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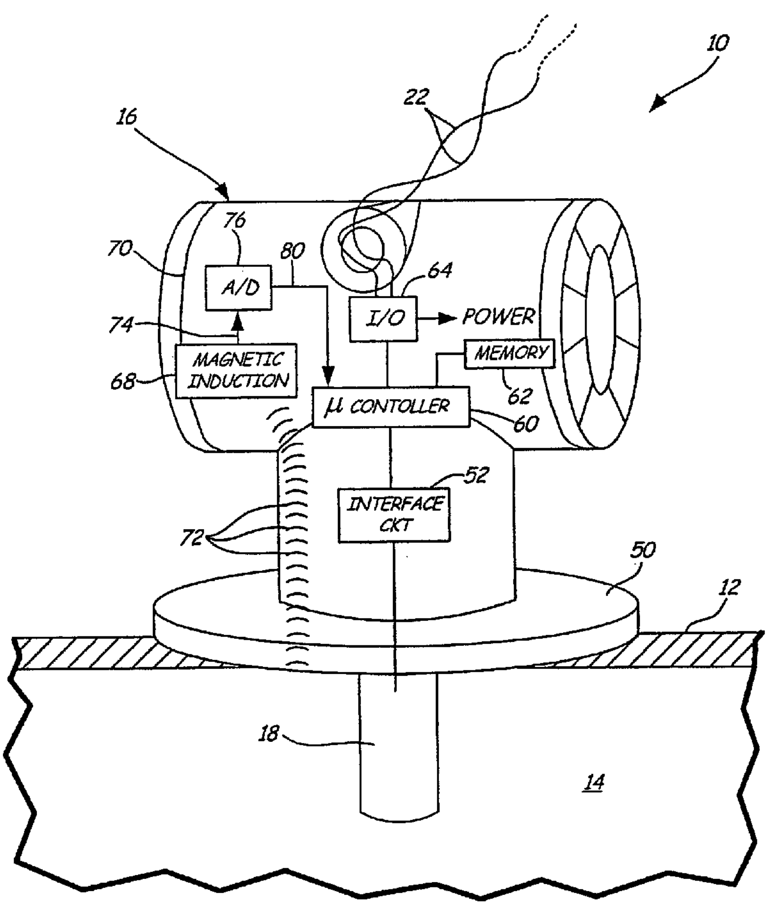
(54) Title: INDUSTRIAL PROCESS DEVICE UTILIZING MAGNETIC INDUCTION



(57) Abstract: A process device for coupling to an industrial process for use in monitoring or controlling the process includes a device housing (16) configured to physically couple to the industrial process. A coil of wire (100) is mounted to the housing and a magnet (104) is configured to move through the coil of wire. The relative movement of the magnet is responsive to vibrations (72) in the industrial process. Such relative movement induces an electrical current. in the coil of wire. Electrical circuitry in the housing includes an input to receive the electrical current from the coil of wire.

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INDUSTRIAL PROCESS DEVICE UTILIZING MAGNETIC INDUCTION

BACKGROUND OF THE INVENTION

The present invention relates to industrial process devices of the type used to couple to industrial process control and monitoring systems.

In industrial settings, control systems are used to monitor and control inventories of industrial and chemical processes, and the like. Typically, a control system performs these functions using field devices distributed at key locations in the industrial process and coupled to the control circuitry located in a control room by a process control loop. The term "field device" refers to any device that performs a function in a distributed control or process monitoring system, including all devices used in the measurement, control and monitoring of industrial processes.

Some field devices include a transducer. A transducer is understood to mean either a device that generates an output signal based on a physical input or that generates a physical output based on an input signal. Typically, a transducer transforms an input into an output having a different form. Types of transducers include various analytical equipment, pressure sensors, thermistors, thermocouples, strain gauges, flow transmitters, positioners, actuators, solenoids, indicator lights, and others. Other field devices include a control element and are used to control the industrial process. Examples of such process devices include valve controllers, valve position controllers, heater controllers, pump controllers, etc.

In many process installations, process devices experience vibrations. The vibrations can occur during normal operation of the process. Additionally, certain types of failures can cause the process device to experience unusual vibrations, for example a failing pump, a loose bracket, etc.

SUMMARY

A process device for coupling to an industrial process for use in monitoring or controlling the process includes a device housing configured to physically couple to the industrial process. A coil of wire is mounted to the housing and a magnet is configured to move through the coil of wire. The relative movement of the magnet is responsive to vibrations in the industrial process. Such relative movement induces an electrical current in the coil of wire. Electrical circuitry in the housing includes an input to receive the electrical current from the coil of wire.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a simplified diagram of a process monitoring or control system for monitoring or controlling an industrial process.

