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Pozgay et al.

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(45) Date of Patent: Apr. 19, 2011

(54) **METHOD AND APPARATUS FOR AN ARTICULATING DRILL**

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(73) Assignee: **Robert Bosch GmbH**, Stuttgart (DE)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 168 days.

(21) Appl. No.: **11/593,187**

(22) Filed: **Nov. 3, 2006**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**
B23B 45/00 (2006.01)
B25B 17/00 (2006.01)

(52) **U.S. Cl.** **173/39**; 173/170; 173/216; 81/57; 81/57.26; 81/57.28

(58) **Field of Classification Search** 173/1, 39, 173/170, 216, 217; 81/57, 57.26, 57.28
See application file for complete search history.

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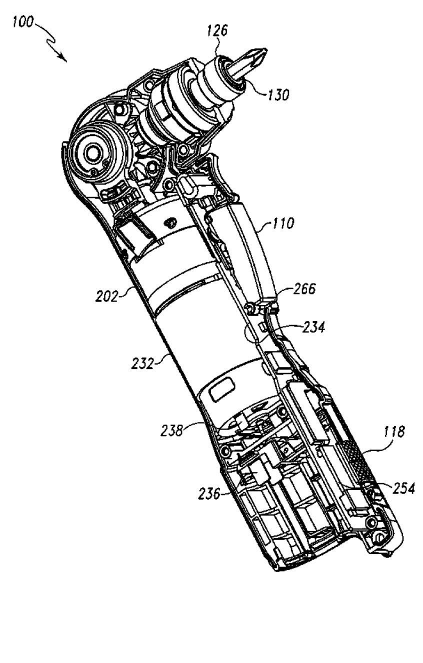
(74) *Attorney, Agent, or Firm* — Maginot, Moore & Beck

(57) **ABSTRACT**

The present invention is an articulating hand power tool with a head portion including a head housing, a bit holder rotatably positioned within the head housing, and a bearing member operable to transfer a first axial force from the bit holder to the head housing. A frame is rotatably connected to the head portion for placement in a plurality of positions with respect to the head portion and operably connected to the head housing for receiving the first axial force transferred to the head housing. The tool further includes an articulating gear system for transferring rotational force generated by a motor to the bit holder at each of the plurality of positions.

20 Claims, 19 Drawing Sheets



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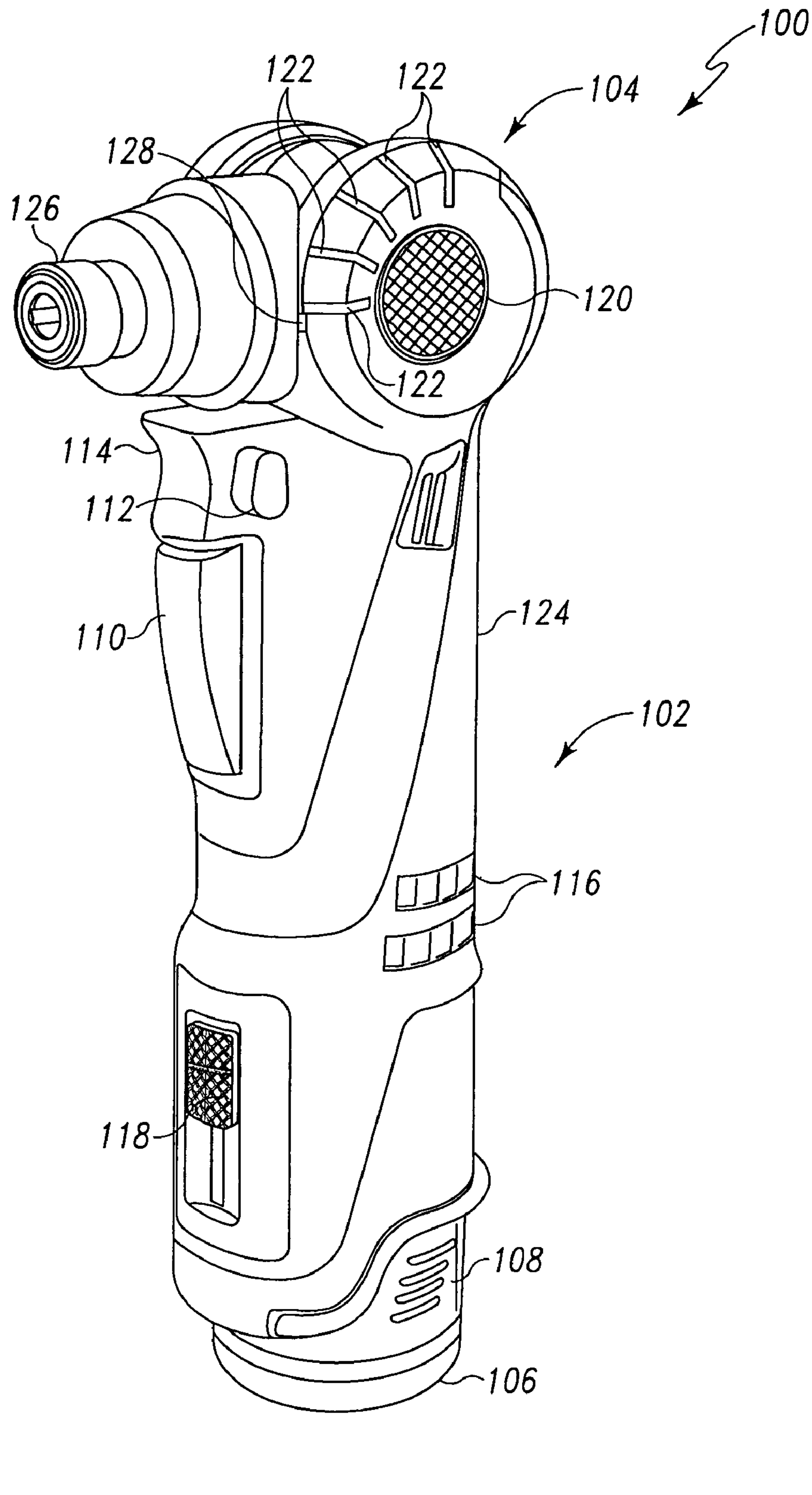
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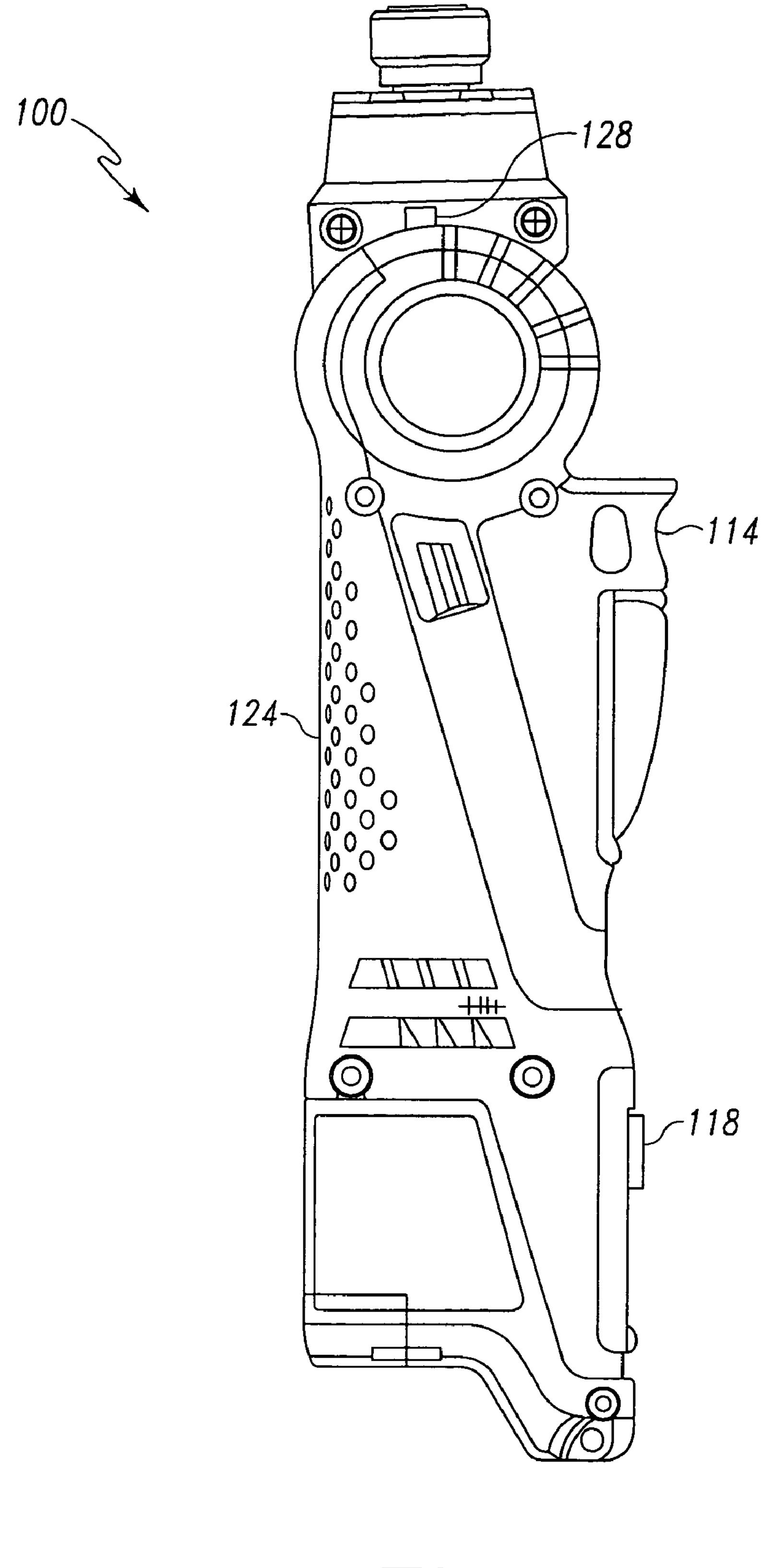

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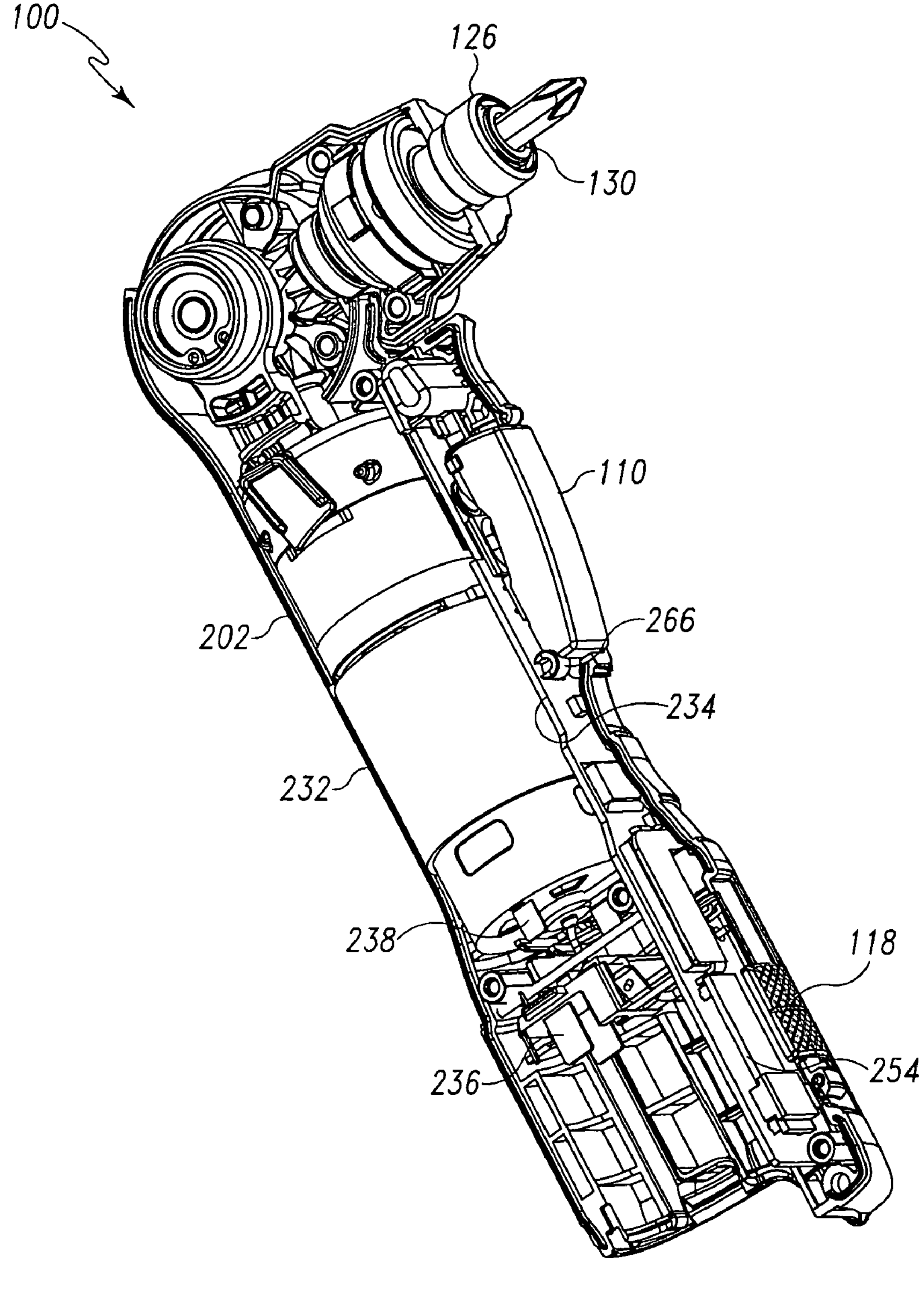

