibiting axial separation of the shaft portions 164a, 164b. Thus, if the pedal arm 108 translates laterally, as discussed above, the translation would be transmitted through the press fit to the



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first shaft portion **164a** and then through the joint **168** to the second shaft portion **164b**. The translation is then inhibited from transmitting to the sensor shafts **236a**, **236b** by the couplings **244a**, **244b**. Axially locating the shaft portions **164a**, **164b** prevents the pedal shaft **124** from changing in length, which may adversely affect the spacing in the couplings **244a**, **244b** and the effectiveness of the spacers **240a**, **240b**. Additionally, if only the first shaft portion **164a** is rotationally fixed with the pedal arm **108** (e.g., by the press fit between the mounting hub **188a** and the opening **160a**), and the pedal arm **108** is rotated about the pedal axis, then the pedal arm **108** drives the first shaft portion **164a** to rotate about the pedal axis **126**, and the joint **168** transmits the rotation from the first shaft portion **164a** to the second shaft portion **164b**. Specifically, the circumferential engagement of the toothed surfaces **200a**, **200b** due to the axial and radial overlap of the ratchet fingers **196a**, **196b** transmits the rotation between the shaft portions **164a**, **164b**. Rotation of the shaft portions **164a**, **164b** is transmitted to the sensor shafts **236a**, **236b** through the couplings **244a**, **244b** and both of the sensor circuits **228a**, **228b** can detect the resulting movement of the target elements **232a**, **232b** and generate the signal indicating the movement of the pedal shaft **124** and pedal arm **108**. Thus, rotationally locating the shaft portions **164a**, **164b** with respect to each other ensures that the pedal shaft **124** can be consistently sensed by either of the sensor circuits **228a**, **228b**.

As discussed above, in the pedal assembly **100** the press fits between the mounting hubs **188a**, **188b** and the openings **160a**, **160b** are designed to act as the primary locating feature to determine the positioning of the shaft portions **164a**, **164b** with respect to each other, and the joint **168** is used as a backup system to support the press fits. In some embodiments, the backup locating features of the joint **168** may be used alongside a detection system or regular maintenance that would monitor the primary locating system, or in other words, ensure both shaft portions **164a**, **164b** are press fit to the pedal arm **108**.

Overall, the joint **168** offers the pedal shaft **124** increased adaptability and ease of assembly without increasing the complexity of the design or negatively impacting the function thereof and offers support to the primary locating features (e.g., the press fits of the shaft portions **164a**, **164b**).

In the pedal assembly **100**, as illustrated in FIGS. 2-7, the pedal shaft **124** includes both the joint **168** and at least one isolating coupling **244a**, **244b** for connecting to the sensor shaft **236a**, **236b**. However, in other embodiments a pedal assembly may include only one of the joint or the coupling(s). For example, a pedal assembly may include a unitary pedal shaft configured to couple to at least one position sensor assembly by an axially isolating coupling. Alternately, a pedal assembly may include a jointed pedal shaft having portions of the position sensor assembly(ies) integrated with the pedal shaft (for example, the pedal assembly **800** illustrated in FIGS. 13-15). The features are therefore independent, and each offer their own advantages, which may be increased when combined into a single assembly, as shown in the pedal assembly **100** shown in FIGS. 2-7.

FIG. 9 illustrates a first embodiment of an alternate coupling **544** between a sensor shaft **536** and a pedal shaft **424**. The alternate coupling **544** may be incorporated into the pedal assembly **100** in place of one or both of the couplings **244a**, **244b**. The alternate coupling **544** transmits rotation between the sensor shaft **536** and the pedal shaft **424** and allows for axial movement of the pedal shaft **424** along the pedal axis **126**. In the illustrated embodiment, the coupling **544** includes a pair of drive projections **548** extend-