Figure 2 shows a cutaway view and simplified block diagram of a process device including magnetic induction circuitry for use in performing diagnostics.

Figure 3 shows a cutaway view and simplified block diagram of a process device including magnetic induction circuitry for use in generating power for the process device.

Figure 4 is an electrical schematic diagram showing the magnetic induction circuit in greater detail.

Figure 5 is a exploded view of a process device showing another example configuration.

DETAILED DESCRIPTION

Figure 1 is a simplified diagram of an industrial process controller monitoring system 10 including a process device 16 in accordance with the present invention. As discussed in more detail below, process device 10 includes an electrical coil and a moveable magnet configured to move in response to vibrations in system 10 and thereby generate an electrical current.

Process device 16 is coupled to process piping 12 which is configured to carry a process fluid 14. A process interface element 18 is configured to couple to the process and is used for input or output to the process device 16. For example, if the process device is configured as a process control transmitter, interface element 18 can comprise some type of a process variable sensor such as a pressure sensor, flow sensor, temperature sensor, etc configured to sense a process variable. On the other hand, if process device 16 is configured as a process control device, interface element 18 can be, for example, a valve, a heater, etc., which is used to control the process. Process device 16 couples to remotely located circuitry such as control room 20 over a process control loop 22. Process control loop 22 is illustrated as a two wire process control loop and can comprise, for example, a process control loop configured to operate in accordance with industrial standards. Example industrial standards include 4-20 mA protocols, the HART® protocol, FieldBus protocols, and others.

Figure 2 is a simplified cross-sectional view showing one example embodiment of the present invention in which process device 16 couples to process piping through a process coupling 50 such as a flange or the like. Field device 16 includes interface circuitry 52 which couples to process interface 18. When configured as a transmitter, interface circuitry 52 can perform initial processing and operate with a process variable sensor. Similarly, when configured as a process controller, interface circuitry 52 is used to control the process interface 18. Field device 16 includes a microcontroller 60 which operates in accordance with programming instructions stored in memory 62. Microcontroller 60 also couples to I/O circuitry 64 which itself couples to process control loop 22. In some configurations, I/O circuitry 64 also provides a power output which is used to power some or all of the circuitry of process device 16.

Magnetic induction circuitry 68 is mounted in a device housing 70 of the process device 16. Magnetic induction circuitry 68 is physically coupled to the housing 70 such that vibrations 72 emanating from the industrial process 10 are received by magnetic induction circuitry 68. In the configuration of Figure 2, magnetic induction circuitry 68 provides an electrical output signal 74 to an analog to digital converter 76. The analog to digital converter 76 receives the output signal 74 and provides a digitized signal 80 to the microcontroller 60. The microcontroller 60 can process the digitized signal as appropriate.

In one example configuration, microcontroller 60 monitors the amplitude, spectral content and/or signature (time and/or frequency) of the vibration signal 72. The signal 72 can be compared against known signals which are representative of nominal operation of the process 10. Nominal signal values such as amplitude, spectral content and/or signature can be stored, for example, in memory 62. As a further example, certain levels or thresholds in the output signal 74 may suggest specific failures in the process such as a broken or failing pump or bracket. Similarly, certain frequencies or groups of frequencies may suggest specific failures such as a failing or failed impeller. The vibration information can also be used to provide prognostic information related to the expected lifetime reduction in the process device due to the exposure to vibrations. If, during operation of the process device 16, the vibration signal 72 varies in a predetermined manner from the stored nominal values, microcontrollers 60 can make a determination that some type of event has occurred in the process which warrants further investigation. For example, the microcontroller 60 can provide an output signal indicative of component failure or potential failure that should be investigated by an operator. The information can also be used for other purposes such as to provide an indication of operation of other components in the industrial process such as a valve controller or the like. If the process coupling 50 has become loose, the vibration signal 72 will also change. In another example, if the vibration signal 72 should suddenly decrease or even disappear completely, this can be an indication that the process 10 has improperly shut down or is in an undesirable state.

