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Zimmermann

[54] **JOYSTICK HAVING ELECTRONICALLY CONTROLLED CENTERING FORCE FEEDBACK**

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[52] **U.S. Cl.** ..... **74/471 XY**

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[57] **ABSTRACT**

A joystick is disclosed which comprises an operator member mounted to a pivotal member, the operator member for moving the pivotal member, a position sensor associated with the pivotal member, a linear solenoid having a pair of plunger members each being positioned within the solenoid on opposite sides of the solenoid, and a cable member connected to the operator member and the plunger members with the cable member for centering the operator member when the solenoid is energized.

20 Claims, 3 Drawing Sheets

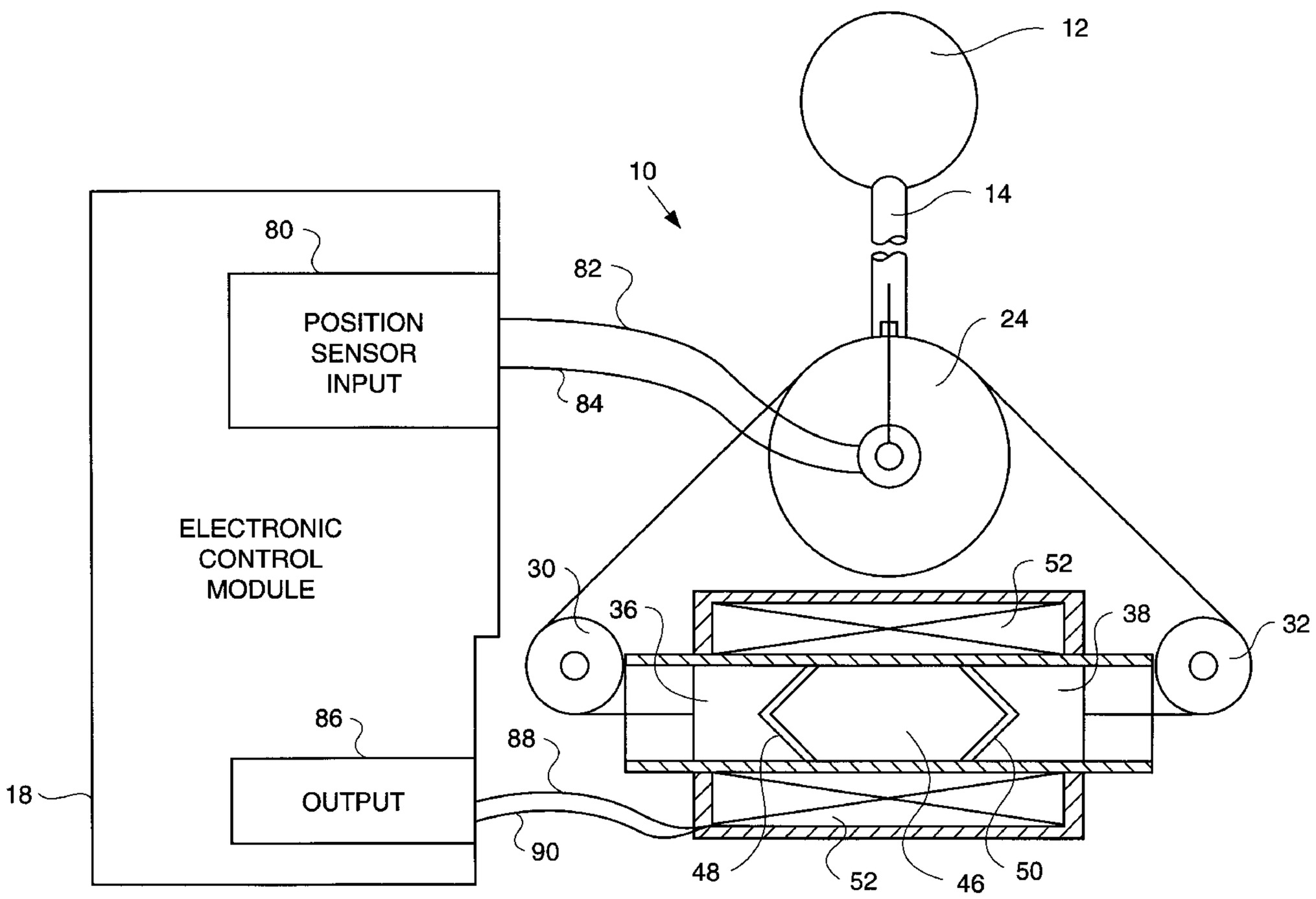


FIG. 1

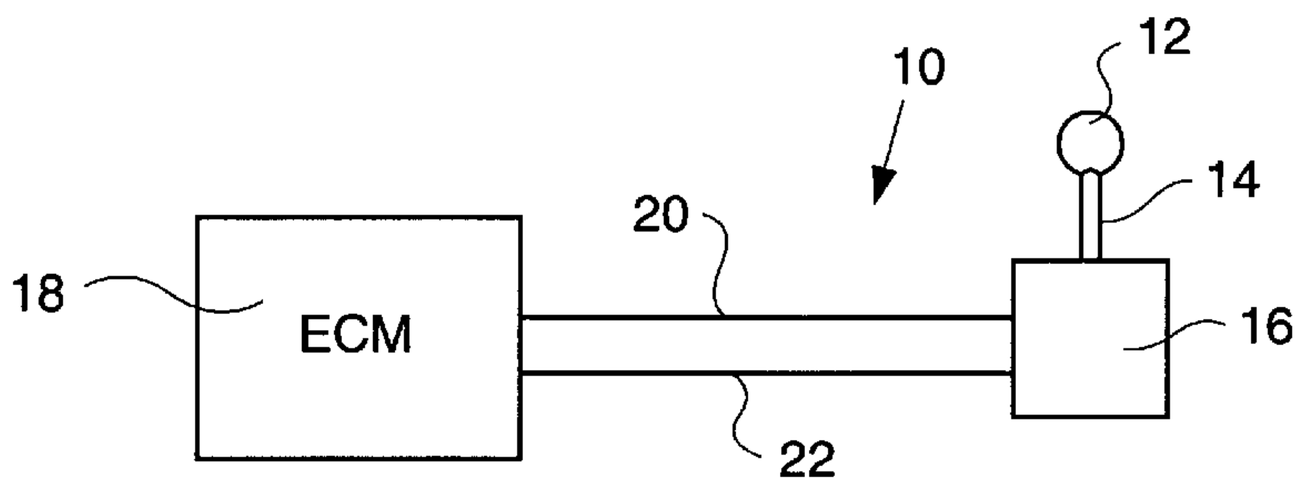
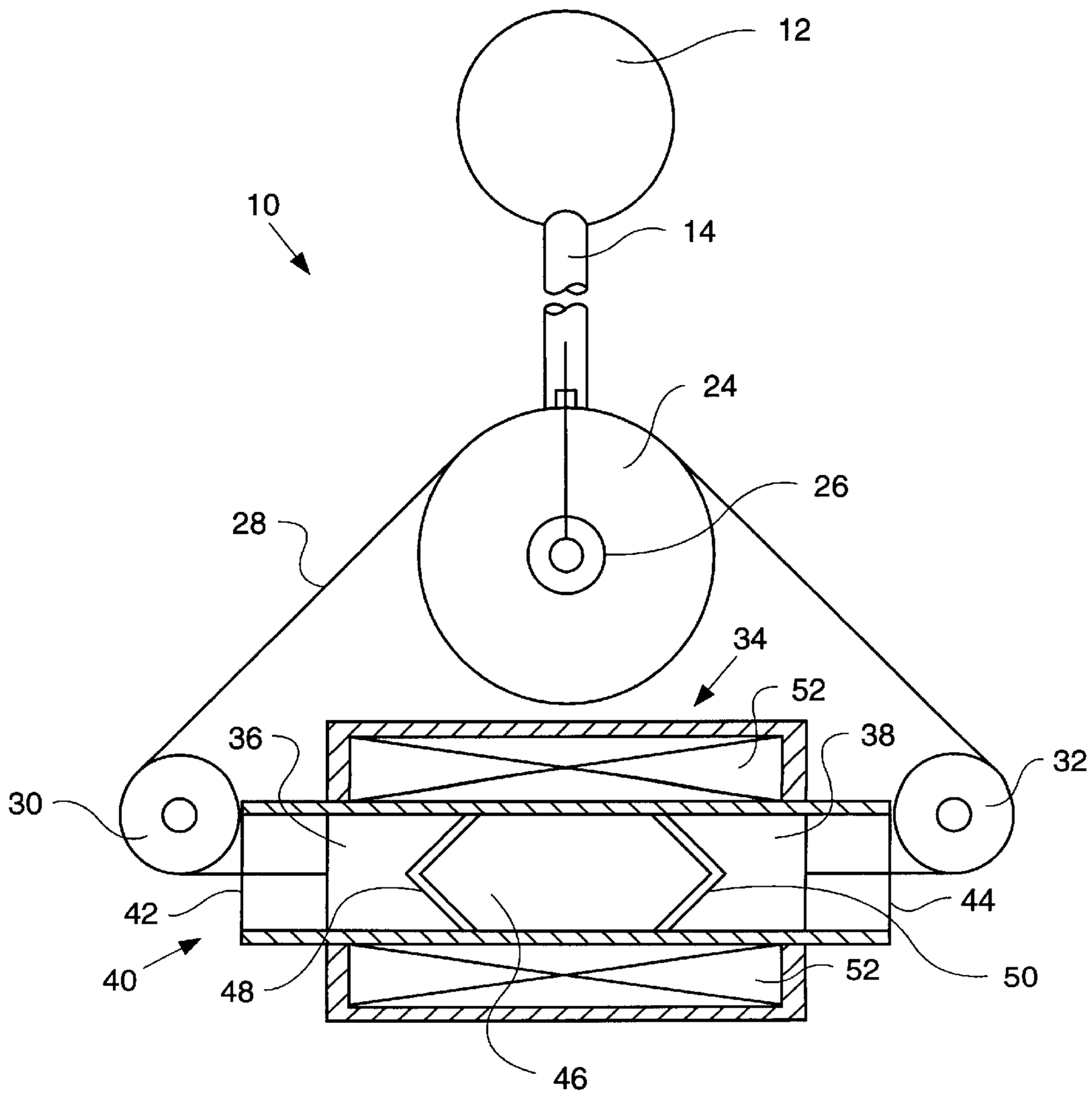