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ing from an outer end **484** of the pedal shaft **424**. The drive projections **548** are slidably received in a set of slots **560** on the sensor shaft **536**. In the illustrated embodiment, the pedal shaft **424** includes the projections **548** and the sensor shaft **536** includes the slots **560**, however, in other embodiments this may be reversed and the pedal shaft **424** may include slots for receiving the projections of the sensor shaft **536**. The circumferential engagement of the projections **548** in the slots **560** transmits rotation between the pedal shaft **424** and the sensor shaft **536**. The drive projections **548** are axially slidable within the slots **560** to allow the pedal shaft **424** to translate relative to the sensor shaft **536** along the pedal axis **126**. Biasing members **540** may be positioned axially between an end surface **549** of the drive projections **548** and a rear wall **561** of the slots **560** to bias the pedal shaft **424** and the sensor shaft **536** apart. When the coupling **544** is incorporated in a pedal assembly, the biasing members **540** of the coupling **544** retain the target element (not shown) on the end of the sensor shaft **536** in close axial proximity to the sensor circuit in the sensor housing (not shown). As mentioned above, the alternate coupling **544** may be used in place of the couplings **244a**, **244b** between one or both of the sensor shafts **236a**, **236b** and the pedal shaft **124**. In some embodiments, the shaft portions **164a**, **164b** may be selected based on the desired coupling and the configuration of the sensor shaft.

FIGS. 10-12 illustrate a second embodiment of an alternate coupling **744**. The alternate coupling **744** can be incorporated into the pedal assembly **100** and replace one or both of the couplings **244a**, **244b**. The coupling **744** connects the sensor shaft **736** with the pedal shaft **624** and transmits rotation therebetween. The coupling **744** also allows movement of the pedal shaft **624** with respect to the sensor shaft **736**. In the illustrated embodiment, the pedal shaft **624** is rotatable about a pedal axis **126**. The sensor shaft **736** is rotatable about a sensor axis **742**. The coupling **744** transmits rotation of the pedal shaft **624** about the pedal axis **126** and drives the sensor shaft **736** to rotate about the sensor axis **742**. The coupling **744** isolates the sensor shaft **736** from axial and radial movement of the pedal shaft **624**. The pedal shaft **624** includes a pair of drive projections **748** extending from an outer end **684**. The sensor shaft **736** similarly includes a pair of driven projections **760** axially extending along the sensor axis **742**. The coupling **744** includes a spacer **740** having an inner hub **764** (FIG. 12), four spurs **768** extending radially outward from the inner hub **764**, and four windows **772** positioned circumferentially between the spurs **768**. When the pedal shaft **624** and sensor shaft **736** are coupled, the spurs **768** are interspersed between the drive projections **748** and driven projections **760**. In other words, the drive projections **748** and driven projections **760** are received in alternating windows **772** of the spacer **740**.

With reference to FIG. 11, in the illustrated embodiment, the spacer **740** is configured to axially isolate the sensor shaft **736** from the pedal shaft **624** in a similar way to the spacer **240b** of the coupling **244b** shown in FIGS. 4 and 6. The spacer **740** is positioned axially between the pedal shaft **624** and the sensor shaft **736**. The spacer **740** may be formed of a compliant material and may be deformable in an axial direction (e.g., along the pedal axis **126**). In an axially neutral position, shown in FIG. 11, the driven projections **760** may be spaced from the outer end **684** of the pedal shaft **624**, and therefore the pedal shaft **624** is able to slide with respect to the sensor shaft **736** in either direction from the neutral position along the pedal axis **126**. The translation of the pedal shaft **624** toward the sensor shaft **736** is absorbed

by the spacer 740 and is not transmitted to the sensor shaft 736. The spacer 740 therefore axially isolates the sensor shaft 736 from the pedal shaft 624. The spurs 768, the drive projections 748, and the driven projections 760, are all positioned in a common axial span 776 along the pedal axis 126 and a common radial span 780 (FIG. 12) such that the spurs 768, the drive projections 748, and the driven projections 760 are all circumferentially engaged to transmit rotation.