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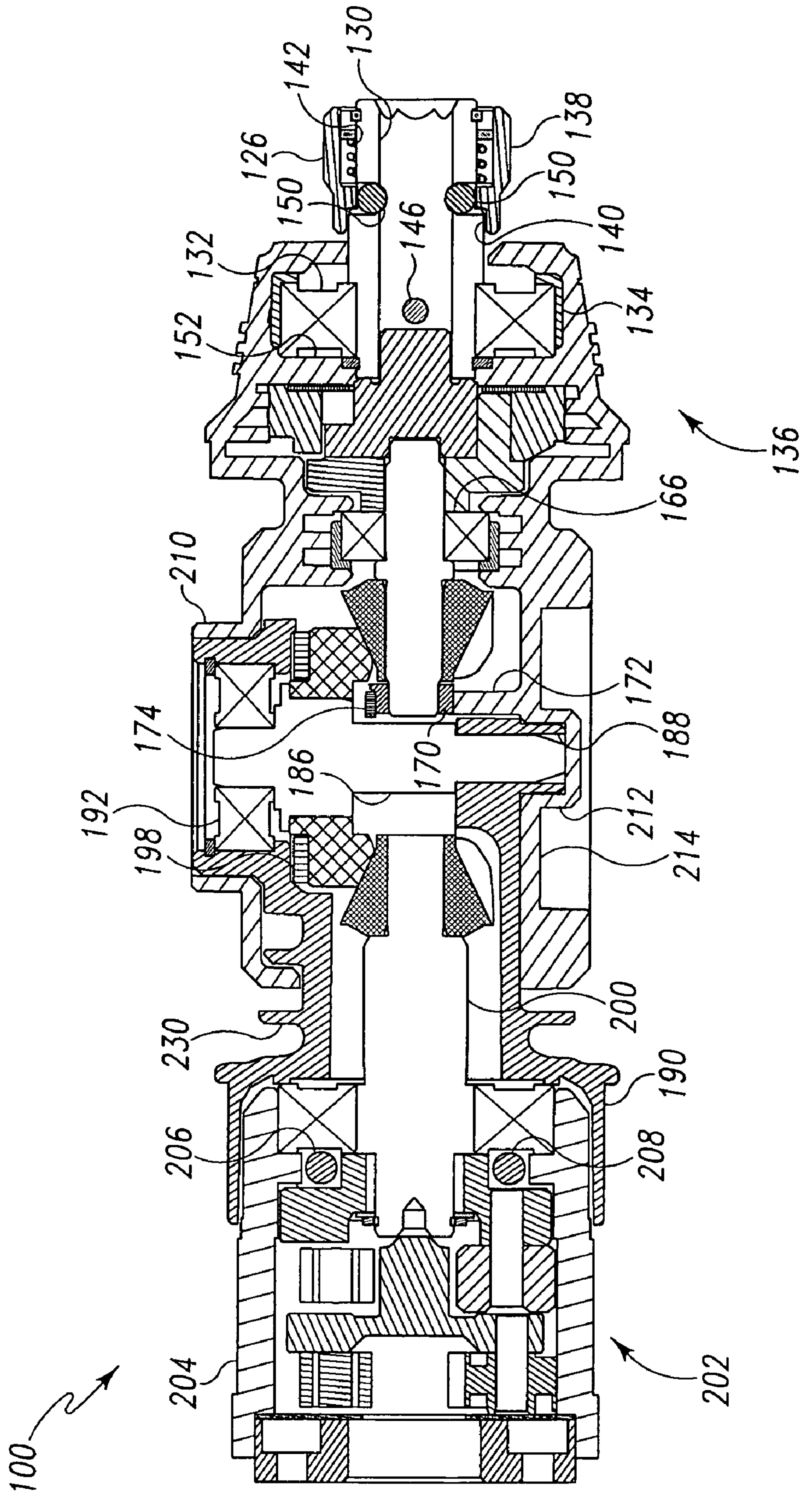
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Fig. 4

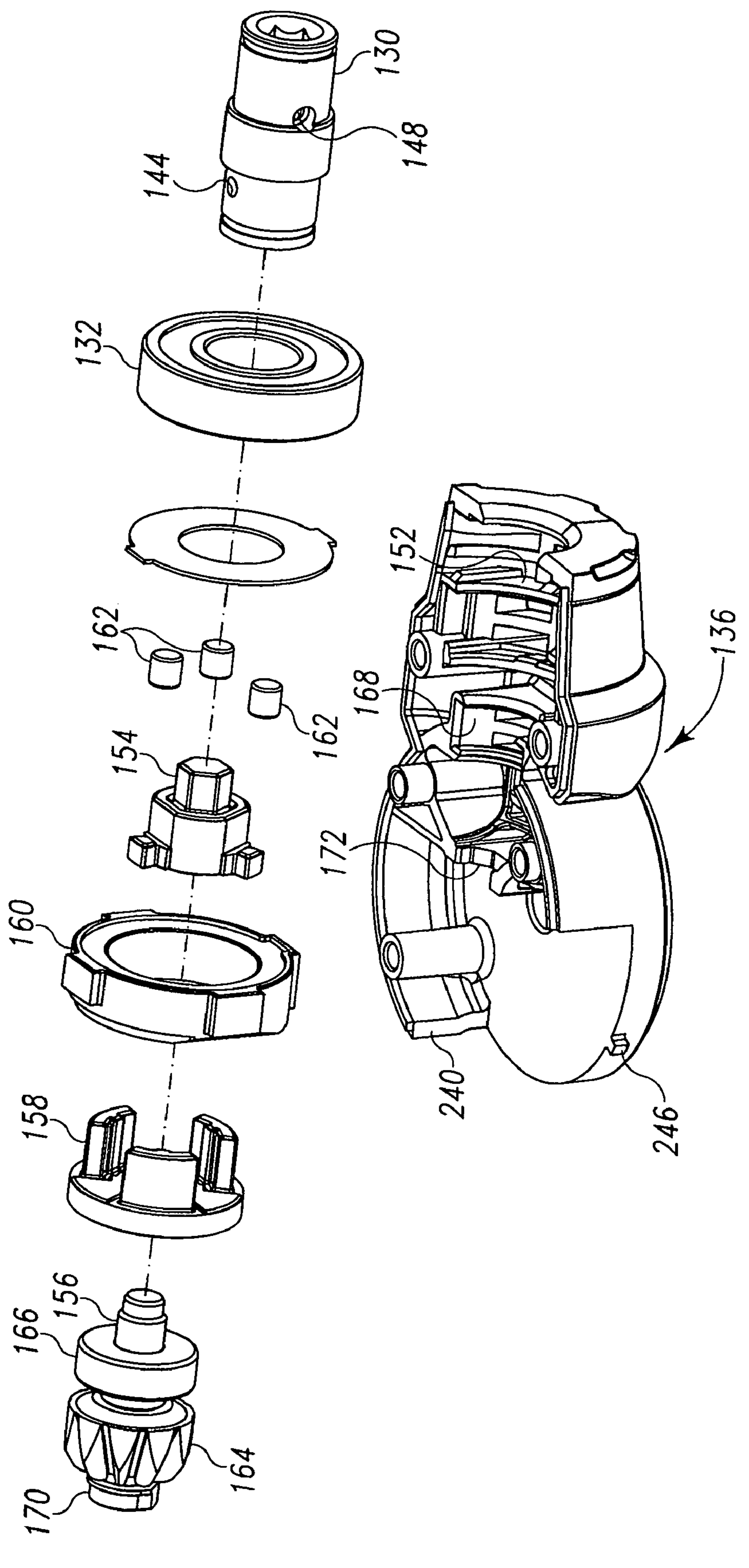
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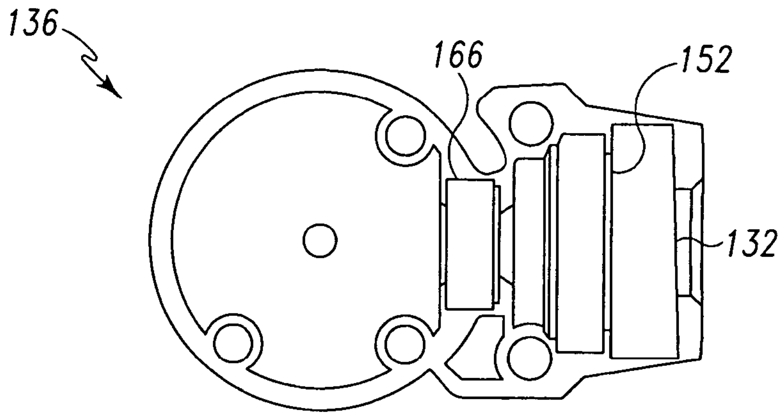
Fig. 5



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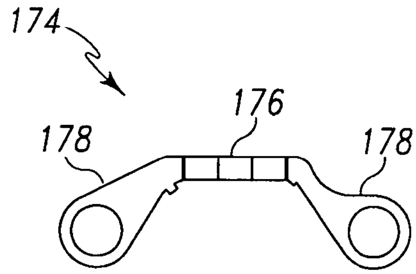

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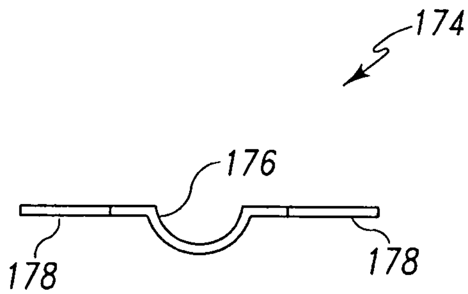

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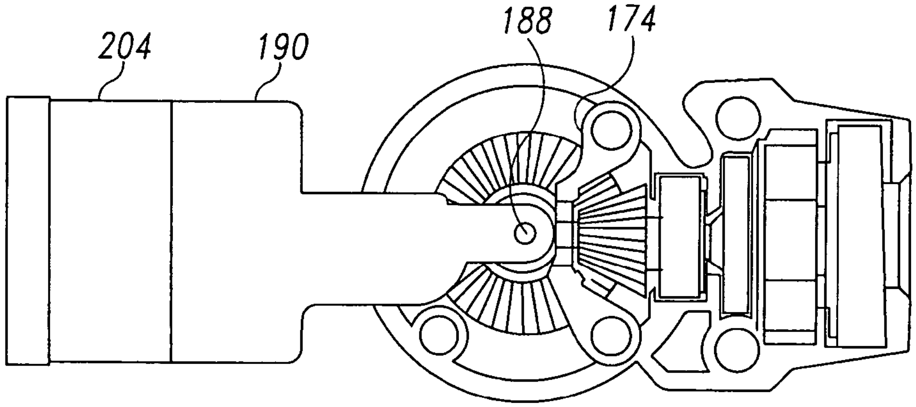

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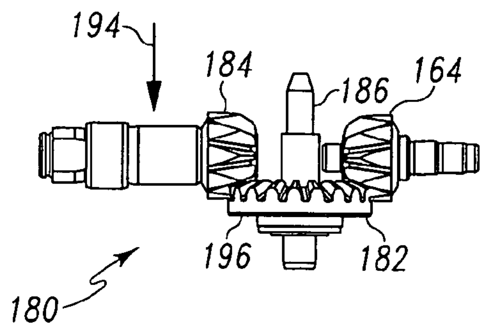

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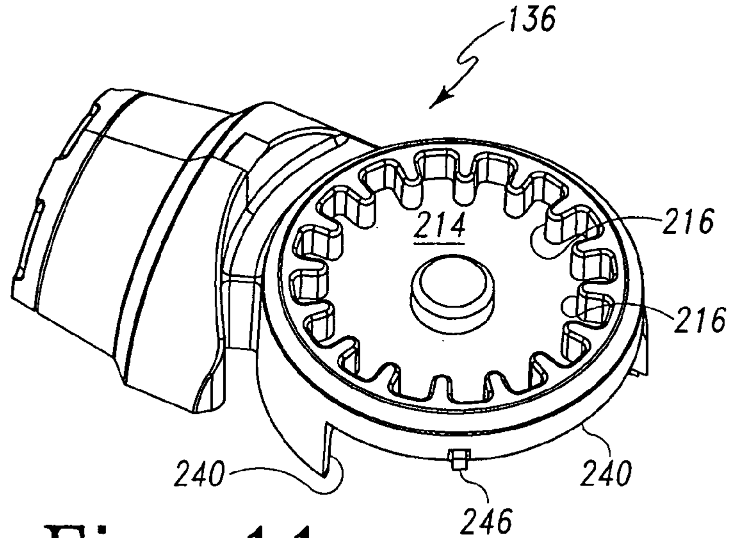

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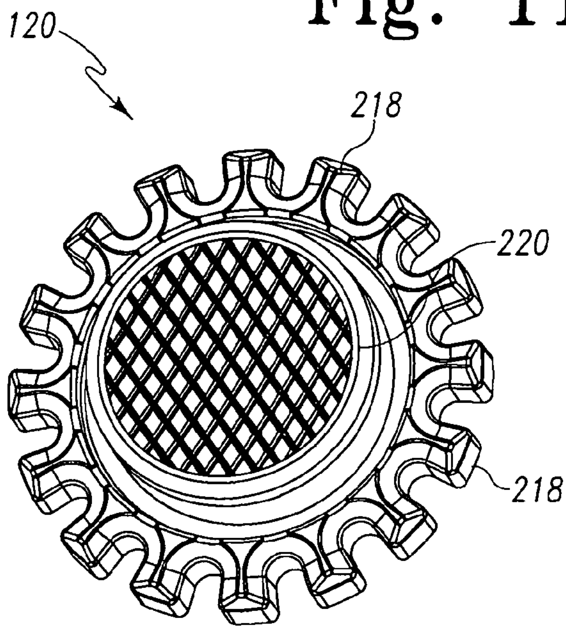

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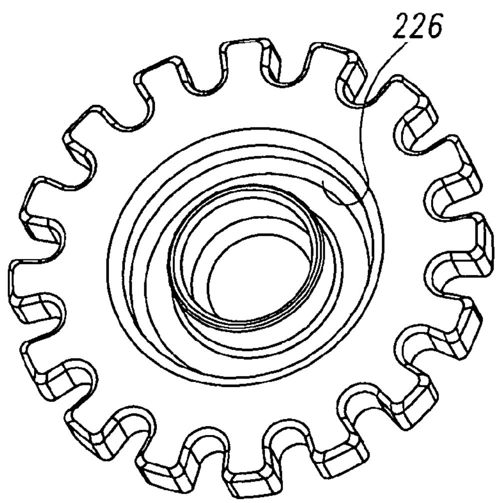

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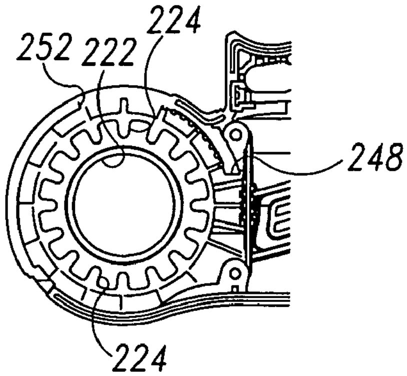

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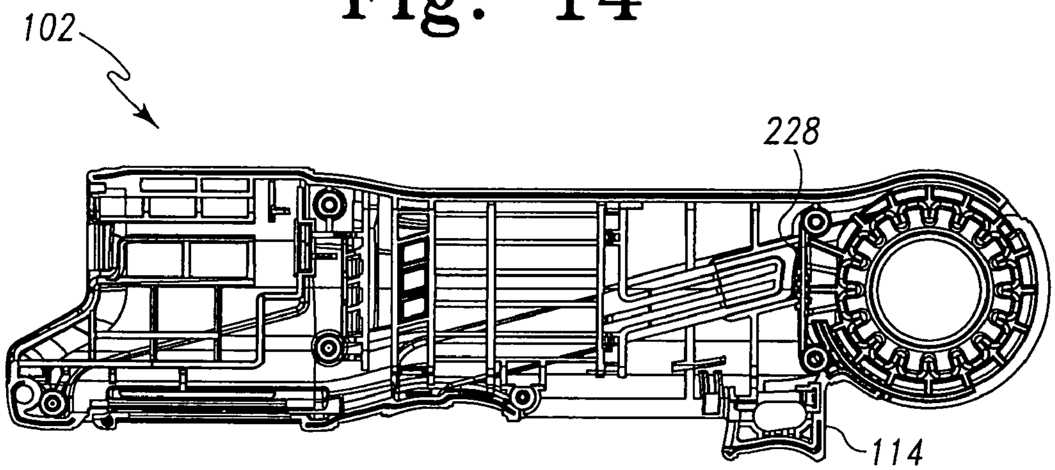