10
12
14
16
18
ECM
20
22

FIG. 2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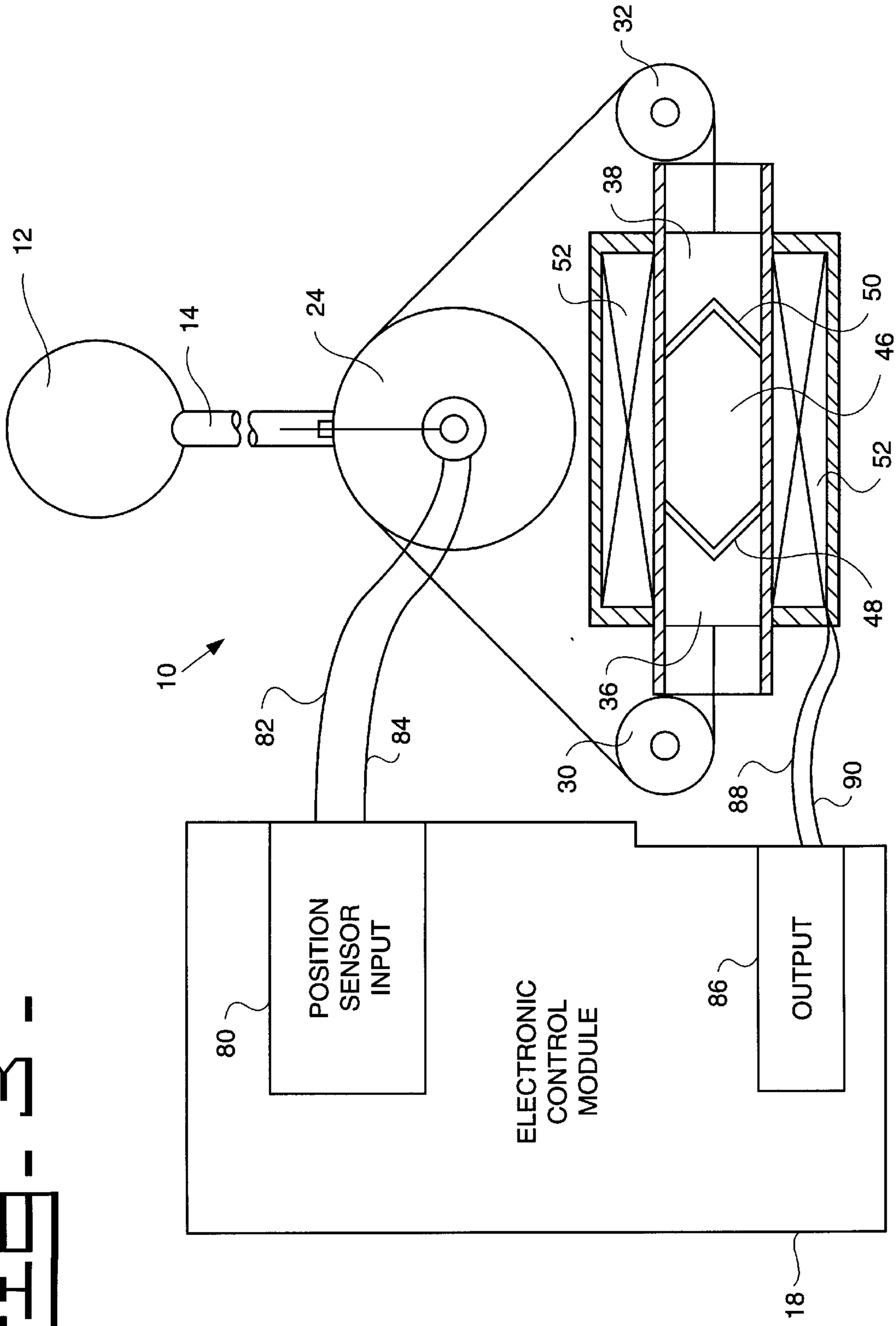
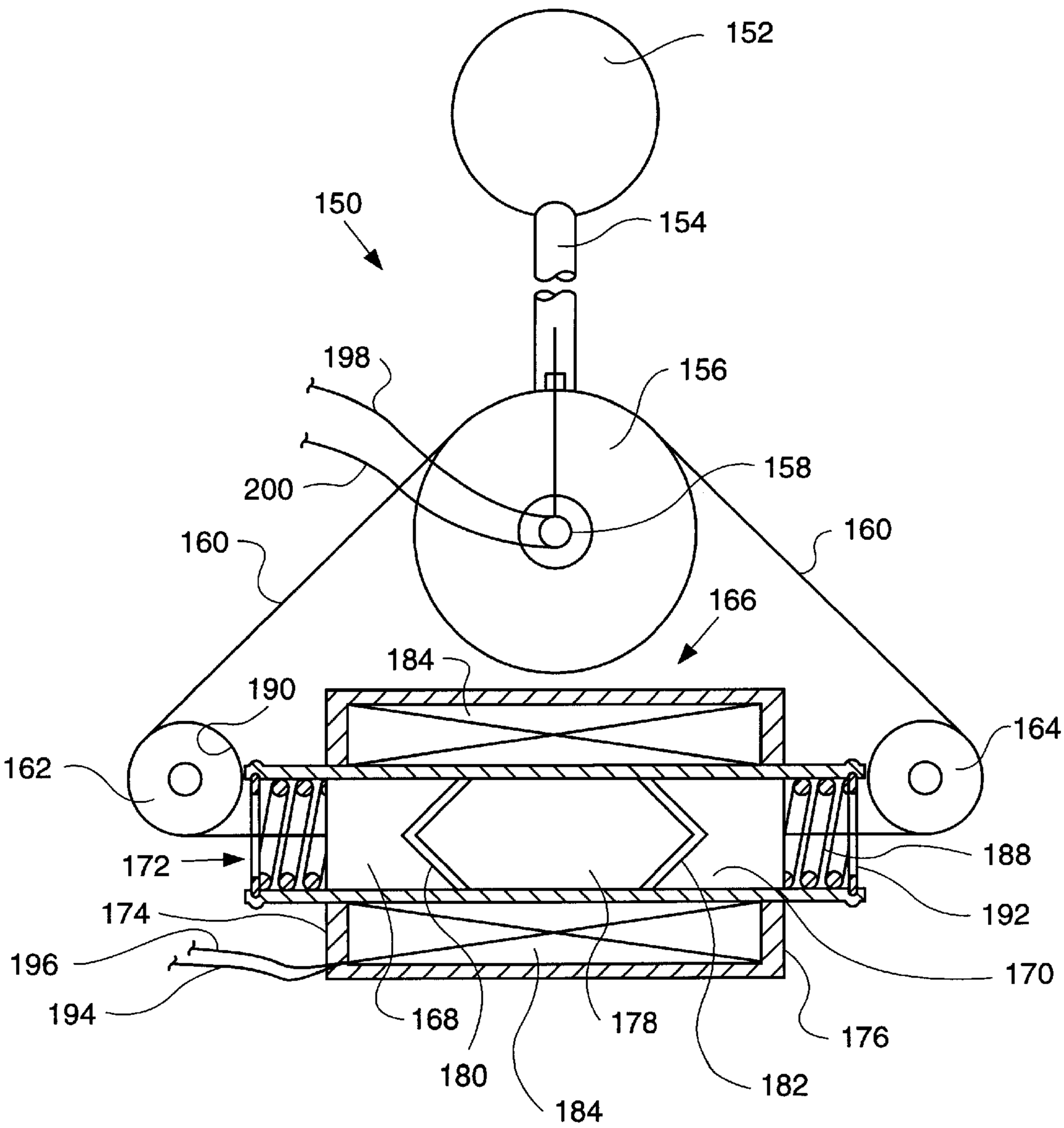