With reference to FIG. 12, the sensor shaft 736 and the pedal shaft 624 are each radially movable with respect to each other and with respect to the spacer 740. As discussed above, the drive projections 748 and driven projections 760 are received in the windows 772, and more specifically, may be press fit with the spacer 740 to position the components in the common axial span 776 and create circumferential engagement therebetween. In a radially neutral position (also referred to as an aligned position), shown in FIG. 12, the sensor axis 242 is aligned with the pedal axis 126. A pair of first gaps 308 are formed between the inner hub 764 and each of the drive projections 748. The drive projections 748 are directly opposite each other across the pedal axis 126, therefore, the pair of first gaps 308 are similarly formed in windows 772 directly opposite each other. The pair of first gaps 308 are aligned along a first axis (e.g., the X-axis of FIG. 12). Thus, one of the pair of first gaps 308 is adjacent the inner hub 764 in a first direction along the X-axis (a first radial direction) and the second of the pair of first gaps 308 is adjacent the inner hub 764 in a second direction along the X-axis, opposite the first direction (a third radial direction). The pedal shaft 624 is able to radially deflect and move along the X-axis in the first and second directions relative to the spacer 740 (and therefore the sensor shaft 736), such that the pedal axis 126 is offset from the sensor axis 742 creating a misalignment of the pedal shaft 624 and the sensor shaft 736. Similarly, a pair of second gaps 312 is formed adjacent the inner hub 764 along a second axis (e.g., the Y-axis of FIG. 12), between the inner hub 764 and each of the driven projections 760. The pedal shaft 624 and the spacer 740 are movable relative to the sensor shaft 736 in a first direction along the Y-axis (a second radial direction) and in a second direction along the Y-axis, opposite the first direction (a fourth radial direction), such that the pedal axis 126 is offset from the sensor axis 742 creating a misalignment of the pedal shaft 624 and the sensor shaft 736.

The gaps 308, 312 are smaller than a radial width of the projections 748, 760 such that at least a portion of the projections 748, 760 remains radially overlapped with the spurs 768. In other words, the drive projections 748, the driven projections 760, and the spurs 768 remain within the common radial span 780 during misalignment. The coupling 744 therefore maintains the circumferential engagement within the common axial span 776 that transmits rotation, even when the pedal axis 126 is offset from the sensor axis 742. The coupling 744 maintains a connection for corotation between the pedal shaft 624 and the sensor shaft 736 regardless of axial or radial movement of the pedal shaft 624 relative to the sensor shaft 736. In other words, the coupling 744 is able to tolerate misalignment between the pedal shaft 624 and the sensor shaft 736 and continue to transmit rotation therebetween. The sensor shaft 736 may be radially constrained with respect to the sensor housing such that during operation, the pedal shaft 624 may deflect radially and move radially along the X and Y axes relative to the sensor shaft 736 and only rotation of the pedal shaft 624 is transmitted to the sensor shaft 736, maintaining a connection for corotation with the pedal shaft 624 during misalignment.

Thus, when the coupling 744 is incorporated into a pedal assembly, the sensor shaft 736 maintains alignment and rotates about the sensor axis 742 with respect to the sensor housing and the target element (coupled to the sensor shaft 736) does not move axially or deflect radially with respect to the sensing circuit (not shown). In some embodiments, the gaps 308, 312 may be used alongside or replaced by a low radial stiffness of the spacer 740. For example, one of the projections 748 may move through one of the first gaps 308 to allow radial deflection of the pedal shaft 624, and/or the projection 748 may engage the inner hub 764 adjacent the window 772 and the inner hub 764 may deform to allow for radial deflection of the pedal shaft 624 with respect to the sensor shaft 736. The directions of movement are discussed with reference to an X-Y coordinate system as applied to FIG. 12. The references to X and Y axes are not intended to limit the discussed movement to horizontal and vertical axes, and the coordinate system shown in FIG. 12 would rotate along with the coupling 744. As discussed above, the coupling 744 may replace either coupling 244a, 244b in the pedal assembly 100 and the shaft portions 164a, 164b may be selected based on the desired coupling and configuration of the sensor shaft 736.