Figure 3 is another simplified block diagram of process device 16 showing another example configuration of the present invention. In Figure 3, elements which are similar to those shown in Figure 2 have retained their numbering. In the configuration of Figure 3, the vibration signal 72 is received by magnetic induction circuitry 68. The current output signal 74 from magnetic induction circuitry 68 is provided to a power storage circuitry 82. Power storage circuitry 82 can be any appropriate device for storing electrical power and can include, for example, an electrical capacitor and rectifying circuitry, a battery, etc., used to store energy from magnetic induction circuitry 68. Power storage circuitry 82 provides a power output signal which can be used to power process device 16. In such a configuration, I/O circuitry 64 may not be required to provide a power output signal. Further, in some configurations process device 16 is configured to operate over a wireless connection and I/O circuitry 64 is used for wireless communication. Power storage circuitry 82 can provide all of the power for process device 16, or can provide supplemental or backup power to the device 16.

Figure 4 is a simplified electrical schematic diagram showing magnetic induction circuitry 68 in greater detail. Magnetic induction circuitry 68 includes a coil of wire 100 wound around a tube 102. Preferably, the wire has a relatively thin diameter to allow a great number of windings around tube 102. However, the wire of coil 100 should have a sufficiently low electrical resistance to carry the electrical current generated by magnetic induction. A slidable permanent magnetic 104 is carried in tube 100 and can move in the direction indicated by arrows 106 between ends 108 of tube 102. In accordance with Faraday's Principle of Magnetic Induction, the movement of magnet 104 passed the coil of wire 100 causes an electrical current to be generated in the coil of wire 100. This current is proportional to the speed of magnet 104 relative to coil 100. Magnet 104 is configured to move in response to the vibration signal 72 shown in Figures 2 and 3. Spring members 110 can be positioned at ends 108 of tube 102 to conserve energy in the movement of magnet 104 as the magnet 104 changes directions within tube 102. The spring members 110 can be of any appropriate configuration such as a coiled spring, elastomeric components, etc. In a related configuration, spring members can be alternatively, or in addition to, mounted on magnet 104. As it is the relative movement between magnet 104 and coil 100 that generates the electrical current, sleeve 102 can be configured to move in response to the vibration signal 72.

Figure 4 also shows an example configuration for power storage circuitry 82 in the form of an electrical capacitor 118. The electrical current from coil 100 is an AC current. In such a configuration, the current from coil 100 should be rectified so that the capacitor 118 is charged with a DC current. Such rectification is performed by a bridge rectifier 120 comprising diodes 122. Capacitor 122 stores an electrical charge which can be used to power electrical circuitry within process device 16. Such a configuration is for use, for example, in the arrangement shown in Figure 3. However, if the magnetic induction circuitry 68 is used for diagnostic purposes and the electrical current is provided to an analog to digital converter 76 such as shown in Figure 2, rectification of the signal may not be necessary and the bridge rectifier 120 can be eliminated. With the elimination of bridge rectifier 120, coil 100 can be coupled directly to analog to digital converter 76. A resistor can be used to convert the electrical current into a voltage signal appropriate for application to analog to digital converter 76.

Although a single magnetic induction circuit 68 is illustrated, multiple circuits can be used. Further, the tubes 102 of multiple magnetic induction circuitry 68 are aligned along different axes such that movement in more than one axis will produce an electrical current.

In one configuration, the orientation of tube 102 is adjustable such that it can be aligned along an access of maximum movement. For example, in one configuration, a vibration sensor 160 is provided which is configured to identify the axis along which the process device 16 experiences the greatest amount of vibration energy. For example, sensor 160 can comprise a number of accelerometers arranged such that there outputs can be observed to identify the axis of maximum vibration. In a specific configuration, three accelerometers all extending at 90° to one another (i.e., extending in the X, Y and Z directions, respectively) can be used to identify vibrations in all directions. For example, sensor 160 can comprise a tri-axis accelerometer. Based upon the outputs from such accelerometers, the axis along which the process device experiences maximum vibration can be identified. The microprocessor 60 of the device (see, for example, Figures 2 and 3) can monitor the output from the accelerometers over a period of time. The accumulative vibrations can be determined over the selected time period and the axis of maximum vibration identified. In some configurations, the axis of maximum vibrations may be the most desirable axis along which to align the induction circuitry. For example, if the process device 16 only infrequently experiences extremely large vibrations in one direction, but more regularly experiences smaller vibrations in another direction, it may be preferable to align the induction circuitry to be the most sensitive to vibrations which occur more regularly, even though they are not the maximum amplitude experienced by the device. Based upon the selected criteria, the microprocessor 60 can provide an output to a local operator (for example over the process controller 22 or over a local display, for example one which is included in sensor 160). The output can provide information to the local operator instructing the local operator how the induction circuit 68 should be aligned based upon the vibrations sensed by sensor 160. Based upon the output, an operator can adjust the orientation of induction circuit 68 as desired. In another configuration, the induction circuitry 68 is arranged such that it aligns itself automatically along the most preferred axis. For example, the alignment can be automated based upon the output from sensor 160, or can be through a mechanical configuration in which the received vibrations cause the induction circuitry 68 to reorient itself along a preferred axis relative to the vibrations.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention. Although the embodiments of Figures 2 and 3 are illustrated separately, the magnetic induction circuitry can be used simultaneously for both diagnostics and well as power generation.