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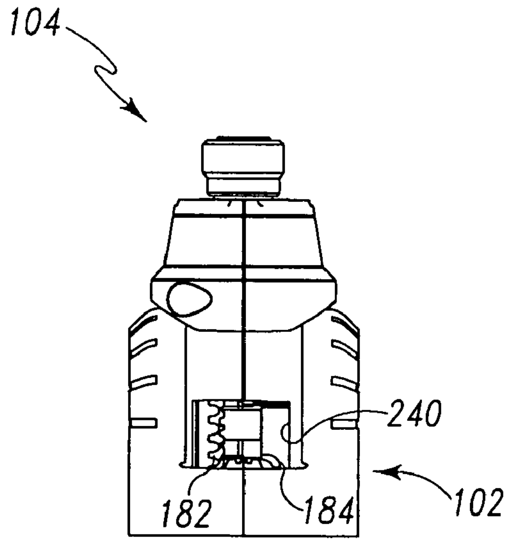

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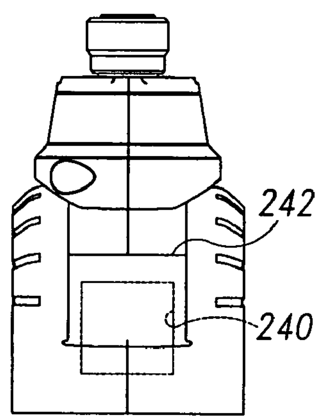
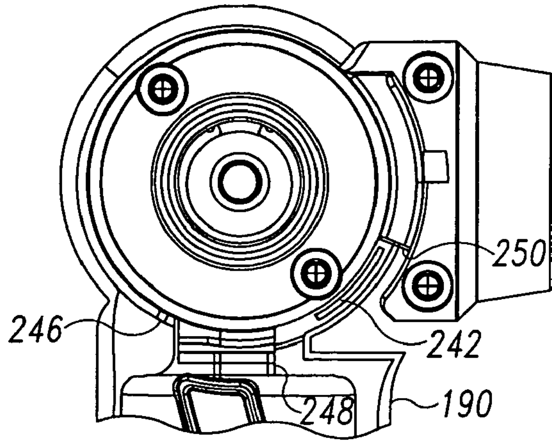


Fig. 17



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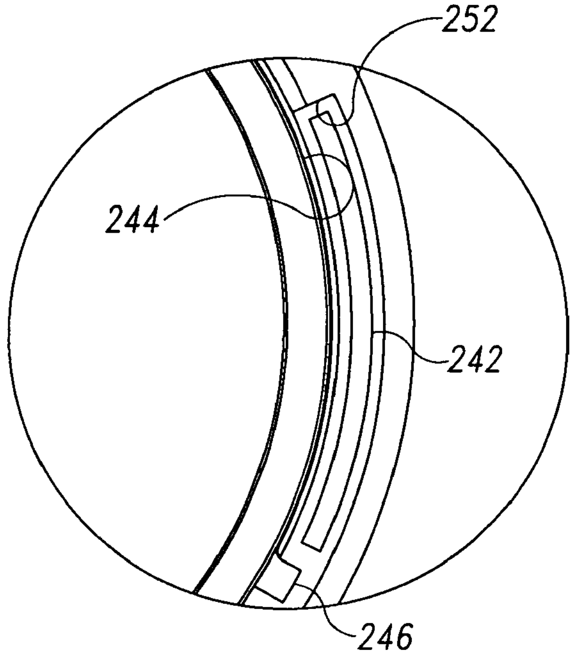
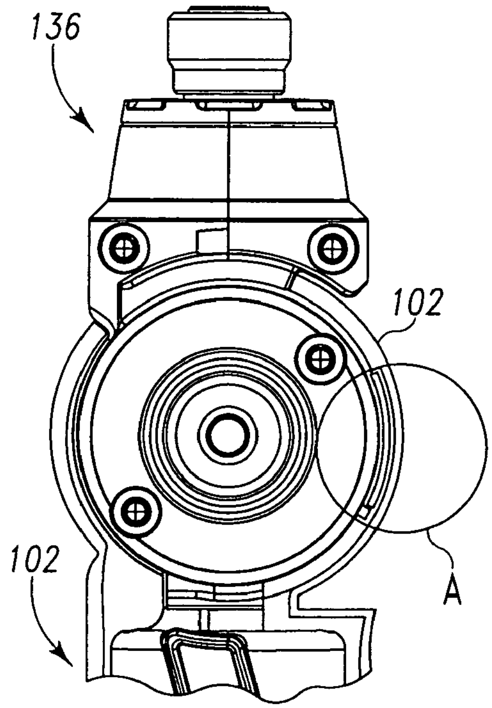


Fig. 20



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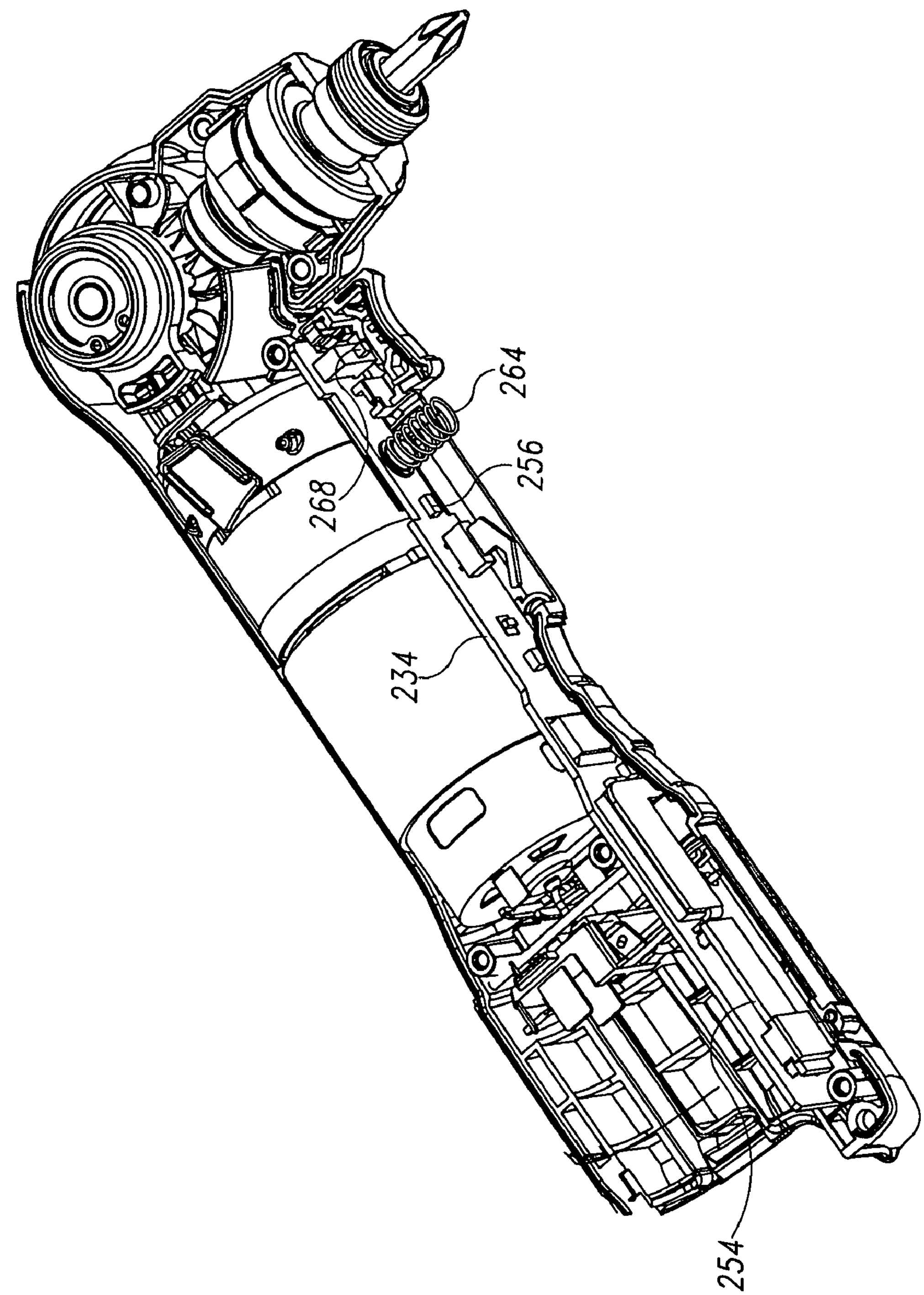

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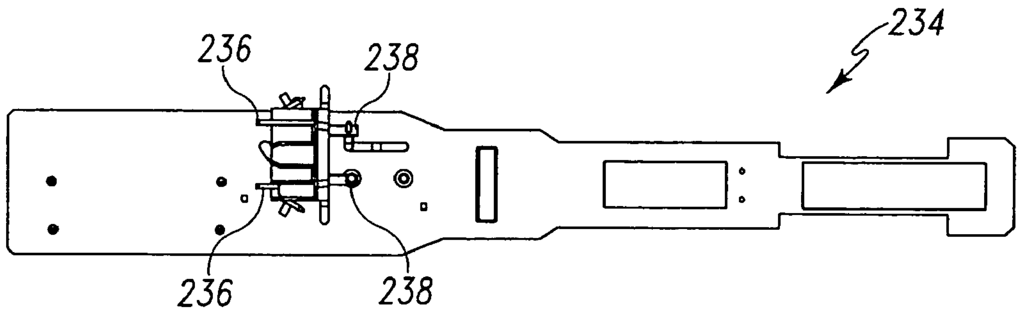

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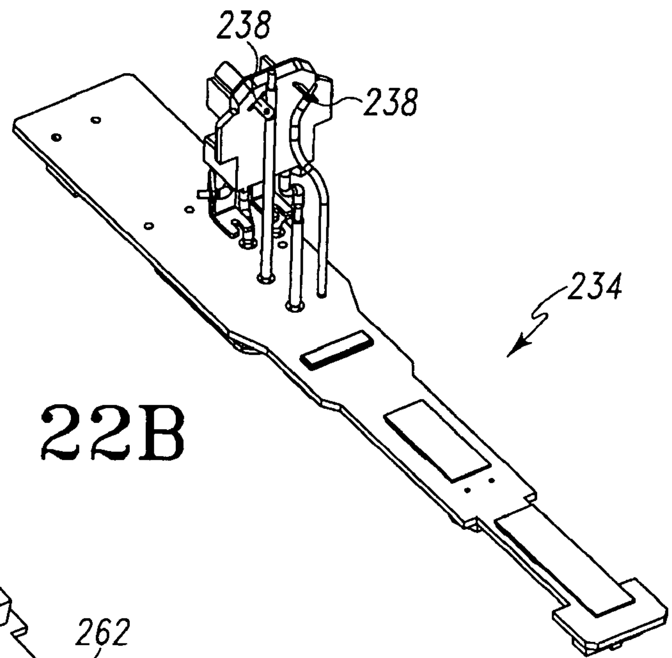

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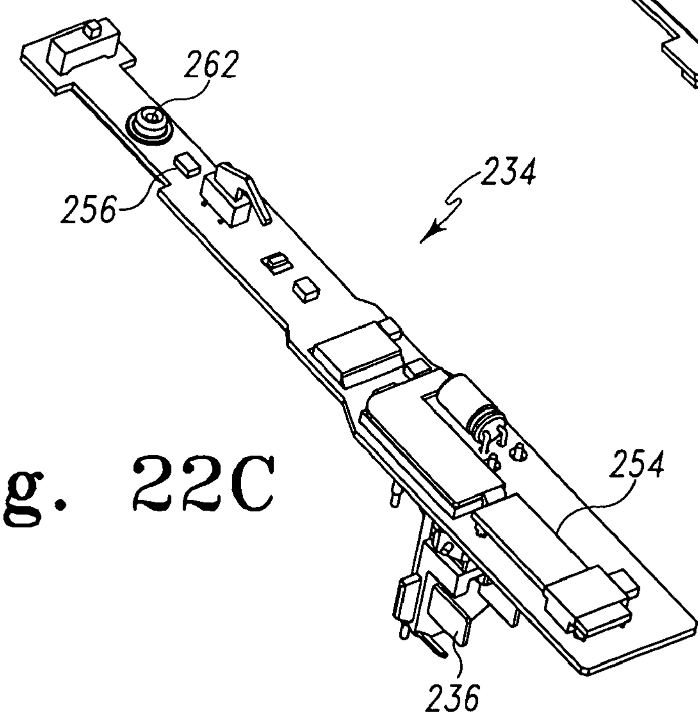

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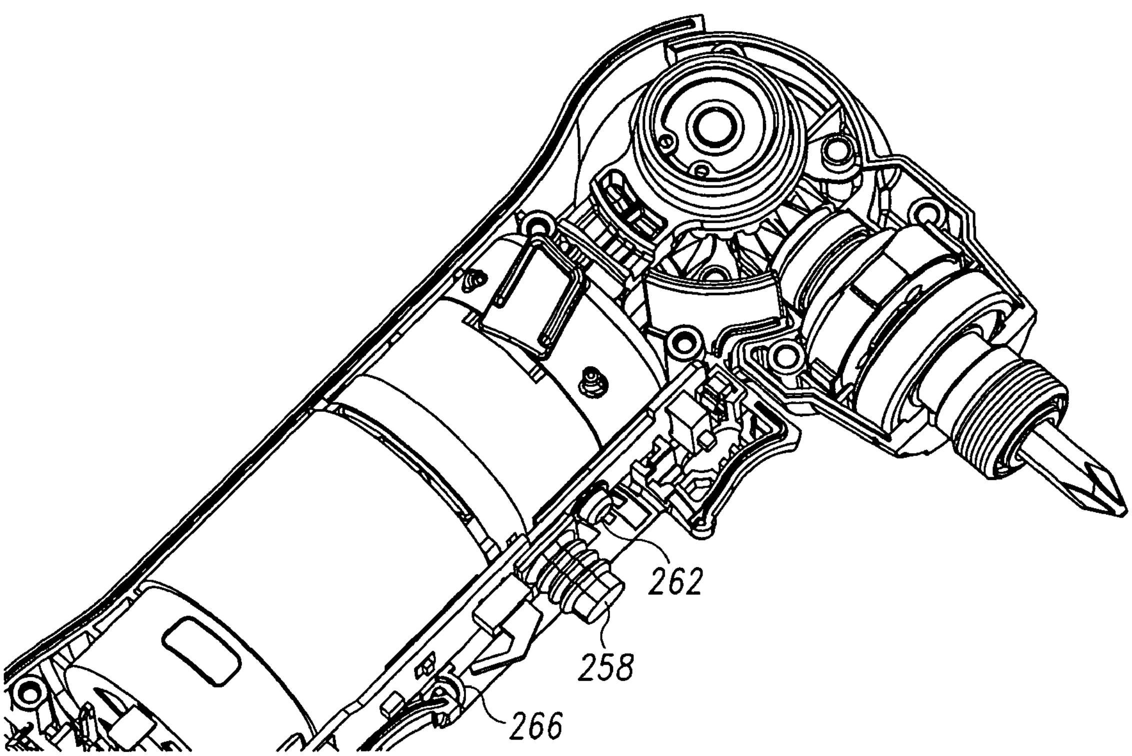