With reference to FIGS. 13-15, an alternative pedal assembly 800 is shown. As discussed above, the benefits of the jointed pedal shaft may be incorporated into pedal assemblies not including translational decoupling of the target element and the pedal shaft. The pedal assembly 800 includes a pedal shaft 824 having a first shaft portion 864a and a second shaft portion 864b coupled by a joint 868. The joint 868 is a one-way ratchet joint that is substantially similar to the joint 168 and only differences between the joints are described herein. As seen best in FIG. 15, the first shaft portion 864a includes a pair of ratchet fingers 896a and the second shaft portion 864b includes a pair of ratchet fingers 896b. Each ratchet finger 896a, 896b includes an axial slot extending lengthwise from a distal end of the ratchet finger along the pedal axis 126. In the illustrated embodiment, each axial slot 897 may extend partially into the mounting hub 888a, 888b. Each axial slot 897 subdivides the ratchet finger 896a, 896b such that a first portion 898 is deflectable with respect to a second portion 899. The ratchet fingers 896a, 896b each include a pair of toothed surfaces 900a, 900b. For example, one of the ratchet fingers 896a includes a first one of the toothed surfaces 900a on the first portion 898 and a second one of the toothed surfaces 900a on the second portion 899. During the coupling of the joint 868, the axial slots 897 provide the ratchet fingers 896a, 896b with greater flexibility to deform relative to the pedal axis 126 and decrease the force required to axially couple the shaft portions 864a, 864b. Specifically, the first portions 898 and second portions 899 of each ratchet fingers 896a, 896b may deflect inward (e.g., toward the axial slot 897), as the teeth on the toothed surfaces 900a, 900b ramp against each other. When the ratchet fingers 896a, 896b are engaged, the toothed surface 900a on the first portion 898 transmits the rotation to the corresponding toothed surface 900b on the first portion 898 of the ratchet finger 896b and the toothed surface 900a on the second portion 899 transmits rotation to the corresponding toothed surface 900b on the second portion 899 of the ratchet finger 896b.

With reference to FIG. 14, in the illustrated embodiment, the first shaft portion 864a and the second shaft portion 864b are structurally unique. The first shaft portion 864a includes a target element 932a coupled to the outer end 884a of the bearing hub 880a (FIG. 15). In the illustrated embodiment, the target element 932a is a metal element configured for use

with an inductive position sensor of a sensor circuit **928b**. The second shaft portion **864b** includes a target element **932b** positioned in a flared portion of the bearing hub **880b**, adjacent the outer end **884b**. In the illustrated embodiment, the target element **932b** is a ring-shaped magnet for use with a Hall sensor of a sensor circuit **928b**. In the illustrated embodiment, the target elements **932a**, **932b** are integrated (e.g., embedded) into the shaft portions **864a**, **864b**. In other embodiments, the target elements **932a**, **932b** may be coupled to a recess on the outer end **884a**, **884b**. The target elements **932a**, **932b** rotate with the pedal shaft **824** and the sensor circuits **928a**, **928b** are able to sense the position of the target elements **932a**, **932b** and generate a signal corresponding to a rotational position of the pedal shaft **824**. As discussed above, the joint **868** in the pedal shaft **824** increases the ease of assembly and the modularity of the pedal assembly **800**. In the illustrated embodiment, each shaft portion **864a**, **864b** may be selected based on the type of sensor used in the sensor circuit **928a**, **928b**, the configuration of the housing **804**, the type of target element **932a**, **932b** coupled to the shaft portion **864a**, **864b**, and other considerations for each side of the pedal assembly **800**. Additionally, the ratchet style joint **868** provides backup or secondary axial and radial locating of the shaft portions **864a**, **864b** independent from and capable of supporting the press fit between the pedal arm **808** and the mounting hubs **888a**, **888b** of the pedal shaft **824**. The joint **868** increases the modularity of the system and adds backup locating features while maintaining an assembly that is easy to manufacture and assemble.