Figure 5 is an exploded view of another configuration of process device 16 in which a terminal board 136 is included having terminals 138 for coupling to a two-wire process control loop 22. In the configuration of Figure 5, the terminal board 136 is an optional component in which the magnetic induction circuitry 68 and optionally power storage circuitry 82 are carried on board 136. The board 136 can be selectively added to device 16 by unscrewing end cap 140.

Capacitor 118 can comprise, for example, a supercapacitor, also known as an ultracapacitor, which allows a significant amount of energy to be stored in a relatively small volume. In one configuration, the moveable magnet of the induction circuit can be oriented in such that it is aligned with the axis of maximum vibration. For example, a tri-axis accelerometer can be used in the transmitter to measure and indicate the axis of maximum vibration. In such a configuration, the tri-axis accelerometer can be a separate component temporarily coupled to process device 16, or can be included in circuitry, for example magnetic induction circuitry 68 of process device 16. The tri-axis accelerometer can provide an output for a installation personnel which indicates the axis of maximum vibration during normal operation. The installation personnel can then align the magnetic conduction circuitry such that the magnet experiences the maximum acceleration.

WHAT IS CLAIMED IS:

1. A process device for coupling to an industrial process for use in monitoring or controlling the process, comprising:

a device housing configured to physically couple to the industrial process;

a coil of wire mounted to the housing;

a magnet configured to move through the coil of wire in response to vibrations in the industrial process thereby inducing an electrical current in the coil of wire; and

electrical circuitry in the housing having an input to receive the electrical current from the coil of wire.

2. The apparatus of claim 1 wherein the electrical circuitry is configured to diagnose operation of the industrial process based upon the electrical current.

3. The apparatus of claim 2 including an analog to digital converter having a digital output related to digitize the electrical current.

4. The apparatus of claim 2 including a microcontroller configured to perform diagnostics.

5. The apparatus of claim 2 wherein the diagnostics are based upon an amplitude of vibrations in the industrial process.

6. The apparatus of claim 2 wherein the diagnostics are based upon a frequency of vibrations in the industrial process.

7. The apparatus of claim 2 wherein the diagnostics are based upon a signature in the vibrations in the industrial process.

8. The apparatus of claim 2 wherein the electrical circuitry provides a diagnostic output based upon the vibrations and data stored in a memory.

9. The apparatus of claim 1 including a process interface configured to sense a process variable.

10. The apparatus of claim 1 wherein the process device includes a process interface configured to control the process.

11. The apparatus of claim 1 wherein the electrical circuitry includes power storage circuitry configured to store power from the electrical current from the coil.

12. The apparatus of claim 11 wherein the power storage circuitry comprises a capacitor.

13. The apparatus of claim 11 including a rectifier to rectify the electrical current from the coil.

14. The apparatus of claim 1 wherein the magnetic induction circuitry includes spring members configured to reverse a direction of movement of the magnet relative to the coil.

15. The apparatus of claim 1 wherein the orientation of the magnet is adjustable.

16. The apparatus of claim 15 including a sensor configured to sense vibration.

17. The apparatus of claim 16 wherein the orientation of the magnet is adjusted based upon the sensed vibrations.

18. The apparatus of claim 16 wherein the sensor comprises a three axis accelerometer.

19. The apparatus of claim 12 wherein the capacitor comprises a supercapacitor.

20. A method for sensing vibrations in a process device coupled to an industrial process of the type used in monitoring or controlling the industrial process, the method comprising:

physically coupling a housing of the process device to the industrial process;

receiving vibrations from the industrial process through the physical coupling;

moving a magnet through a coil of wire in response to the vibrations and generating an electrical current in the coil of wire; and

providing the electrical current to circuitry of the process device.