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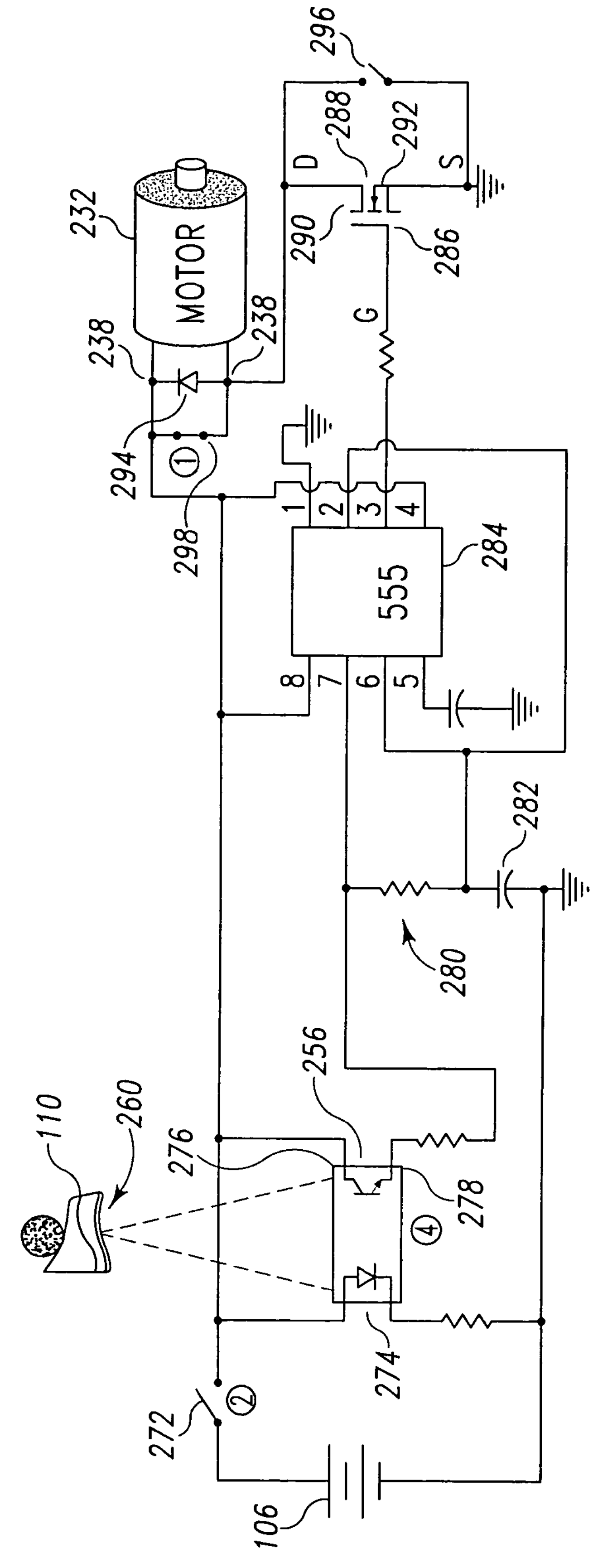
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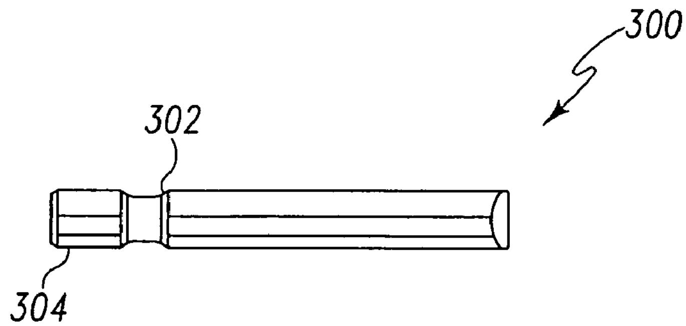
Fig. 24



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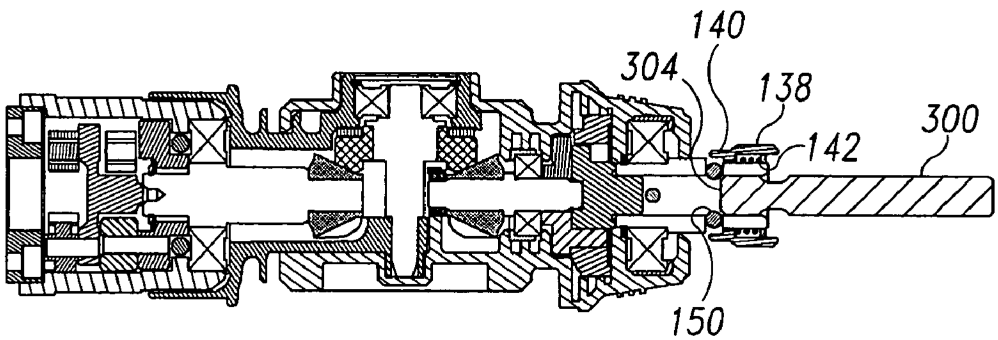

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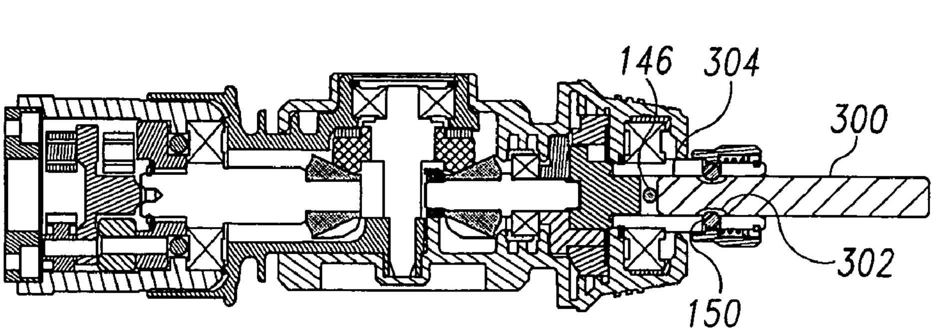

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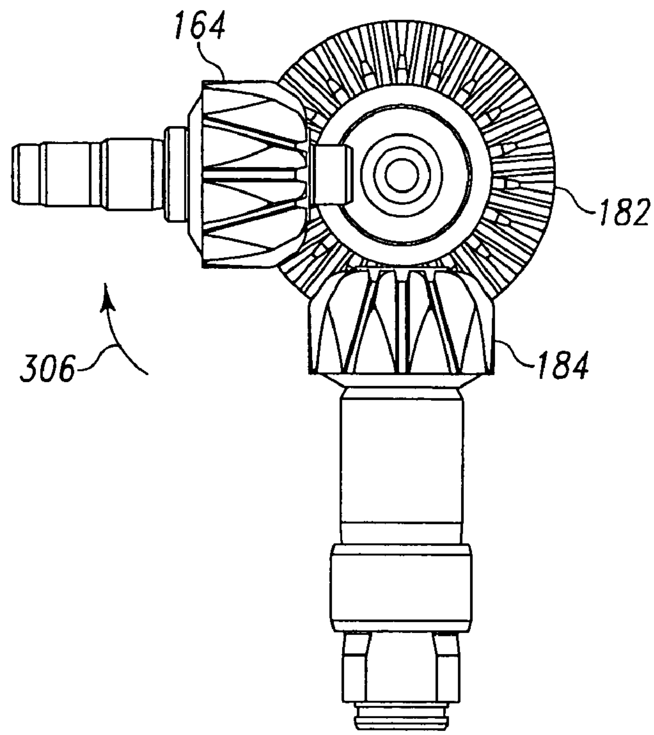

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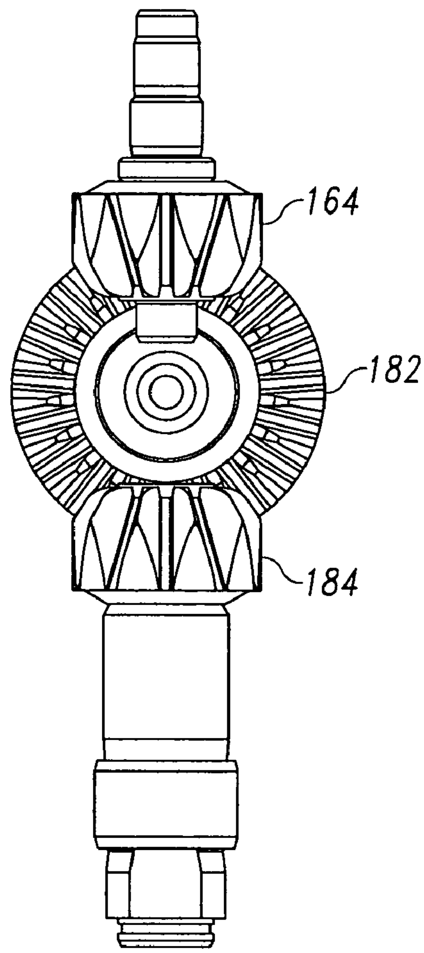

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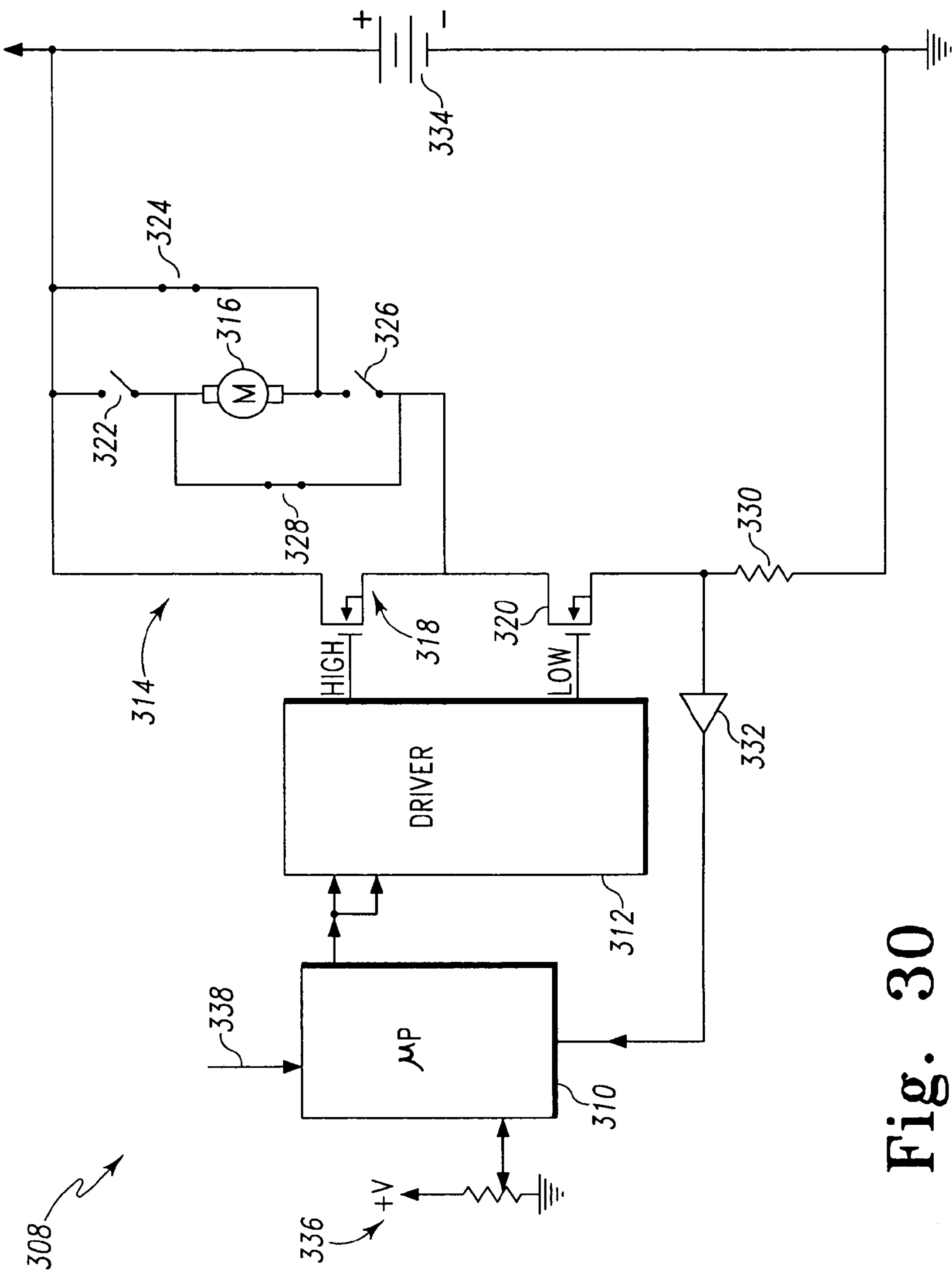