32
38
52
50
46
52
48
12
14
24
10
36
30
82
84
88
90
80
POSITION SENSOR INPUT
ELECTRONIC CONTROL MODULE
86
OUTPUT
18

FIG - 3 -

FIG. 4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150
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198
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200
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JOYSTICK HAVING ELECTRONICALLY CONTROLLED CENTERING FORCE FEEDBACK

TECHNICAL FIELD

This invention relates generally to a joystick for controlling a hydraulic system and more particularly to a joystick having electronically controlled centering force feedback.

BACKGROUND ART

In present hydraulic systems, such as pilot valve hydraulic systems, a joystick is used to control operation thereof. Such joysticks have force feedback as part of their operational characteristics. This tactile feedback provides an operator with information concerning how much force the machine function is exerting. Although such pilot valve hydraulic systems have been useful in the past, there is a new generation of controls which are all electronic. The electric controls allow for additional advanced functions such as coordinated motion between axis to the operator with much higher levels of flexibility than has been previously provided. However, with the electric controls the tactile feedback to the operation is completely lost. The operator has no knowledge or feel for how much force is being exerting by the machine.

In view of the above, it would be desirable to provide a joystick which is electronic and provides for tactile feedback to an operator. Further, it would be advantageous to provide a joystick which is capable of providing a residual centering force prior to operation or actuation of the joystick.

Accordingly, the present invention is directed to overcoming one or more of the problems as set forth above.