21. The method of claim 20 including diagnosing operation of the industrial process based upon the electrical current.

22. The method of claim 21 wherein the diagnosing is based upon an amplitude of vibrations.

23. The method of claim 21 wherein the diagnosing is based upon a frequency of vibrations.

24. The method of claim 21 wherein the diagnosing is based upon a signature in the vibrations.

25. The method of claim 21 wherein the diagnosing is based upon the vibrations and stored data.

26. The method of claim 20 including storing power storage based from the electrical current from the coil.

27. The method of claim 20 including rectifying the electrical current from the coil.

28. The method of claim 20 including adjusting orientation of the magnet.

29. The method of claim 28 including sensing vibrations and adjusting the orientation of the magnetic based upon the sensed vibrations.

30. The method of claim 29 wherein sensing vibrations includes monitoring an output of a tri-axis accelerometer.

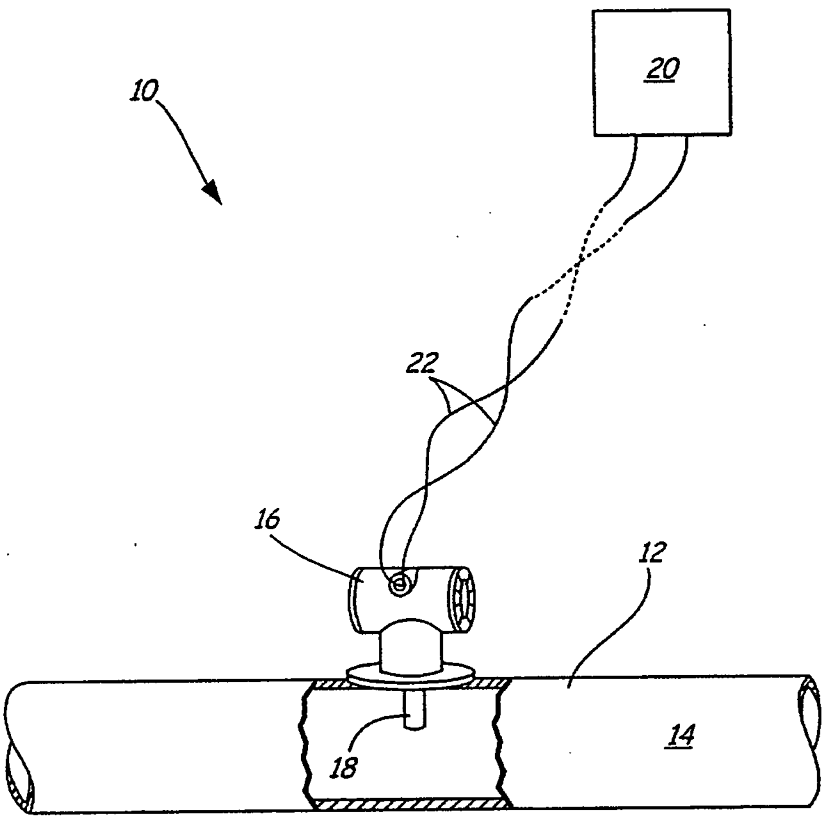
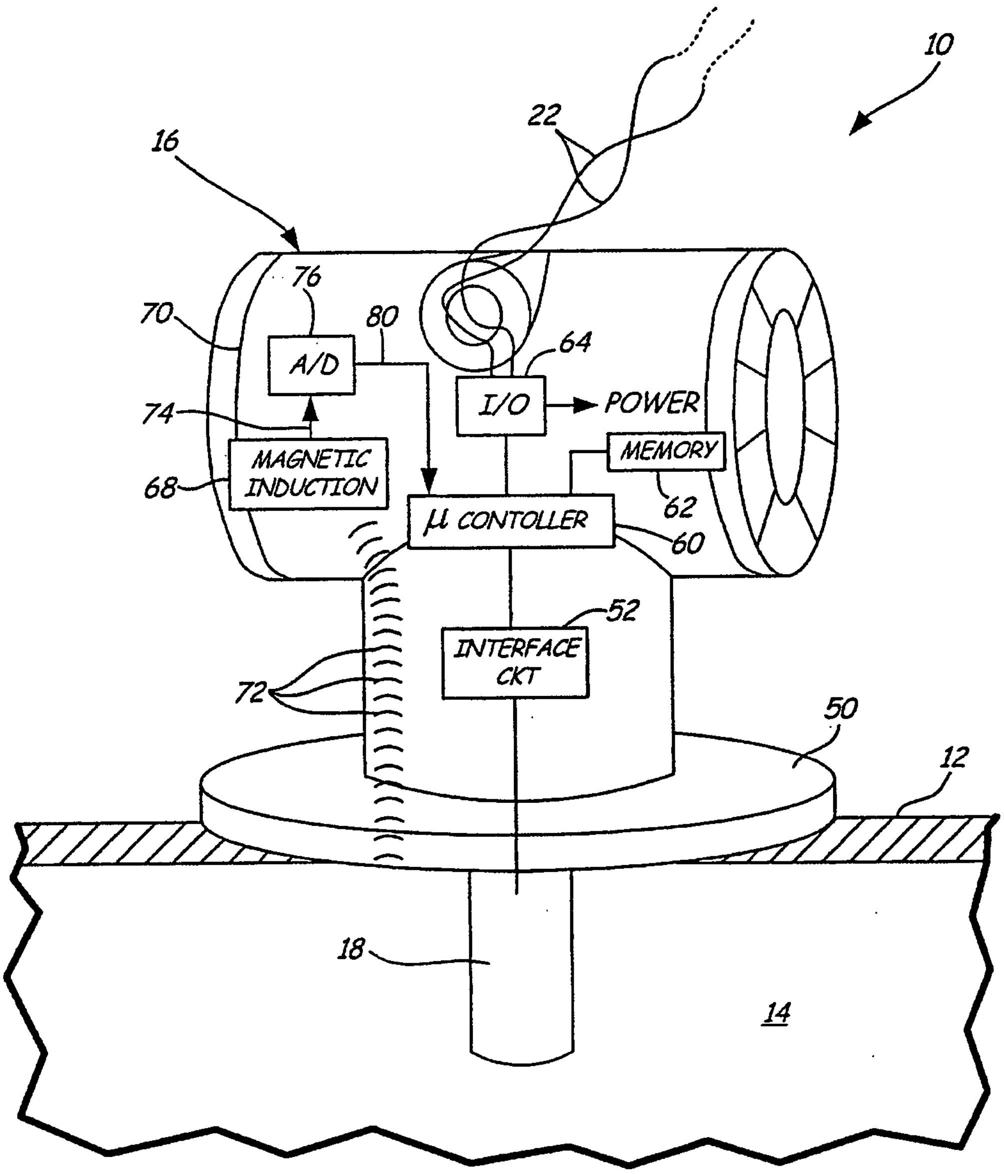