DRIVER
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LOW
μP
M
+V
+
-
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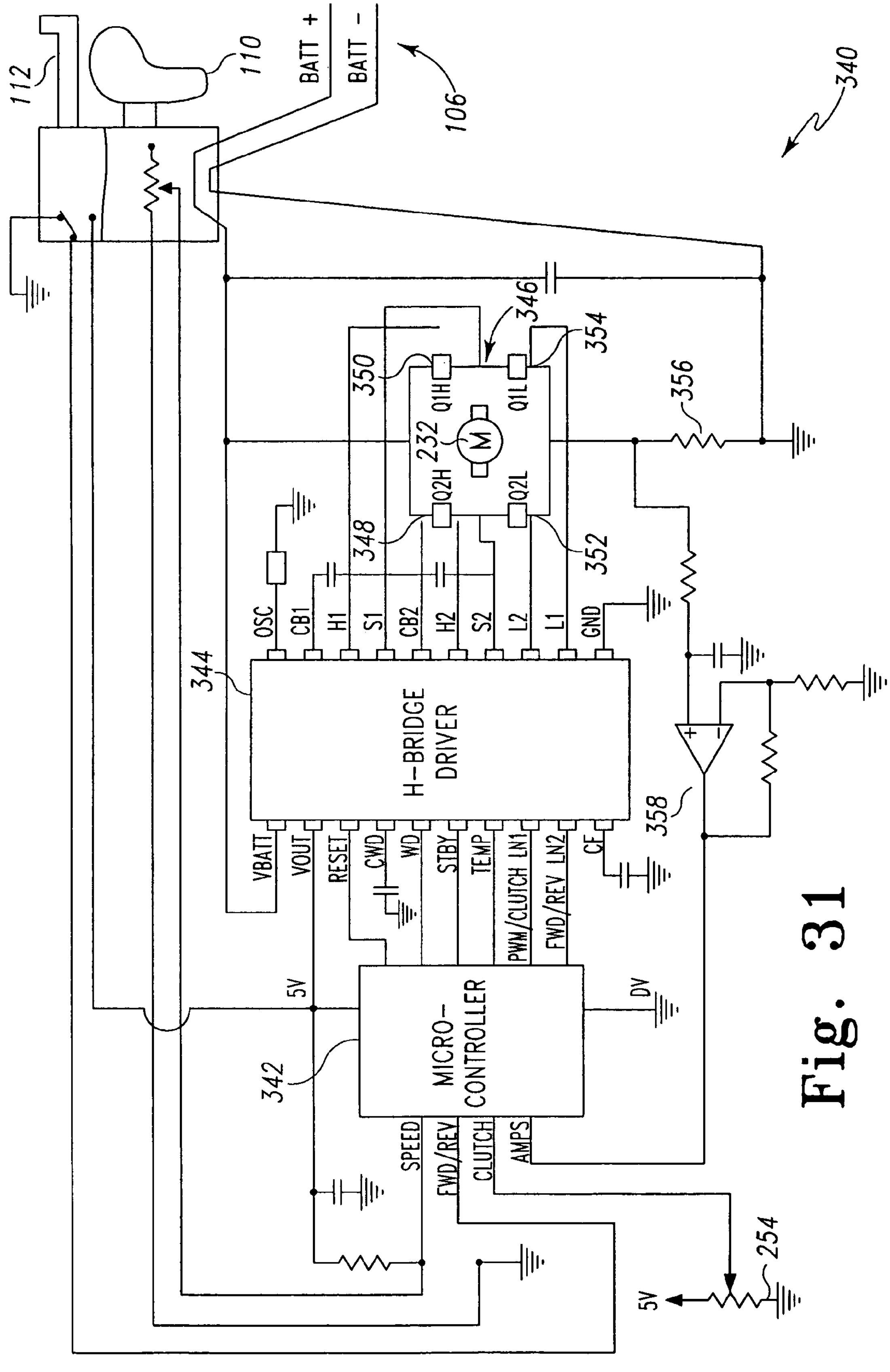
Fig. 30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M
Q2H
Q2L
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356
OSC
CB1
H1
S1
CB2
H2
S2
L2
L1
GND
344
H-BRIDGE
DRIVER
VBATT
VOUT
RESET
CWD
WD
STBY
TEMP
PWM/CLUTCH LN1
FWD/REV LN2
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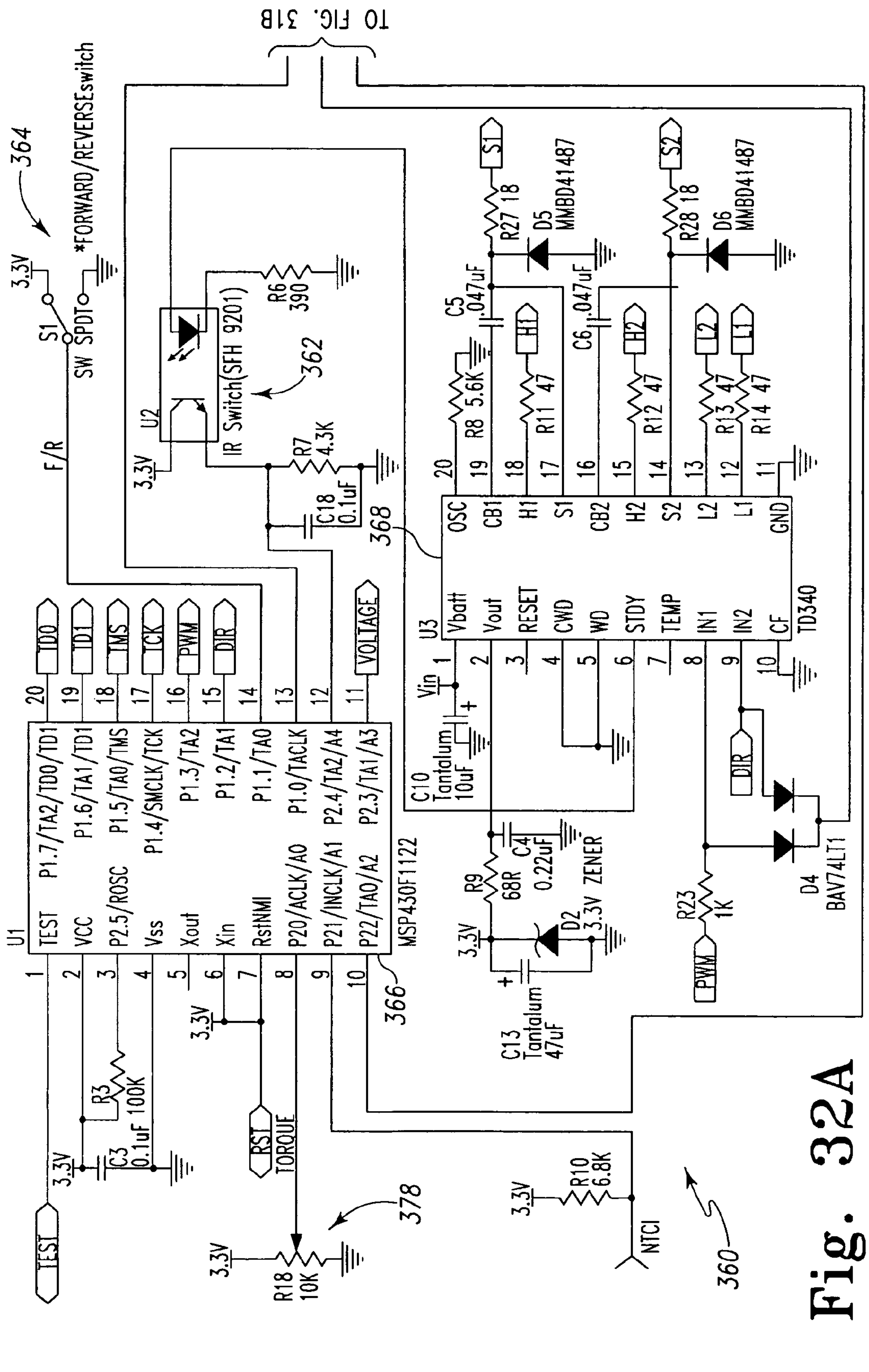
MICRO-
CONTROLLER
DV
SPEED
FWD/REV
CLUTCH
AMPS
254
5V

Fig. 31


TO FIG. 31B
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*FORWARD/REVERSEswitch
3.3V
S1
SW SPDT
F/R
U2
IR Switch(SFH 9201)
362
R6 390
R7 4.3K
C18 0.1uF
S1
R27 18
D5 MMBD41487
C5 .047uF
S2
R28 18
D6 MMBD41487
C6 .047uF
R8 5.6K
H1
R11 47
H2
R12 47
L2
R13 47
L1
R14 47
368
OSC
CB1
H1
S1
CB2
H2
S2
L2
L1
GND
U3
Vbatt
Vout
RESET
CWD
WD
STDY
TEMP
IN1
IN2
CF
TD340
Vin
C10 Tantalum 10uF
U1
TEST
VCC
P2.5/ROSC
Vss
Xout
Xin
RstNMI
P20/ACLK/A0
P21/INCLK/A1
P22/TA0/A2
MSP430F1122
P1.7/TA2/TD0/TD1
P1.6/TA1/TD1
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P2.4/TA2/A4
P2.3/TA1/A3
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TD1
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TCK
PWM
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C13 Tantalum 47uF
R23 1K
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R10 6.8K
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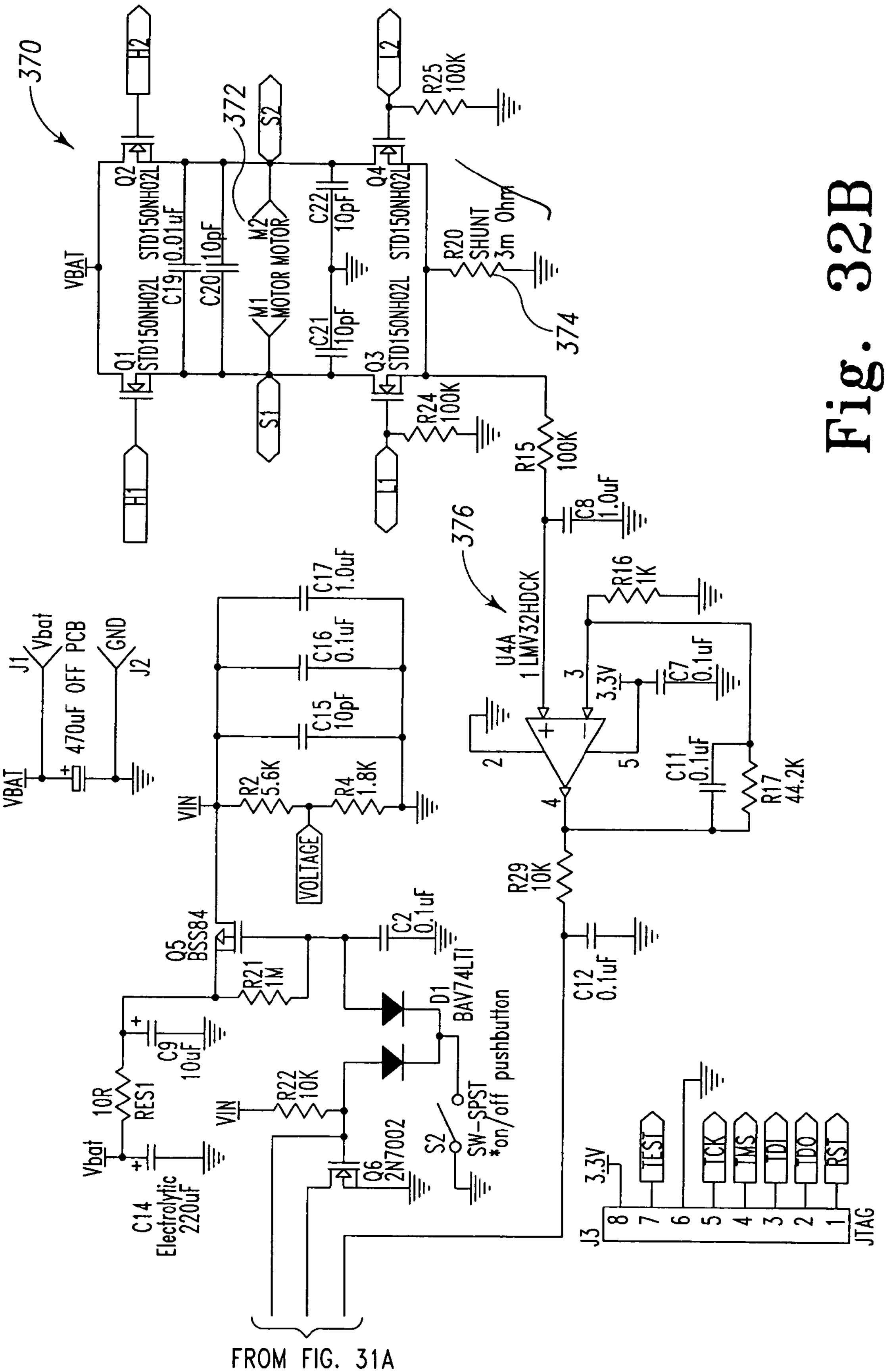
Fig. 32A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C22 10pF
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M2 MOTOR
R20 SHUNT 3m Ohm
R24 100K
R25 100K
R15 100K
C8 1.0uF
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R16 1K
3.3V
C7 0.1uF
C11 0.1uF
R17 44.2K
R29 10K
C12 0.1uF
J1 Vbat
470uF OFF PCB
J2 GND
VIN
C17 1.0uF
C16 0.1uF
C15 10pF
R2 5.6K
R4 1.8K
VOLTAGE
Q5 BSS84
R21 1M
C2 0.1uF
D1 BAV74LT1
C9 10uF
10R RES1
R22 10K
Vbat
C14 Electrolytic 220uF
Q6 2N7002
S2 SW-SPST *on/off pushbutton
TEST
TCK
TMS
TDI
TDO
RST
J3
JTAG
FROM FIG. 31A

Fig. 32B

METHOD AND APPARATUS FOR AN ARTICULATING DRILL

This application claims the benefit of provisional U.S. Patent Application No. 60/733,546, filed on Nov. 4, 2005. The disclosure of this provisional patent application is hereby totally incorporated by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates to an electric hand tool and more particularly to an articulating power hand tool.

BACKGROUND

Electric drills are usually constructed as straight-drilling machines in which the drill spindle extends parallel to the motor shaft and axis of the housing and, for specific purposes, as angular-drilling machines in which the drill spindle is aligned at a right angle to the motor shaft and housing axis. In certain applications in which both straight and angular drilling must be carried out, as is the case in installations in wooden house construction, the two machines must be at hand for continuous alternation.

The use of a tool receptacle head serving as special accessory for a conventional drill to eliminate the need for two drills is known. By way of example, DE 36 34 734 A1 discloses a drill that includes two separate housing parts which are located opposite one another to define a hollow space and which are guided along a diagonally extending dividing plane. One housing part carries a support for a drive shaft and the other housing part carries a support for a power take-off shaft which projects out of the tool receptacle head and carries a drill chuck. The drive shaft and power take-off shaft are connected with one another by a double cardan or universal joint so as to be rigid with respect to torsion relative to one another. One hollow-cylindrical housing part of the tool receptacle head is placed on the spindle neck of the drill and the drill spindle of the drill is coupled with a driver by means of a double edge. The driver sits on the drive shaft so as to be fixed with respect to rotation relative to it. In the basic position of the two housing parts, the axes of the drive and power take-off shafts are flush with one another. Due to the relative rotation of the two housing parts, the power take-off shaft can be aligned in such a way that its axis encloses an acute or right angle with the axis of the drive shaft.

A standard drill can be re-tooled with this known tool receptacle head so as to form an angle drill which can also perform straight drilling. While such a separate tool receptacle head serving as attachment may be suited to the requirements of some hobbyists, it is not acceptable for professional machines.

U.S. Pat. No. 5,533,581 discloses a drill suitable for professional use that includes a drill with a housing, an electric motor which is received in the housing, a motor shaft parallel to the housing axis, and a work spindle which is driven by the electric motor via a transmission gearing. The housing is divided along a dividing plane for the purpose of switching from straight drilling to angular drilling and it is provided that the front housing part containing a bearing for the work spindle and the rear housing part containing the electric motor can swivel relative to one another in such a way that the work spindle projecting out of the front housing part can occupy any angle between 0 degrees and 90 degrees or more relative to the motor shaft. A catch lock which can be unlocked and/or locked manually stops the two housing parts in the selected swivel position. A torsionally rigid transmission of force from the motor shaft to the work spindle is realized in every swivel position of the housing parts in the transmission gearing.

While the prior art drills are useful, they have various limitations. For example, drills are frequently exposed to impacts, both intentional and accidental, on the bits which are held by the drills. The prior art drills generally transmit these impact forces through the gearing mechanisms which allow for the relative positioning of the work spindle with respect to the motor shaft. Accordingly, the gears must be designed to absorb the impact forces. Such gears may increase the weight of the drill and increase the size of the forward section of the drill. Increased weight increases the fatigue experienced by a user, particularly users who use the tool infrequently. Moreover, the additional bulk of the drill reduces the usefulness of the tool in confined areas.

Additionally, the locking mechanisms used to restrict articulation in prior articulating drill systems may be difficult to use or susceptible to accidental activation. Furthermore, in certain known devices the articulating gear mechanism is exposed allowing contaminants into the mechanism as well as presenting a safety concern as clothing or appendages may be caught by revolving gears.

What is needed is an articulating power hand tool which protects internal components from damage resulting from axial impact. It would be beneficial to further protect the internal components from contamination and reduce the potential for external items becoming entrapped by the internal components.

What is further needed is an articulating power hand tool with a reduced forward section and a compact articulating system to allow for use of the tool in confined areas.

What is also needed is an articulating power hand tool having a latch mechanism exhibiting increased strength and which further reduces the potential of accidental manipulation.