DISCLOSURE OF THE INVENTION

In one embodiment of the present invention, a joystick is disclosed which comprises an operator member mounted to a pivotal member, the operator member for moving the pivotal member, a position sensor associated with the pivotal member, a linear solenoid having a pair of plunger members each being positioned within the solenoid on opposite sides of the solenoid, and a cable member connected to the operator handle and the plunger members with the cable member for centering the operator handle when the solenoid is energized.

Another embodiment of the present invention is a joystick capable of being electrically centered which comprises an operator handle mounted to a pivotal member, the operator handle for moving the pivotal member about an arc, a position sensor associated with the pivotal member with the position sensor capable of determining the amount of movement of the pivotal member about the arc, a linear solenoid having a pair of plunger members each being positioned within the solenoid on opposite sides of the solenoid, the plunger members capable of moving within the solenoid once the solenoid is energized, and a cable member connected to the operator handle and the plunger members with energizing the solenoid causing the plunger members to move within the solenoid and causing the cable member to center the operator handle.

In another embodiment of the present invention a joystick comprises an operator member mounted to a pivotal member, the operator member for moving the pivotal member, a position sensor associated with the pivotal member, a linear solenoid having a pair of plunger members each being positioned within the solenoid on opposite sides of the solenoid, a compression spring associated with each of the plunger members, and a cable member connected to the operator member and the plunger members with the cable member for centering the operator member when the solenoid is energized and the compression springs for centering the operator member prior to the solenoid being energized.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a perspective view of a joystick constructed according to the present invention with the joystick connected to an electronic control module;

FIG. **2** is a partial cross-sectional diagram of the joystick constructed according to the present invention;

FIG. **3** is a partial cross-sectional diagram of the joystick shown in FIG. **2** with the joystick shown connected to the electronic control module; and

FIG. **4** is a partial cross-sectional diagram of an alternate embodiment of a joystick constructed according to the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring now to the drawings, FIG. **1** illustrates a joystick **10** constructed according to the present invention with the joystick **10** having a knob **12** and a handle **14** with the handle **14** being mounted within a housing **16**. The housing **16** is shown to be connected to an electronic control module (ECM) **18** by a pair of leads **20** and **22**. The ECM **18** is a control module having a microprocessor (not shown) or other suitable electronic circuitry for receiving and transmitting signals over the leads **20** and **22** for controlling operation or determining the position of the joystick **10**. As is known, the knob **12** and the handle **14** may be manually manipulated to be moved or pivoted in any direction which an operator desires, such as side-to-side, left-to-right, fore-to-aft, or forward-to-backward. Movement of the knob **12** and the handle **14** is sensed by the ECM **18** which is used to control operation of a machine (not shown). The handle **14** is normally maintained in a center or home position. Additionally, the handle **14** may be operated about an arc of movement or displacement with an example being a displacement of 30° off center in either direction of movement or travel of the handle **14**.

Further details of the joystick **10** are illustrated in FIG. **2**. The joystick **10** comprises the knob **12** and the handle **14** with the handle **14** being connected to a drum or a pivotal member **24**. The pivotal member **24** is connected to a position sensor **26** which is used to determine how far the handle **14** has been moved by an operator of the joystick **10**. A flexible member such as a cable **28** is tangentially connected to the pivotal member **24**. The cable **28** may be composed of a metal band or a flexible non-stretchable member. The cable **28** is capable of having constant length under tension. The cable **28** is wrapped around a pair of rotatable or movable members **30** and **32** and through a linear solenoid **34**.

The linear solenoid **34** has a pair of plunger members **36** and **38** which are positioned within a tube or a bore **40** in the sides **42** and **44** of the linear solenoid **34**. The linear solenoid **34** also has a centrally located fixed pole piece **46** which has tapered ends **48** and **50**. The linear solenoid **34** further includes a coil **52** which may be energized by providing a current through the coil **52**. The plunger members **36** and **38** are also connected to the cable **28**.