The embodiments described above and illustrated in the figures are presented by way of example only and are not intended as a limitation upon the concepts and principles of the present invention. As such, it will be appreciated that various changes in the elements and their configuration and arrangement are possible without departing from the spirit and scope of the present invention. Accordingly, the specification and figures are to be regarded in an illustrative rather than a restrictive sense, and all such modifications are intended to be included within the scope of present teachings.

The benefits, advantages, solutions to problems, and any element(s) that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as a critical, required, or essential features or elements of any or all the claims. The invention is defined solely by the appended claims including any amendments made during the pendency of this application and all equivalents of those claims as issued.

The Abstract of the Disclosure is provided to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. In addition, in the foregoing Detailed Description, it may be seen that various features are grouped together in various examples for the purpose of streamlining the disclosure. This method of disclosure is not to be interpreted as reflecting an intention that the claimed examples require more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive subject matter lies in less than all features of a single disclosed example. Thus, the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separately claimed subject matter.

Various features and advantages of the invention are set forth in the following claims.

What is claimed is:

1. A vehicular pedal assembly comprising:

a pedal housing configured for mounting within a vehicle; a pedal shaft supported by the pedal housing for rotation about a pedal axis;

a pedal arm coupled to the pedal shaft and configured to pivot in response to input from a driver to drive the pedal shaft to rotate about the pedal axis; and

a position sensor assembly coupled to the pedal shaft to determine a rotational position of the pedal shaft and generate a signal based on the rotational position,

wherein the position sensor assembly includes

a target element,

a sensor circuit configured to sense the target element and generate the signal, and

a sensor shaft configured to rotate about a sensor axis and fixed for corotation with the pedal shaft,

wherein the target element is positioned on the sensor shaft and is configured to rotate with the sensor shaft about the sensor axis to move the target element with respect to the sensor circuit and change the signal generated by the sensor circuit,

wherein a coupling between the pedal shaft and the sensor shaft is configured to simultaneously transmit rotation and absorb movement of the pedal shaft along the pedal axis to axially isolate the sensor shaft.

2. The vehicular pedal assembly of claim 1, wherein the sensor shaft is constrained against a reference surface of the pedal housing to axially fix a position of the target element with respect to the sensor circuit.

3. The vehicular pedal assembly of claim 1, wherein the position sensor assembly further includes a sensor housing coupled to the pedal housing, the sensor circuit positioned in the sensor housing, and

the sensor shaft includes a flange configured to be constrained between the sensor housing and the pedal housing to axially fix the sensor shaft and the target element with respect to the sensor housing.

4. The vehicular pedal assembly of claim 1, wherein the coupling includes a spacer positioned axially between the pedal shaft and the sensor shaft and the spacer transmits rotation between the pedal shaft and the sensor shaft.

5. The vehicular pedal assembly of claim 4, wherein the spacer includes an inner hub and a spur extending radially outward from the inner hub.

6. The vehicular pedal assembly of claim 5, wherein the spur transmits rotation from the pedal shaft to the sensor shaft and the spacer is configured to simultaneously transmit rotation and absorb movement of the pedal shaft along the pedal axis to axially isolate the sensor shaft.

7. The vehicular pedal assembly of claim 1, wherein the pedal shaft extends along the pedal axis between a first end and a second end,

the position sensor assembly is a first position sensor assembly coupled to the first end of the pedal shaft, and the vehicular pedal assembly includes a second position sensor assembly coupled to the second end of the pedal shaft.

8. The vehicular pedal assembly of claim 7, wherein one of the first and second position sensor assemblies includes a hall sensor configured to sense the target element and the other of the first and second position sensor assemblies includes an inductive sensor configured to sense the target element.