SUMMARY

The present invention is an articulating hand power tool. In one embodiment, the tool includes a head portion including a head housing, a bit holder rotatably positioned within the head housing, and a bearing member operable to transfer a first axial force from the bit holder to the head housing. A frame is rotatably connected to the head portion for placement in a plurality of positions with respect to the head portion and operably connected to the head housing for receiving the first axial force transferred to the head housing. The tool further includes an articulating gear system for transferring rotational force generated by a motor to the bit holder at each of the plurality of positions.

One method of transferring axial forces in an articulating power tool in accordance with the invention includes transferring an axial force from a bit holder rotatably positioned within a head housing of a tool to a bearing member, transferring the axial force from the bearing member to the head housing, and transferring the axial force from the head housing to a main housing, wherein the head housing is rotatable with respect to the main housing.

These and other advantages and features of the present invention may be discerned from reviewing the accompanying drawings and the detailed description of the preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention may take form in various system and method components and arrangement of system and method components. The drawings are only for purposes of illustrating exemplary embodiments and are not to be construed as limiting the invention.

FIG. **1** shows a perspective view of an articulating drill incorporating features of the present invention;

FIG. **2** shows a side elevational view of the articulating drill of FIG. **1** with the rechargeable battery pack removed;

FIG. **3** shows a perspective view of the articulating drill of FIG. **1** with the battery pack, a portion of the main housing cover, and a portion of the head housing removed and a bit in the bit holder;

FIG. **4** shows a cross-sectional view of the head portion, the articulating gear system and the planetary gear system of the articulating drill of FIG. **1**;

FIG. **5** shows an exploded perspective view of the head portion, including an automatic spindle lock system, of the articulating drill of FIG. **1**;

FIG. **6** shows a top plan view of the head portion of the drill of FIG. **1** with some components located within bays in the head housing;

FIG. **7** shows a top plan view of a bracket used to support an output pinion shaft in the articulating drill of FIG. **1**;

FIG. **8** shows a side plan view of the bracket of FIG. **7**;

FIG. **9** shows a top elevational view of the planetary gear section, articulating section and head portion of the articulating drill of FIG. **1** with the main housing and a portion of the head housing removed;

FIG. **10** shows a side elevational view of the articulating gear system of the articulating drill of FIG. **1** including a bevel gear and two pinion gears;

FIG. **11** is a perspective view of a portion of the head housing of the drill of FIG. **1** with a plurality of teeth in a well which are formed complimentary to teeth on the articulation button;

FIG. **12** shows a perspective view of the articulating button of the articulating drill of FIG. **1**;

FIG. **13** shows a perspective view of the bottom of the articulating button of FIG. **12**;

FIG. **14** shows a partial top elevational view of the inner surface of the outer housing of the articulating drill of FIG. **1** with teeth formed complimentary to the teeth on the articulation button and a hole for receiving a raised portion of the articulating button;

FIG. **15** shows a top elevational view of the inner surface of the outer housing of the articulating drill of FIG. **1**;

FIG. **16** shows a partial plan view of the articulating drill of FIG. **1** with the head portion aligned with the main housing portion and without a dust lid;

FIG. **17** shows a partial plan view of the articulating drill of FIG. **1** with the head portion aligned with the main housing portion with a dust lid;

FIG. **18** shows a side elevational view of the articulating drill of FIG. **18** with the head portion rotated to an angle of 90 degrees from the main housing portion of the drill and a portion of the main housing portion removed to show the position of the dust lid of FIG. **17**;

FIG. **19** shows a side elevational view of the articulating drill of FIG. **18** with the head portion rotated to an angle of 180 degrees from the main housing portion of the drill and a portion of the main housing portion removed to show the position of the dust lid of FIG. **17**;

FIG. **20** shows a detail view of the dust lid of FIG. **19**;

FIG. **21** shows a perspective view of the articulating drill of FIG. **1** with the variable speed trigger switch, clutch control and a portion of the main housing removed;

FIGS. **22***a*, **22***b* and **22***c* show various views of a printed circuit board of the articulating drill of FIG. **1** in accordance with principles of the invention;

FIG. **23** shows a perspective view of the articulating drill of FIG. **21** with a collapsible boot with an internal reflective surface installed over a light generator and a light sensor;

FIG. **24** shows a schematic/block diagram of the drill of FIG. **1** incorporating an optical switch for motor speed control;

FIG. **25** shows a side elevational view of a drill bit in the form of a screw driver bit that may be used with the articulating drill of FIG. **1**;

FIG. **26** shows a cross-sectional view of the drill bit of FIG. **25** being inserted into the articulating drill of FIG. **1**;

FIG. **27** shows a cross-sectional view of the drill bit of FIG. **25** inserted into the articulating drill of FIG. **1**;

FIG. **28** shows a partial top elevational view of a bevel gear in accordance with principles of the invention with two pinion gears at a 90 degree spacing;

FIG. **29** shows a partial top elevational view of the bevel gear of FIG. **28** with the two pinion gears at a 180 degree spacing;

FIG. **30** shows an electrical diagram/schematic of a powered tool that dynamically brakes the tool motor using a motor interface circuit having a half bridge to provide vibratory feedback to the operator that the torque limit has been reached;

FIG. **31** shows an electrical diagram/schematic of a circuit that may be used with the drill of FIG. **1** which dynamically brakes the drill motor using a motor interface circuit having a full H-bridge circuit to provide vibratory feedback to the operator that the torque limit has been reached; and

FIGS. **32**A and **32**B show an electrical diagram/schematic of a powered tool that provides solid state motor speed control in correspondence with a variable speed signal from an optical switch and that dynamically brakes the motor to indicate a torque limit has been reached.

DESCRIPTION

An articulating drill generally designated **100** is shown in FIG. **1**. In the embodiment of FIG. **1**, the drill **100** includes a main housing portion **102** and a head portion **104**. The main housing portion **102** houses a motor and associated electronics for control of the drill **100**. The main housing portion **102** includes a battery receptacle for receiving a rechargeable battery pack **106** as is known in the art. In one embodiment, the rechargeable battery pack **106** comprises a lithium-ion battery. The battery pack **106** is removed by depression of the battery release tabs **108**. FIG. **2** shows the drill **100** with the battery pack **106** removed. The drill **100** may alternatively be powered by an external power source such as an external battery or a power cord.

A variable speed trigger switch **110** controls the speed at which the motor rotates. The direction of rotation of the motor is controlled by a reversing button **112** which slides within a finger platform **114**. Ventilation openings **116** allow for cooling air to be circulated around the motor inside of the main housing **102**. A clutch control **118** sets the maximum torque that may be generated when using the drill **100**. At the position shown in FIG. **1**, the clutch control **118** is at the highest setting or drill mode. At the highest setting, the clutch is disabled to provide maximum torque. By sliding the clutch control **118** downwardly from the position shown in FIG. **1**, a user may set a desired torque limit that is allowed to be generated by the drill **100** as discussed in more detail below.

Accordingly, at settings other than the highest setting, a torque above the setting of the clutch control **118** causes the clutch to activate.

The main housing portion **102** also includes an articulation button **120** and a plurality of angle reference indicators **122** molded onto the outer surface **124** of the main housing **102**. In the embodiment of FIG. **1**, there are five angle reference indicators **122** used to identify five angular positions in which the head portion **104** may be placed.

The head portion **104** includes a collet locking device **126** and an angle indicator **128**. The angle at which the head portion **104** is positioned is indicated by the angle reference indicator **122** with which the angle indicator **128** is aligned. As shown in FIG. **1**, the head portion **104** is at a 90 degree angle with respect to the main housing portion **102**. In FIG. **2**, the head portion **104** is axially aligned with the main housing portion **102**. Although the embodiment of FIGS. **1** and **2** has five angle reference indicators **122**, there may be additional or fewer angle reference indicators **122** and corresponding angles at which the head portion **104** may be placed with respect to the main housing portion **102**.

Referring now to FIGS. **3-6**, the collet locking device **126** is located around a bit holder **130** which is in turn supported by a ball bearing **132** that is fixed within a bearing pocket **134** of the head housing **136**. The collet locking device **126** includes a sleeve **138** with recesses **140**. A spring **142** is positioned about the bit holder **130**. The bit holder **130** includes a hole **144** which receives a cylinder pin **146** and recesses **148** which receive steel balls **150**.

The bearing **132** abuts the head housing **136** of the head portion **104** at the outer rear periphery of the bearing **132**. More specifically, the bearing **132** abuts a flange **152**. In this embodiment, the flange **152** is continuous about the housing **136**, although a flange may alternatively be in the form of a plurality of fins located about the inner portion of the housing **136**.

The bit holder **130** is operably coupled to a drive collet **154** which is in turn connected to an output pinion shaft **156** through a drive plate **158** which is fixedly attached to the output pinion shaft **156**. A lock ring **160** surrounds the drive collet **154** and three locking pins **162**. The lock ring **160**, the drive collet **154**, the drive plate **158**, and the locking pins **162** all comprise an automatic spindle lock system such that the output bit holder **130** can only be driven from the pinion side as known in the art. When driven from the bit side, i.e., when the tool **100** is used as a manual screwdriver, the spindle lock system keeps the output pinion shaft **156** from rotating thus facilitating use of the tool **100** as a manual screwdriver. In an alternative embodiment, a manually manipulated locking device may be used.

A pinion gear **164** is located at the opposite end of the output pinion shaft **156** from the drive plate **158**. One end of the output pinion shaft **156** is maintained in axial alignment by a bearing **166** which fits within bearing pocket **168**. The opposite end of the output pinion shaft **156** is supported by a sleeve **170**. The sleeve **170** is supported on one side by a flange **172** on the head housing **136**. On the opposite side, the sleeve **170** is supported by a bracket **174** also shown in FIGS. **7** and **8**.

The bracket **174** includes a support area **176** configured complimentary to a portion of the sleeve **170**. Two connection arms **178** are configured to be attached to the head housing **136** as shown in FIG. **9**. The bracket **174** eliminates the need to provide a matching flange for flange **172** molded into the opposite side of the head housing **136**. The elimination of the need for an opposing flange allows for a significant increase in design freedom as the space requirements for the support structure for the sleeve **170** are reduced. The bracket **174** may be stamped from W108 steel to provide the needed rigidity and strength.

Referring now to FIG. **10**, the pinion gear **164** forms a portion of an articulating gear system **180**. The articulating gear system **180** further includes a bevel gear **182** which is engaged at the output portion of the articulating gear system **180** with the pinion gear **164** and further engaged on the motor portion by pinion gear **184**. The shaft **186** of the bevel gear **182** is supported at one end within a hole **188** (see FIG. **4**) of the frame **190**. The frame **190** is made from a zinc and aluminum alloy ZA-8. This material provides a sufficiently low coefficient of friction to ensure relatively small frictional forces exist between the shaft **186** and the frame **190**.

The shaft **186** is radially and axially supported at the opposite end by a ball bearing **192** supported by the frame **190**. At this end of the shaft **186**, however, comparatively larger forces are generated than at the end of the shaft **186** inserted within the hole **188**. More specifically, as shown in FIG. **10**, both pinion gear **164** and pinion gear **184** are located on the same side of the bevel gear **182**. Accordingly, as the articulating gear system **180** rotates, a force is generated on the bevel gear **182** in the direction of the arrow **194** toward the base **196** of the bevel gear **182**. This force acts to disengage the bevel gear **182** from the pinion gear **164** and the pinion gear **184**. With this increased force acting upon the bevel gear **182**, an unacceptable amount of axial force would be transmitted to the bearing **192**. Accordingly, a thrust bearing **198** is provided to protect the ball bearing **192** and to provide a low friction support for the base **196** of the bevel gear **182**. The thrust bearing **198** is made of a material with an acceptably low coefficient of friction such as oil impregnated bronze commercially available from McMaster Carr of Chicago, Ill. Accordingly, the friction generated at the base **196** of the bevel gear **182** is maintained within acceptable levels.

Referring again to FIG. **4**, the pinion gear **184** is fixedly attached to a planetary gearbox shaft **200** which receives torque from a planetary gear system generally indicated as reference numeral **202**. The planetary gear system **202** receives torque from a motor as is known in the art. The planetary gear system **202** is located within a planetary gear housing **204** which is inserted partially within the frame **190**. This arrangement allows for the planetary gear system **202** to be separately manufactured from the other components while simplifying assembly of the planetary gear system **202** with the other components. This modularity further allows for alternative gearings to be provided in the planetary gear system **202** while ensuring a proper fit with the other components.

Generally, it may be desired to provide a simple friction fit between the planetary gear housing **204** and the frame **190**. In the embodiment of FIG. **4**, however, the articulating gear system **180** generates an axial force along the planetary gearbox shaft **200**. This axial force acts to disengage the planetary gear housing **204** from the frame **190**. Accordingly, pins **206** and **208** which extend through both the planetary gear housing **204** and the frame **190** are provided. The pins **206** and **208** ensure the planetary gear housing **204** does not become detached from the frame **190** during operation of the drill **100**. Alternatively, the planetary gear housing **204** and the frame **190** may be formed as an integral unit.

Continuing with FIG. **4**, the frame **190** is configured to slidingly mate with the head housing **136**. To this end, the head housing **136** includes a shroud portion **210** which is complimentarily formed to the frame **190** about the ball bearing **192**. The head housing **136** further includes a recess **212** which is configured to receive the portion of the frame **190** which defines the hole **188**. Also shown in FIG. **4** is a well **214** which includes a plurality of teeth **216** shown in FIG. **11**.

With further reference to FIGS. **12-14**, the well teeth **216** are formed complimentary to a plurality of teeth **218** which are formed in the articulation button **120**. The articulation button **120** includes a raised center portion **220** which is configured to fit within a hole **222** in the main housing portion **102**. The teeth **218** of the articulation button **120** are further configured to mesh with a plurality of teeth **224** formed on the inner side of the main housing portion **102** around the hole **222**. The articulation button **120** also includes a spring receiving well **226** on the side of the articulation button **120** facing the well **214**. When assembled, a spring (not shown) is located within the well **214** and extends into the spring receiving well **226** forcing the raised center portion **220** of the articulation button **120** toward a position wherein the articulation button **120** projects into the hole **222**.

Referring to FIGS. **4** and **15**, the frame **190** is supported axially in the main housing portion **102**, which in this embodiment is made of plastic, by a rib **228**. The rib **228** lies beneath a fin **230** of the frame **190** when the frame **190** is installed in the main housing portion **102** as shown in FIG. **3**. The planetary gear system **202** is mechanically secured to a motor **232** which is itself electrically connected to a printed circuit board **234** which in turn is electrically connected to a battery contact holder **236**. The contact holder **236** mates with battery pack receptacles on the battery pack **106** and transmits battery power to the electronic circuit board **234** through lead wires (not shown). Another pair of lead wires (not shown) extend from the circuit board **234** to the motor terminals **238** to deliver the required voltage level to the motor **232**.

Referring now to FIG. **5**, a gap **240** is provided in the portion of the head housing **136** surrounding the bevel gear **182** which allows the head housing **136** to be rotated with respect to the main housing portion **102** while the pinion gear **164** remains engaged with the bevel gear **182**. When the head portion **104** is axially aligned with the main housing portion **102**, however, the gap **240** is exposed as shown in FIG. **16**. The articulating gear system **180** is thus exposed allowing contaminants access to the articulating gear system **180** which could foul the articulating gear system as well as presenting a safety concern since clothing, fingers or hair could become enmeshed in the articulating gear system **180**. Accordingly, a floating dust lid **242** shown in FIG. **17** is used to prevent contamination of the articulating gear system **180** and to avoid exposure of moving gears to an operator through the gap **240**, particularly when the head housing **136** is axially aligned with the main housing portion **102** as shown in FIG. **17**.