In operation, the joystick **10** is turned on and current is provided through the coil **52**. The linear solenoid **34** is energized which causes the plunger members **36** and **38** to be attracted into the linear solenoid **34**. Once the plunger members **36** and **38** are attracted into the linear solenoid **34** the cable **28** also moves which then centers the handle **14**. Additionally, once the joystick **10** is centered, movement of the handle **14** off of the center position in either direction causes one of the plunger members **36** or **38** to move out of the linear solenoid **34**. This causes one air gap to be created in a magnetic circuit within the linear solenoid **34**. The ECM **18** is able to provide current to the coil **52** to energize the coil **52**.

Referring now to FIG. **3**, the joystick **10** is shown connected to the ECM **18**. The position sensor **26** is connected to a position sensor input **80** of the ECM **18** by a pair of leads **82** and **84**. The coil **52** is connected to an output **86** of the ECM **18** by a pair of leads **88** and **90**. For example, the output **86** of the ECM **18** may be a pulse width modulated signal having a 0% to 100% duty cycle. In operation, the coil **52** is initially energized by sending a current at the output **86** over the leads **88** and **90**. Once the coil **52** is energized the plunger members **36** and **38** are pulled into the linear solenoid **34**. Pulling the plunger members **36** and **38** into the linear solenoid **34** also pulls the cable **28** to center the handle **14**. Signals sent over the leads **82** and **84** from the position sensor **26** inform the ECM **18** which direction the handle **14** has been moved.

FIG. **4** illustrates an alternate embodiment of a joystick **150** constructed according to the present invention. The joystick **150** includes the knob **152** and the handle **154** with the handle **154** being connected to a drum or a pivotal member **156**. The pivotal member **156** is connected to a position sensor **158** which is used to determine how far the handle **154** has been moved by an operator of the joystick **150**. A flexible member such as a cable or a metal band **160** is tangentially connected to the pivotal member **156**. The cable **160** is wrapped around a pair of rotatable or movable members **162** and **164** and through a linear solenoid **166**.

The linear solenoid **166** has a pair of plunger members **168** and **170** which are positioned within a tube or a bore **172** in the sides **174** and **176** of the linear solenoid **166**. The linear solenoid **166** also has a centrally located fixed pole piece **178** which has tapered ends **180** and **182**. The linear solenoid **166** further includes a coil **184** which may be energized by providing a current through the coil **184**. The plunger members **168** and **170** are also connected to the cable **160**. The plunger members **168** and **170** are each further biased by a compression spring **186** and **188** placed within the tube **172** with the compression springs **186** and **188** providing a residual centering force prior to current being applied to the linear solenoid **166**. Each of the compression springs **186** and **188** are held in place within the tube **172** between the plunger members **168** and **170** and a snap ring **190** and **192**, respectively.

The joystick **150** may also be connected to the ECM **18** which is not shown in FIG. **4**. The coil **184** may be connected to the ECM **18** via a pair of leads **194** and **196**. Current provided from the ECM **18** over the leads **194** and **196** is used to energize the coil **184**. Additionally, the position sensor **158** is connected to the ECM **18** by wires **198** and **200**. Signals provided over the wires **198** and **200** from the position sensor **158** are indicative of the direction in which the handle **154** has been moved by an operator.

In operation, prior to current being provided to the coil **184**, the compression springs **186** and **188** center the handle

154. Once current is applied to the coil **184** the plunger members **168** and **170** will be attracted into the linear solenoid **166** which pulls the cable **160** to further center the handle **154**. Once the joystick **150** is centered movement of the handle **154** off of the center position in either direction will cause one of the plunger members **168** or **170** to move out of the linear solenoid **166**. Once either of the plunger members **168** or **170** moves out of the linear solenoid **166** an air gap will be created in a magnetic circuit set up by the linear solenoid **166**.

The joysticks **10** and **150** have been shown for movement in a single direction or axis. It is also contemplated and possible that a joystick may be constructed for dual axis operation. In order to construct such a joystick, the drum **24** would be replaced by a sphere and a second linear solenoid which would be perpendicular to the linear solenoid **34** would be required. Additional inputs and outputs to the ECM **18** would also be required.