9. The vehicular pedal assembly of claim 1, wherein the coupling includes a first projection of the pedal shaft and a second projection of the sensor shaft.

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10. The vehicular pedal assembly of claim 9, wherein the coupling is configured to allow the pedal shaft to move relative to the sensor shaft along a pair of axes perpendicular to each other and perpendicular to the pedal axis.

11. The vehicular pedal assembly of claim 1, wherein the coupling between the pedal shaft and the sensor shaft is configured to tolerate misalignment between the pedal shaft and the sensor shaft and maintain a connection for corotation between the pedal shaft to the sensor shaft.

12. The vehicular pedal assembly of claim 1, wherein the vehicular pedal assembly is a brake pedal, and the pedal arm is coupled to a brake footpad configured to be engaged by the driver to pivot the pedal arm and actuate one or more braking elements.

13. A vehicular pedal assembly for a vehicle, the vehicular pedal assembly comprising:

a pedal housing configured for mounting in the vehicle; a pedal shaft supported by the pedal housing for rotation about a pedal axis, the pedal shaft extending along the pedal axis between a first end and a second end;

a pedal arm drivably engaged with the pedal shaft, the pedal arm having a footpad configured to be engaged by a driver to pivot the pedal arm and rotate the pedal shaft about the pedal axis;

a position sensor assembly coupled to the first end of the pedal shaft and configured to determine a rotational position of the pedal shaft and generate a signal based on the rotational position,

wherein the position sensor assembly includes

a sensor housing coupled to the pedal housing and containing a sensor circuit,

a sensor shaft configured to rotate about a sensor axis and fixed for corotation with the pedal shaft, and

a target element positioned on the sensor shaft, wherein the sensor circuit is configured to sense the target element and generate the signal; and

a spacer positioned between the sensor shaft and the first end of the pedal shaft to transmit rotation from the pedal shaft to the sensor shaft, the spacer configured to absorb movement of the pedal shaft along the pedal axis to axially isolate the sensor shaft.

14. The vehicular pedal assembly of claim 13, wherein rotation of the sensor shaft moves the target element relative to the sensor circuit and changes the signal generated by the position sensor assembly.

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15. The vehicular pedal assembly of claim 13, wherein the sensor shaft is constrained between the sensor housing and the pedal housing to axially fix a position of the sensor shaft with respect to the sensor housing.

16. The vehicular pedal assembly of claim 15, wherein the position sensor assembly is a first position sensor assembly coupled to the first end of the pedal shaft and the vehicular pedal assembly includes a second position sensor assembly coupled to the second end of the pedal shaft.

17. The vehicular pedal assembly of claim 13, wherein the first end of the pedal shaft includes a first projection extending from the first end along the pedal axis, the sensor shaft includes an inner end having a second projection extending from the inner end along the sensor axis, and the first projection, the second projection, and the spacer are all positioned within a common span of the pedal axis.

18. The vehicular pedal assembly of claim 17, wherein the spacer includes an inner hub and a spur extending radially outward from the inner hub, the spur is positioned circumferentially between the first projection and the second projection, and the spur is configured to transmit rotation of the pedal shaft between the first projection and the second projection to rotate the sensor shaft with the pedal shaft.

19. The vehicular pedal assembly of claim 18, wherein a first gap is disposed adjacent the inner hub and the first projection is configured to move within the first gap along a first axis to allow movement of the pedal shaft with respect to the sensor shaft along the first axis, and a second gap is disposed adjacent the inner hub and the second projection is configured to move within the second gap along a second axis to allow movement of the pedal shaft with respect to the sensor shaft along the second axis.

20. The vehicular pedal assembly of claim 13, wherein a coupling includes the pedal shaft, the sensor shaft, and the spacer and the coupling is configured to tolerate misalignment between the pedal shaft and the sensor shaft and maintain a connection for corotation between the pedal shaft to the sensor shaft.

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