The dust lid **242** is located in a channel **244** defined by the main housing portion **102** and the head housing **136** as shown in FIGS. **18-20**. The position of the dust lid **242** at the lower portion (as depicted in FIGS. **18** and **19**) of the channel **244** is constrained either by a movable dust lid travel limiter **246** positioned on the head housing **136**, shown most clearly in FIGS. **11** and **20**, or by a portion **248** of the frame **190**. The position of the dust lid **242** at the upper portion of the channel **244** is constrained either by a neck portion **250** of the head housing **136** or by a lip **252** in the main housing portion **102**.

Referring now to FIGS. **3**, and **21-23**, the clutch control **118** is mechanically interfaced with a linear potentiometer **254** on the circuit board **234**. Also located on the circuit board **234** is a light sensor **256** which is covered by a collapsible rubber boot **258** which is in turn mechanically fastened to the variable speed trigger **110**. A reflective surface **260** (see FIG. **24**) is located on the inside of the rubber boot **258**. A plastic spring locating member **262** which is mechanically secured to the circuit board **234** serves to locate and support a spring **264** which is mechanically fastened to the variable speed trigger **110**. The spring **264** biases the variable speed trigger **110** in a direction away from the circuit board **234** about a pivot **266**. The circuit board **234** also contains a two position slide switch **268** which is mechanically interfaced to the reversing button **112**.

Manipulation of the variable speed trigger **110** about the pivot **266** changes the position of the reflective surface **260** relative to the light sensor **256** to produce a variable speed control signal. While the embodiment of tool **100** incorporates an optical signal generator and receiver for provision of a variable speed control signal, such a tool may alternatively use a pressure transducer, a capacitive proximity sensor, or an inductive proximity sensor. In these alternative embodiments, a pressure sensing switch for generating the variable motor speed control signal may include a pressure transducer for generating a variable speed control signal that corresponds to a pressure applied to the pressure transducer directly by the operator or through an intermediate member such as a moveable member that traverses the distance between the stop position and the full speed position.

An embodiment of the variable motor speed control signal implemented with a capacitive proximity sensor may include a capacitive sensor that generates a variable speed control signal that corresponds to an electrical capacitance generated by the proximity of an operator's finger or moveable member's surface to the capacitive sensor. An embodiment implemented with an inductive proximity sensor generates a variable speed control signal that corresponds to an electrical inductance generated by the proximity of an operator's finger or moveable member's surface to the inductive sensor.

Referring to FIG. **23**, the variable speed control circuit **270** of the tool **100** is schematically shown. The variable speed control circuit **270** includes a power contact **272** which is operably connected to the variable speed trigger switch **110**. An optical signal generator **274** is coupled to the battery **106** and arranged on the circuit board **232** such that light emitted from the optical signal generator **274** is directed toward the reflective surface **260** of the variable speed trigger switch **110** and directed toward the light sensor **256**.

The light sensor **256** and the optical signal generator **274** may be located in the same housing or each may be within a separate housing. When the two components are located in the same housing, the light generator and sensor may emit and receive light through a single sight glass in the housing. Alternatively, each component may have a separate sight glass. An integrated component having the light generator and sensor in a single housing is a QRD1114 Reflective Object Sensor available from Fairchild Semiconductor of Sunnyvale, Calif. Such a housing is substantially smaller than a potentiometer that has a wiper, which traverses approximately the same distance as the trigger traverses from the stop to the full speed position.

The optical signal generator **274** and the light sensor **256** may be an infrared light emitter and an infrared light receiver. In an alternative embodiment, an IR transceiver may be contained within a flexible dust cover that is mechanically fastened to the back of the variable speed trigger switch. In such an embodiment, the inside of the cover in the vicinity of the moveable trigger reflects the optical signal to the receiver for generating the speed control signal.

Control of a tool incorporating the light sensor **256** may be adversely affected by external energy sources such as the sun. Accordingly, in one embodiment, the collapsible boot or dust cover **258** is made from an opaque material or coated with an opaque material such that energy from the sun which may leak past the housing and trigger arrangement does not affect the signal received by the light sensor **256**. Alternatively, a light sensor that is sensitive to a specific frequency band may be used with a device which shields the light sensor from only that specific frequency band. In further embodiments, other circuitry or coding which uniquely identifies the energy from the reflected signal from interfering energy may be used.

The light sensor **256** is an optical transistor having a collector **276** coupled to the battery pack **106** through the contact **272** and an emitter **278** coupled to electrical ground though a voltage divider **280** and a capacitor **282**. A timing signal generator **284** receives voltage from the voltage divider **280**. In the tool **100**, the timing signal generator **264** is a commonly known 555 timer, although other timing signal generators may be used.

The output of the timing signal generator **264** is coupled to a gate **286** of a MOSFET **288** that has a drain **290** coupled to one of the motor terminals **238** and a source **292** coupled to electrical ground. The other motor terminal **238** is coupled to the battery pack **106** through the contact **272**. A freewheeling diode **294** is coupled across the motor terminals **238**. A bypass contact **296**, which is operatively connected to the variable speed trigger switch **110**, is located in parallel to the MOSFET **288** between the motor terminal **238** and electrical ground and a brake contact **298** is in parallel with the freewheeling diode **294**.

Operation of the drill **100** is explained with initial reference to FIGS. **24-26**. The collet locking device **126** is configured to operate with bits such as the screw driver bit **300** shown in FIG. **24**. The screw driver bit **300** and the bit holder **130** are complimentarily shaped. In this example, both the screw driver bit **300** and the bit holder **130** are generally hexagonal in shape, although alternative shapes may be used. The screw driver bit **300** has a diameter slightly less than the bit holder **130** so that it may fit within the bit holder **130**. The screw driver bit **300** includes a notched area **302** and a tail portion **304**.

Initially, the sleeve **138** is moved to the right from the position shown in FIG. **4** to the position shown in FIG. **26** thereby compressing the spring **142**. As the sleeve **138** moves, recesses **140** in the sleeve **138** are positioned adjacent to the recesses **148** in the bit holder **130**. Then, as the screw driver bit **300** is moved into the bit holder **130**, the tail portion **304** forces the steel balls **150** toward the recesses **140** and out of the channel of the bit holder **130**, allowing the tail portion **304** to move completely past the steel balls **150**.

At this point, the notched area **302** is aligned with the recesses **148**. The sleeve **138** is then released, allowing the spring **142** to bias the sleeve **138** onto the bit holder **130** which is to the left from the position shown in FIG. **27**. As the sleeve **138** moves, the recesses **140** are moved away from the recesses **148** thereby forcing the steel balls **150** partially into the channel of the bit holder **130** as shown in FIG. **27**. Movement of the steel balls **150** into the channel of the bit holder **130** is allowed since the notched area **302** is aligned with the recesses **148**. At this point, the bit **300** is firmly held within the bit holder **130**.

The head housing **136** is then articulated to a desired angle with respect to the main housing portion **102**. Initially, the spring (not shown) in the spring receiving well **226** forces the articulation button **120** to extend into the hole **222**. Accordingly, the teeth **218** of the articulation button **120** are meshed with the teeth **224** in the main housing portion **102** as well as the teeth **216** in the well **214** of the head housing **136**, thereby angularly locking the articulation button **120** (and the head housing **136**) with the main housing portion **102**. Additionally, the dust lid **242** is constrained at the upper portion of the channel **244** by the neck portion **250** of the head housing **136** and at the lower portion of the channel **244** by the portion **248** of the frame **190** as shown in FIG. **18**.

The operator then applies force to the articulation button **120** causing the spring (not shown) to be depressed thereby disengaging the teeth **218** from the teeth **224**. Thus, even though the teeth **218** remain engaged with the teeth **216**, the head portion **104** is allowed to pivot with respect to the main housing portion **102**. As the head portion **104** is articulated, for example, from the position shown in FIG. **1** to the position shown in FIG. **2**, the pinion gear **164** articulates about the bevel gear **182**. By way of example, FIG. **28** shows the positions of the pinion gears **164** and **184** with respect to the bevel gear **182** when the drill **100** is in the configuration shown in FIG. **1**. In this configuration, the pinion gear **164** is approximately 90 degrees away from the pinion gear **184** about the perimeter of the bevel gear **182**. As the head portion **104** is articulated in the direction of the arrow **306**, the pinion gear **164** articulates about the bevel gear **182** in the same direction. Thus, when the head portion **104** is aligned with the main housing portion **102**, the pinion gear **164** is positioned on the bevel gear **182** at a location 180 degrees away from the pinion gear **184** as shown in FIG. **29**.

Throughout this articulation, the pinion gears **164** and **184** remain engaged with the bevel gear **182**. Accordingly, the bit holder **130** may be rotated by the motor **232** as the head housing **136** is articulated. Additionally, the articulation of the head housing **136** causes the movable dust lid travel limiter **246** to contact the dust lid **242** and push the dust lid **242** along the channel **244**. Thus, the dust lid **242**, which is configured to be wider than the gap **240** as shown in FIG. **17**, restricts access from outside of the drill **100** to the articulating gear system **180**.

When the articulating drill **100** is rotated to the desired location, the operator reduces the force applied to the articulating button **120**. The spring (not shown) in the spring receiving well **226** is then allowed to force the articulation button **120** away from the well **214** until the articulation button **120** extends through the hole **222**. Accordingly, the teeth **218** of the articulation button **120** are meshed with the teeth **224** in the main housing portion **102** as well as the teeth **216** in the well **214** of the head housing **136**, thereby angularly locking the articulation button **120** (and the head housing **136**) with the main housing portion **102**.

The desired direction of rotation for the bit **300** is then established by placing the reversing button **112** in the position corresponding to the desired direction of rotation in a known manner. Rotation is accomplished by moving the variable speed trigger switch **110** about the pivot **266** to close the power contact **272**. The closing of the contact **272** completes a circuit allowing current to flow to the optical signal generator **274** causing light to be emitted.

The emitted light strikes the reflective surface **260** and a portion of the light is reflected toward the light sensor **256**. The amount of light reflected by the reflective surface **260** increases as the reflective surface **260** is moved closer to the light sensor **256**. The increased light sensed by the light sensor **256** causes increased current to be conducted by the light sensor **256** and the flow of current through the light sensor **256** causes current to flow from the collector **276** to the emitter **278**. Thus, as the intensity of the light impinging on the light sensor **256** increases, the current conducted by the light sensor **256** increases. This increase in current causes the voltage level presented by the voltage divider **280** to the timing signal generator **284** to increase. The increased signal is the variable speed signal and it causes the timing signal generator **284** to generate a timing signal in a known manner.

In the depicted drill **100**, the timing signal generator **284** is a commonly known 555 timer, although other timing signal generators may be used.

The timing signal generator **284** generates a timing pulse having a logical on-state that corresponds to the level of the variable speed signal. This signal is presented to the gate **286** of the MOSFET **288**. When the signal present at the gate **286** is a logical on-state, the MOSFET **288** couples one of the motor terminals **238** to ground while the other motor terminal **238** is coupled to battery power through the main contact **272**. Thus, when the variable speed trigger switch **110** reaches a position where the light sensor **256** begins to detect reflected light and generate a variable speed signal, the timing signal generator **284** begins to generate a signal that causes the MOSFET **288** to couple one of the motor terminals **238** to ground. Once this occurs, current begins to flow through the MOSFET **288** and the motor **232** begins to rotate in the direction selected by the reversing button **112**.

The freewheeling diode **294** causes appropriate half-cycles of the current in the windings of the motor **232** to flow out of the motor **232**, through the diode **294**, and back into the motor **232** when the MOSFET **288** does not conduct in response to the timing signal being in the off-state. This action is known as freewheeling and is well known.

When the variable speed trigger **110** is in the full speed position, the timing signal is predominantly in the on-state and the bypass contact **296** closes. The closing of the bypass contact **296** enables the battery current to continuously flow through the motor **232** so that the motor **232** rotates at the highest speed.

When rotation is no longer desired, the operator releases the variable speed trigger switch **110** and the spring **264** causes the variable speed trigger switch **110** to rotate about the pivot **266** causing the bypass contact **296** to open. Additionally, the brake contact **298** closes thereby coupling the motor terminals **238**. The coupling of the two motor terminals **238** to one another through the brake contact **298** enables dynamic braking of the motor.

The electronic control of the tool **100** thus requires less space for the components that generate the variable speed signal than prior art control systems. Because the distance traveled by the variable speed trigger switch **110** does not have to be matched by the light signal generator **274** and the light sensor **256**, considerable space efficiency is gained. Additionally, the light signal generator **274** and the light sensor **256** do not require moving parts, so reliability is improved as well. Advantageously, the light signal generator **274** and the light sensor **256** may be mounted on the same printed circuit board **234** on which the timing signal generator **284** is mounted.

As the drill **100** is operated, the bit **300** is subjected to axial forces. The axial forces may result from, for example, pressure applied by the operator or by an impact on the bit. In either instance, the articulating gear system **180** is protected from damage without increasing the bulk of the components within the articulating gear system **180**. This is accomplished by directing axial forces from the bit **300** to the main housing portion **102** of the drill **100** while bypassing the articulating gear system. With initial reference to FIG. **27**, an impact on the bit **300** tends to move the bit **300** further into the drill **100**, or to the left as depicted in FIG. **27**. In prior art designs, not only could such a force damage the gear system, but the steel balls used to retain the bit within the bit holder would frequently jam necessitating replacement of the collet locking device.

As shown in FIG. **27**, however, the cylinder pin **146** is positioned such that the tail portion **304** of the bit **300** will contact the cylinder pin **146** before the wall of the notched area **302** contacts the steel balls **150**. Thus, an axial impact will not cause the steel balls **150** to jam. Of course, the cylinder pin **146** must be made from a material sufficient to withstand the axial impact. In accordance with one embodiment, the cylinder pin **146** is made of AISI 4135 steel.

Referring now to FIG. **4**, in the event of an axial impact, the force is transferred from the cylinder pin **146** to the to the bit holder **130**. The axial force is transmitted from the bit holder **130** to the bearing **132** which is located within the bearing pocket **134**. Accordingly, the axial force is transferred into the flange **152** (see also FIG. **5**) of the head housing **136**. The head housing **136** in this embodiment is made from aluminum alloy A380 so as to be capable of receiving the force transmitted by the bearing **132**. The force is subsequently transferred to the frame **190** and into the rib **228** of the main housing portion **102**.

More specifically, two paths for the transfer of axial forces are provided around the articulating gear system **180**. The first path predominantly transfers axial forces when the head housing **136** is axially aligned with the main housing portion **102**. In this configuration, axial forces pass from head housing **136** to the frame **190** primarily through the recess **212** where the head housing **136** engages the frame **190** about the hole **188** (see FIG. **4**) and at the shroud portion **210** where the head housing **136** engages the frame **190** outwardly of the base of the bevel gear **196**.

The second path predominantly passes axial forces when the head housing **136** is at a ninety degree angle with respect to the main housing portion **102**. In this configuration, axial forces are again transferred from the cylinder pin **146** to the to the bit holder **130**. The axial forces then pass primarily from the teeth **216** in the well **214** of the head housing **136** to the teeth **218** on the articulation button **120** and then to the teeth **224** in the main housing portion **102**.