INDUSTRIAL APPLICABILITY

The present invention is applicable in situations where an operator is using an electronic joystick and needs to be provided with tactile feedback. The present invention is useful to provide a residual centering force prior to operation of the joystick. Additionally, torque curves associated with a linear solenoid having tapered pole pieces increases as the joystick approaches the neutral or center position. This characteristic provides operation of the joystick at greatly reduced power at lower angles of displacement of the joystick. Even at 30 degrees displacement from center the linear solenoid having tapered pole pieces will compare favorably with more expensive rotary solenoids for torque versus power.

Other aspects, objects and advantages of the present invention can be obtained from a study of the drawings, the disclosure and the appended claims.

I claim:

1. A joystick comprising:

an operator member mounted to a pivotal member, the operator member for moving the pivotal member;

a position sensor associated with the pivotal member;

a linear solenoid having a pair of plunger members each being positioned within the solenoid on opposite sides of the solenoid; and

a cable member connected to the operator member and the plunger members with the cable member for centering the operator member when the solenoid is energized.

2. The joystick of claim **1** further comprising an electronic control module connected to the joystick for receiving signals corresponding to the amount of movement that the operator member has been moved and for energizing the linear solenoid.

3. The joystick of claim **2** wherein the electronic control module is connected to the position sensor.

4. The joystick of claim **3** wherein the linear solenoid further comprises a coil and the electronic control module is connected to the coil.

5. The joystick of claim **1** wherein the linear solenoid comprises a fixed pole piece with the pole piece having a pair of tapered ends.

6. The joystick of claim **1** wherein the cable member is tangentially connected to the pivotal member.

7. The joystick of claim **1** further comprising a pair of rotatable members with the cable member being placed around the rotatable members.

8. A joystick capable of being electrically centered, the joystick comprising:

an operator handle mounted to a pivotal member, the operator handle for moving the pivotal member about an arc;

a position sensor associated with the pivotal member with the position sensor capable of determining the amount of movement of the pivotal member about the arc;

a linear solenoid having a pair of plunger members each being positioned within the solenoid on opposite sides of the solenoid, the plunger members capable of moving within the solenoid once the solenoid is energized; and

a cable member connected to the operator handle and the plunger members with energizing the solenoid causing the plunger members to move within the solenoid and causing the cable member to center the operator handle.

9. The joystick of claim **8** further comprising an electronic control module connected to the joystick for receiving signals corresponding to the amount of movement that the operator handle has been moved and for energizing the linear solenoid.

10. The joystick of claim **9** wherein the electronic control module is connected to the position sensor.

11. The joystick of claim **10** wherein the linear solenoid further comprises a coil and the electronic control module is connected to the coil.

12. The joystick of claim **8** wherein the linear solenoid comprises a fixed pole piece with the pole piece having a pair of tapered ends.

13. The joystick of claim **8** wherein the cable member is tangentially connected to the pivotal member.

14. The joystick of claim **8** wherein the pivotal member is capable of moving in a forward or a backward direction and the arc of travel is 30° in either direction.

15. A joystick comprising:

an operator member mounted to a pivotal member, the operator member for moving the pivotal member;

a position sensor associated with the pivotal member;

a linear solenoid having a pair of plunger members each being positioned within the solenoid on opposite sides of the solenoid;

a compression spring associated with each of the plunger members; and

a cable member connected to the operator member and the plunger members with the cable member for centering the operator member when the solenoid is energized and the compression springs for centering the operator member prior to the solenoid being energized.

16. The joystick of claim **15** further comprising an electronic control module connected to the joystick for receiving signals corresponding to the amount of movement that the operator member has been moved and for energizing the linear solenoid.

17. The joystick of claim **15** wherein the linear solenoid comprises a fixed pole piece with the pole piece having a pair of tapered ends.

18. The joystick of claim **15** wherein the cable member is tangentially connected to the pivotal member.

19. The joystick of claim **15** further comprising a pair of rotatable members with the cable member being placed around the rotatable members.

20. The joystick of claim **15** wherein the cable member is a flexible member and non-stretchable.

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