FIG. 1


10
22
16
76
80
70
A/D
64
I/O
POWER
74
MAGNETIC INDUCTION
MEMORY
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60
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INTERFACE CKT
72
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18
14

FIG. 2

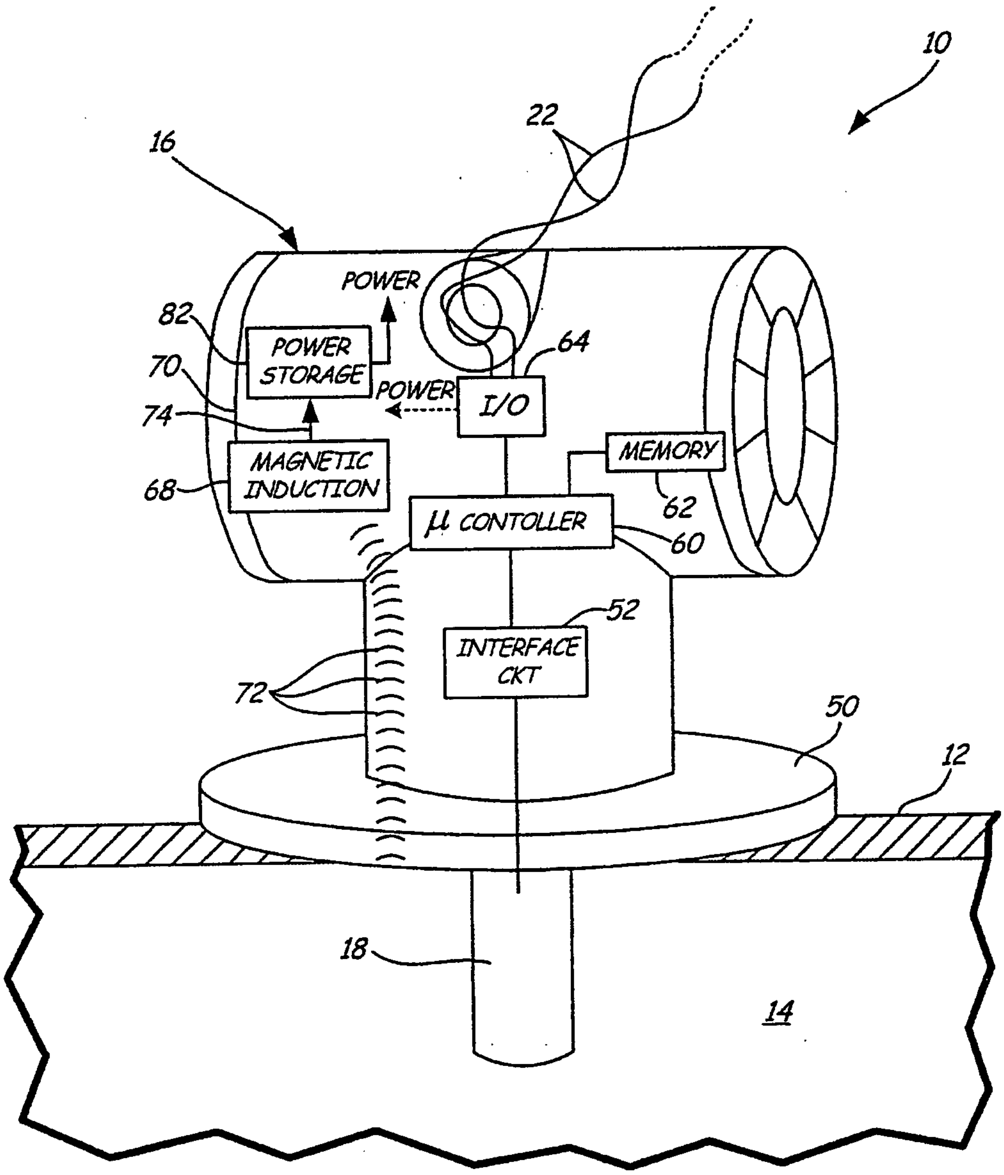
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FIG. 3

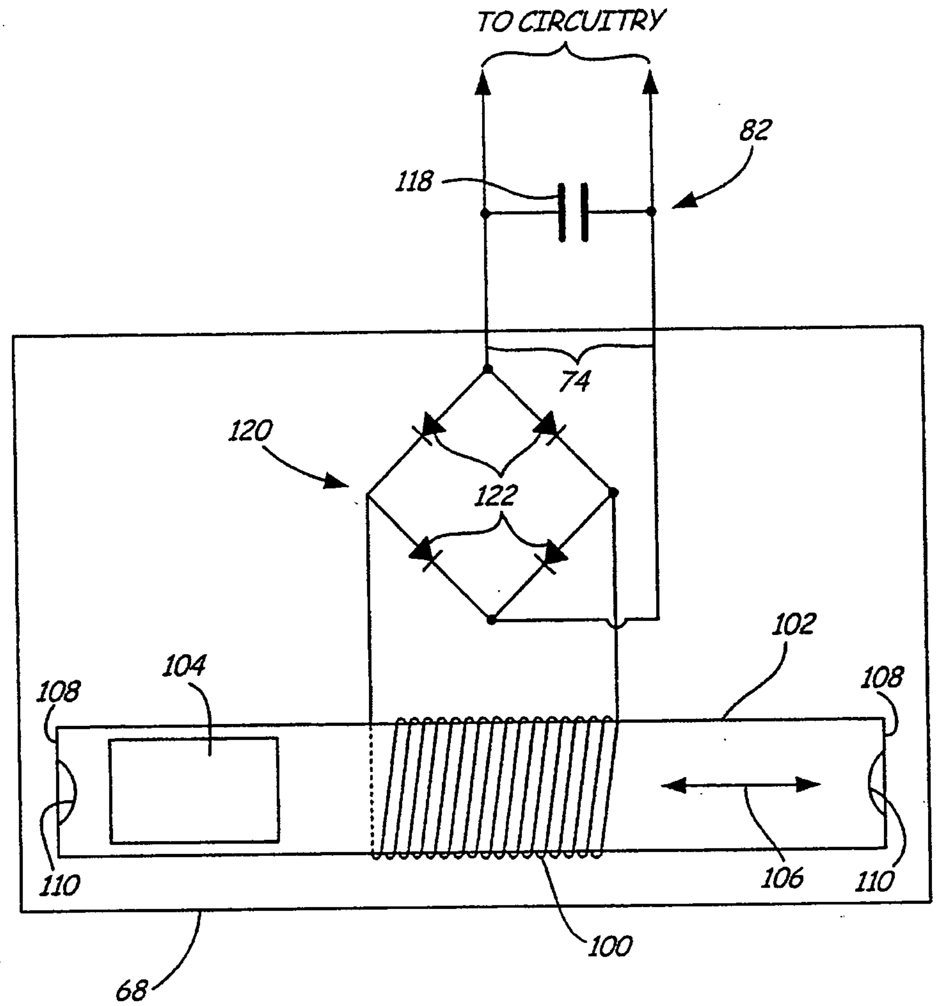
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FIG. 4