When the head housing **136** is neither completely aligned with the main housing portion **102** or at a ninety degree angle with respect to the main housing portion **102**, axial forces generally pass through both of the foregoing pathways. Accordingly, the effect of axial forces on the articulating gear system **180** of the drill **100** are reduced. Because the articulating gear system **180** is thus protected, the articulating gear system **180** may be constructed to be lighter than other articulating gear systems.

In one embodiment, a printed circuit board which may be used in the drill **100** or another power tool includes a circuit that provides vibratory feedback to the operator as shown in FIG. **30**. The vibratory feedback circuit **308** includes a microcontroller **310**, a driver circuit **312**, and motor interface circuit **314**. The driver circuit **312** in this embodiment is an integrated circuit that generates driving signals for a half-bridge circuit from a single pulse width modulated (PWM) signal, a torque limit indicating signal, which may be the same signal as the PWM signal, and a motor direction control signal. The driver circuit **312** may be a half bridge driver, such as an Allegro 3946, which is available from Allegro Microsystems, Inc. of Worcester, Mass.

The output of the driver circuit **312** is connected to a motor **316** through two transistors **318** and **320** which may be MOSFETs, although other types of transistors may be used. The transistor **318** may be connected to either terminal of the motor **316** through switches **322** and **324** while the transistor **320** may be connected to either terminal of the motor **316** through switches **326** and **328**. A shunt resistor **330** is coupled between the transistor **320** and electrical ground. The high potential side of the resistor **330** is coupled to the microcontroller **310** through an amplifier **332**. A power source **334** is also provided in the vibratory feedback circuit **308** and a maximum torque reference signal is provided from a torque reference source **336** which may be a linear potentiometer such as the linear potentiometer **254**.

The half-bridge control of the motor **316** eliminates the need for a freewheeling diode because the driver circuit **312** generates motor interface circuit signals for selectively operating the motor interface circuit **314** to control the rotational speed of the motor **316**. More specifically, a variable speed control signal **338**, which may be from a trigger potentiometer or the like, is provided to the microcontroller **310** for regulation of the rotation of the motor **316** by the microcontroller **310**. Based upon the variable speed control signal **338**, the microcontroller **310** generates a PWM signal that is provided to the driver circuit **312**. In response to the PWM signal, the driver circuit **312** turns transistors **318** and **320** on and off.

During typical operations, the transistor **318** is the complement of the transistor **320** such that when the transistor **320** is on, the transistor **318** is off. The rate at which the transistor **320** is turned on and off determines the speed of motor **316**. The direction of rotation of the motor **316** is determined by the position of the switches **322**, **324**, **326** and **328** under the control, for example, of a reversing switch.

The current through the motor **316** is provided through the transistor **320** and the resistor **330** to electrical ground when the transistor **320** is in the on-state. This current is related to the torque at which the motor **316** is operating. Thus, the voltage at the high potential side of the resistor **330** is related to the torque on the motor **316**. This motor torque signal is amplified by the amplifier **332** and provided to the microcontroller **310**. The microcontroller **310** compares the amplified motor torque signal to the torque limit signal established by the torque reference source **336**. The torque limit signal, which may alternatively be provided by a different type of torque limit signal generator, provides a reference signal to the microcontroller **310** that corresponds to a current through the motor **316** that represents a maximum torque setting for the motor **316**.

In response to the microcontroller **310** receiving a motor torque signal that exceeds the maximum torque setting for the motor **316**, the microcontroller **310** generates a braking signal that is provided to the driver circuit **312**. In response to the braking signal, the driver circuit **312** turns transistor **320** to the off-state and leaves transistor **318** in the on-state. This enables regenerative current to dynamically brake the rotation of the motor **316**.

As dynamic braking occurs, the torque experienced by the motor **316** decreases until the sensed torque is less than the maximum torque setting for the motor **316**. The microcontroller **310** then returns the transistor **320** to the on-state, thereby rotating the motor **316** and increasing the torque experienced by the motor **316**. In this manner, the motor **316** alternates between rotating and dynamically braking which causes the tool to vibrate and alert the operator that the torque limit has been reached. An effective frequency for providing this vibratory feedback is 30 Hz. The torque limit indicating signal that results in this operation continues as long as the trigger remains depressed. Alternatively, the microcontroller may be programmed to generate the torque limit indicating signal for a fixed duration and then to stop to reduce the likelihood that the motor will be overpulsed.

In one embodiment, vibratory feedback is provided for the drill **100** with the circuit shown in FIG. **31**. The vibratory feedback circuit **340** includes a microprocessor **342**, an H-bridge driver circuit **344** and a motor interface circuit **346**. Four MOSFETs **348**, **350**, **352** and **354** control power to the motor **232** from the rechargeable battery pack **106** under the control of the H-bridge driver circuit **344**. A shunt resistor **356** is provided between the MOSFETs **352** and **354** and electrical ground. The signal at the high potential side of the resistor **356** corresponds to the torque being generated by the motor **232**. This motor torque signal is amplified by an amplifier circuit **358**, which may be implemented with an operational amplifier as shown in FIG. **31**, and provided to the microcontroller **342**. The microcontroller **342** compares the motor torque signal to the torque limit signal and generates a torque limit indicating signal in response to the motor torque signal being equal to or greater than the torque limit signal. The torque limit indicating signal may have a rectangular waveform.

In one embodiment, the microcontroller **342** provides a torque limit indicating signal that is a rectangular signal having an off-state of at least 200 μseconds at a frequency of approximately 30 Hz. This torque limit indicating signal causes the driver circuit **344** to generate motor interface control signals that disconnect power from the motor **232** and couple the MOSFETs **348**, **350**, **352** and **354** together so the current within the windings of the motor **232** flows back through the motor **232** to dynamically brake the motor **232**.

The dynamic braking causes the motor **232** to stop. Before application of the next on-state pulse, the microcontroller inverts the signal to the direction control input of the H-bridge driver **344**. Thus, the subsequent on-state of the rectangular pulse causes the H-bridge driver circuit **344** to operate the H-bridge to couple the motor **232** to the rechargeable battery pack **106** with a polarity that is the reverse of the one used to couple the motor **232** and the rechargeable battery pack **106** prior to braking. This brake/reverse/start operation of the motor at the 30 Hz frequency causes the tool to vibrate in a manner that alerts the operator that the torque limit has been reached while preventing the bit from continuing to rotate during the clutching operation. The dynamic braking may also be used without inverting the signal.

In yet another embodiment, the rectangular waveform may be generated for a fixed duration, for example, 10 to 20 pulses, so the motor is not over-pulsed. Also, the microcontroller **342** may invert the direction control signal to the H-bridge driver **344** during the off-time of the rectangular waveform so that the motor **232** starts in the opposite direction each time. This action results in the net output rotation being zero during the clutching duration. Additionally, the microcontroller **342** may disable the clutching function in response to the motor direction control signal indicating reverse, rather than forward, operation of the motor **232**.

FIGS. **32**A and **32**B show an embodiment of a circuit used in a tool that eliminates the need for mechanical contacts. The circuit **360** includes an optical speed control switch **362**, a two position forward/reverse switch **364**, a microcontroller **366**, a driver circuit **368**, an H-bridge circuit **370**, a motor **372**, a shunt resistor **374**, a motor torque signal amplifier **376**, and a torque limit signal generator **378**. In this embodiment, power is coupled to the motor **372** through the H-bridge circuit **370**, but the main contact, brake contact, and bypass contact are no longer required. Thus, this embodiment significantly reduces the number of components that are subject to mechanical wear and degradation. Because the optical control switch **362**, microcontroller **366**, driver circuit **368**, H-bridge circuit **370**, and torque signal amplifier **376** may all be implemented with integrated circuits, then ICs may be mounted on a common printed circuit and the space previously occupied by the mechanical contacts and variable signal potentiometer are gained. This construction further enables the tool components to be arranged in more efficient geometries.

In the circuit **360**, the optical speed control switch **362** operates as described above to generate a variable control signal from the reflection of an optical signal directed at the reflective surface of a pivoting trigger. The variable speed control signal is provided to the microcontroller **366** for processing. The microcontroller **366**, which may be a microcontroller available from Texas Instruments and designated by part number MSP430, is programmed with instructions to generate a PWM pulse with an on-state that corresponds to the level of the variable speed signal. The microcontroller **366** provides the PWM signal to the driver circuit **368** for generation of the four motor interface control signals used to couple battery power to the motor **372**. The direction in which the motor **372** is driven is determined by the contacts in the two position forward/reverse switch **364** through which a signal is provided to the microcontroller **366**. In the circuit **360**, the contacts of the two position forward/reverse switch **364** do not need to carry the current provided to the motor **372** so the contacts of the two position forward/reverse switch **364** may be smaller than contacts in other systems. The directional signal is also provided by the microcontroller **366** to the driver circuit **368** so the driver circuit **368** is capable of two directional control of current in the H-bridge circuit **370**.

The motor torque signal amplifier **376** provides the torque signal from the high potential side of the shunt resistor **374** to the microcontroller **366**. The torque limit signal generator **378** may be implemented with a potentiometer as described above to provide a reference signal for the microcontroller **366**. When the microcontroller **366** determines that the motor torque signal equals or exceeds the motor torque limit, the microcontroller **366** generates a torque limit indicating signal so the driver circuit **368** generates the motor interface control signals that operate the motor **372** in a manner that causes vibration. For the TD340 driver circuit, the torque limit indicating signal generated by the microcontroller **366** is a rectangular signal having an off-state of at least about 200 μseconds at a frequency of about 30 Hz.

While the present invention has been illustrated by the description of exemplary processes and system components, and while the various processes and components have been described in considerable detail, applicant does not intend to restrict or in any limit the scope of the appended claims to such detail. Additional advantages and modifications will also readily appear to those skilled in the art. The invention in its broadest aspects is therefore not limited to the specific details, implementations, or illustrative examples shown and described. Accordingly, departures may be made from such details without departing from the spirit or scope of applicant's general inventive concept.

The invention claimed is:

1. An articulating hand power tool comprising:
- a head portion including,
  - a head housing,
  - a bit holder rotatably supported by the head housing and defining a first axis of rotation, and
  - a bearing member operable to transfer a first axial force along the axis of rotation from the bit holder to the head housing;
- a frame supporting a motor and rotatably connected to the head portion for placement in a plurality of positions with respect to the head portion and operably connected to the head housing for receiving the first axial force transferred to the head housing; and
- an articulating gear system for transferring rotational force generated by the motor to the bit holder at each of the plurality of positions, wherein the first axial force is transferred from the bearing member to the frame without passing through any portion of the articulating gear system.

2. The hand power tool of claim **1** wherein the articulating gear system comprises a bevel gear with a bevel shaft and the frame is configured as a flat bearing surface for the bevel shaft.

3. The hand power tool of claim **2**, further comprising:
- a first pinion gear engaged with a first side of the bevel gear; and
- a second pinion gear engaged with the first side of the bevel gear.

4. The hand power tool of claim **3**, further comprising:
- a thrust bearing located between the frame and a second side of the bevel gear, the second side opposite to the first side.

5. The hand power tool of claim **1**, further comprising:
- an outer housing for receiving at least a portion of the frame and operably connected to the frame such that the first axial force received by the frame is transferred to the housing.

6. The hand power tool of claim **5**, further comprising:
- a variable speed trigger switch extending outwardly from the outer housing and operably connected to the motor for variably controlling the speed of the motor and movable within a plane between a first position corresponding to a first motor speed and a second position corresponding to a second motor speed; and
- a finger platform extending outwardly from the outer housing and located at least partially within the plane and adjacent to an upper end portion of the variable speed trigger switch, the finger platform having a length along an axis of the outer housing substantially shorter than the length of the variable speed trigger along the axis.

7. The hand power tool of claim **6**, wherein the variable speed trigger switch pivots about a pivot axis, the upper end portion of the variable speed trigger switch located between the pivot axis and the articulating gear system.

8. The hand power tool of claim **1**, wherein the bit holder defines a bit holder bore, the tool further comprising:
- a cylinder pin extending across the bit holder bore for receiving the first axial force from a bit positioned within the bit holder and operable to transfer the first axial force from the bit to the bit holder.

9. The hand power tool of claim **8**, wherein the axis of rotation intersects the cylinder pin.

10. The hand power tool of claim **1**, further comprising:
- an outer housing for receiving at least a portion of the frame; and
- an articulation button movable between a first position wherein the articulation button contacts the outer housing and the head housing so as to restrict rotation of the head housing with respect to the outer housing and a second position wherein the articulation button does not restrict rotation of the head housing with respect to the outer housing.

11. The hand power tool of claim **10**, wherein:
- the bearing member is operable to transfer a second axial force from the bit holder to the head housing; and
- the articulation button is configured to transfer the second axial force from the head housing to the outer housing.

12. The hand power tool of claim **10**, wherein:
- the head housing comprises a first plurality of teeth;
- the articulation button comprises a second plurality of teeth; and
- the outer housing comprises a third plurality of teeth, wherein the second plurality of teeth is engaged with both the first plurality of teeth and the third plurality of teeth when the articulation button is in the first position and the second plurality of teeth is engaged with only

one of the first plurality of teeth and the third plurality of teeth when the articulation button is in the second position.

13. The hand power tool of claim **1** wherein the articulating gear system includes an output pinion gear, the head portion further comprising:

a sleeve radially supporting a shaft of the output pinion gear;

a flange in the head housing contacting the sleeve; and

a bracket attached to the head housing and contacting the sleeve.

14. The hand power tool of claim **13**, wherein:

the flange is located on a first side of the head housing; and

the bracket is attached to the first side of the head housing.

15. The hand power tool of claim **1**, further comprising:

an outer housing engaged with the head housing and configured to receive and support at least a portion of the frame;

a gap in the portion of the head housing surrounding the articulating gear system, into which a portion of the head housing can be rotated; and

a dust lid which is configured to be wider than the gap to restrict access from outside of the hand power tool to the articulating gear system.

16. The hand power tool of claim **15**, further comprising:

a channel defined between the head housing and the outer housing, the dust lid slidingly supported by the channel.

17. The hand power tool of claim **16**, further comprising:

a first dust lid travel limiter on the head housing configured to contact the dust lid such that the dust lid slides within the channel as the frame rotates with respect to the head portion from a first of the plurality of positions to a second of the plurality of positions; and

a second dust lid limiter on the outer housing configured to prevent movement of the dust lid past the second dust lid limiter as the frame rotates with respect to the head portion from the first of the plurality of positions to a third of the plurality of positions, the third of the plurality of positions and the second of the plurality of locations located on opposite sides of the first of the plurality of positions.

18. The hand power tool of claim **15**, further comprising:

an articulation detent system including a spring loaded, toothed button which interfaces with mating toothed pockets in the head housing and the outer housing in a locked position and which interfaces only with the head housing in an unlocked position thus allowing rotation of the head portion relative to the outer housing, the detent system being concentric with a bevel gear of the articulating gear system.

19. The hand power tool of claim **18**, wherein the articulating gear system further comprises:

a motor side pinion gear engaged with a first side of the bevel gear, and

an output side pinion gear engaged with a second side of the bevel gear.

20. The hand power tool of claim **19**, further comprising:

a thrust bearing supporting a second side of the bevel gear, the second side opposite to the first side.

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