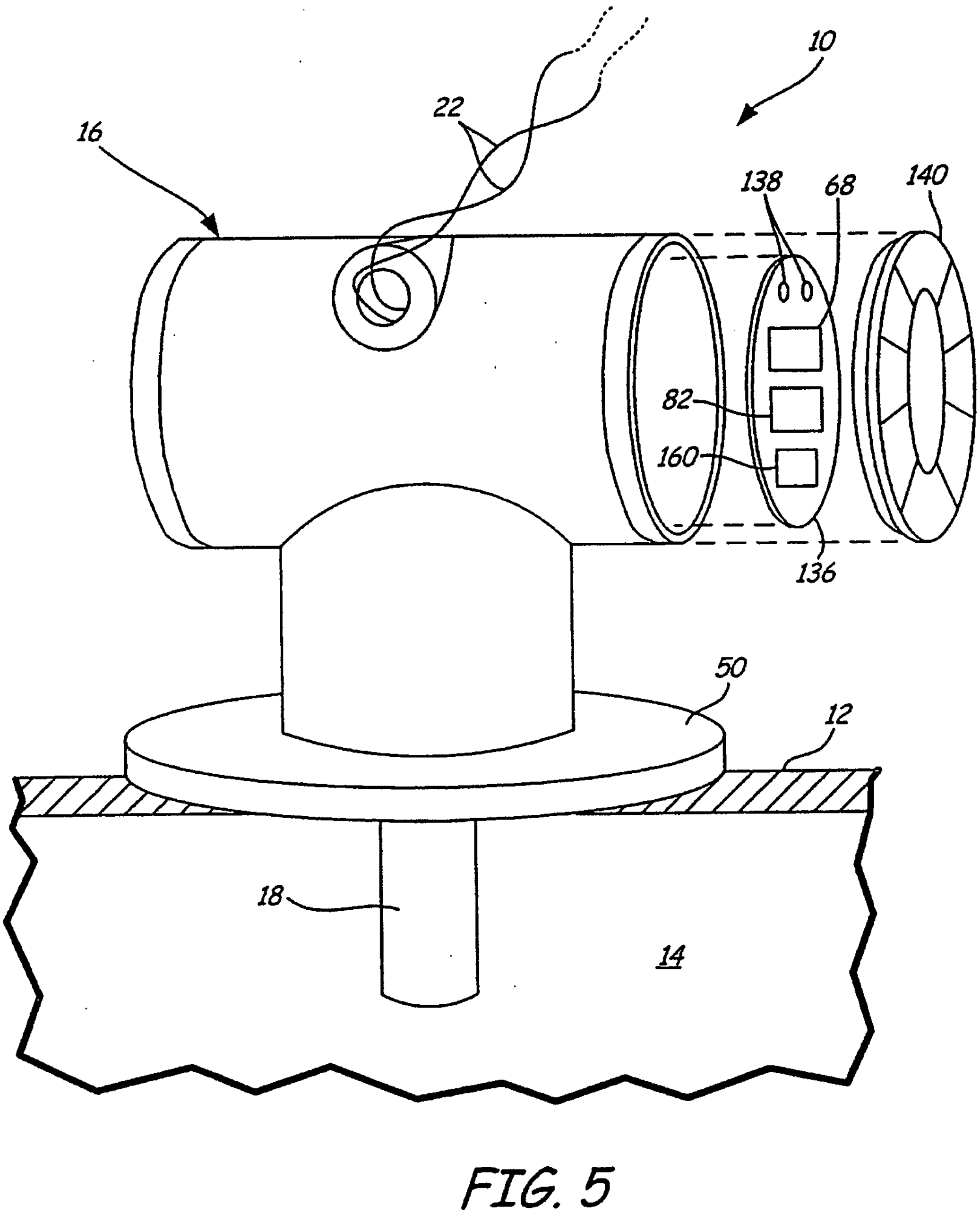

FIG. 5