

Integrated Current Source Feedback and Current Limiting Element

Field of the Invention

This invention relates to a power supply for an intrinsically safe load. More particularly, this invention relates to circuitry that limits the current supplied to the load to meet intrinsically safe standards.

Problem

Electronic devices are often used in hazardous environments containing volatile material. It is often a problem that a spark or heat from the electronic devices can cause the volatile material to ignite. Therefore, makers of electronic devices for use in these hazardous environments must provide some protection to ensure that the electronic devices do not ignite the volatile material.

One such form of protection is to make a circuit intrinsically safe. Intrinsically safe standards are set by regulating authorities such as the UL in the United States, CENELEC in Europe, CSA in Canada, and TIS in Japan. In order to be intrinsically safe the current, power, and voltage through the circuit are limited to levels that prevents ignition of the volatile material from a spark or heat generated by the circuit.

It is a problem to deliver electricity to an intrinsically safe device. The power, voltage and current of the electricity are limited to the levels insufficient to ignite the volatile material. Therefore, components are needed in the power supply to limit the power, voltage, and current delivered to the intrinsically safe device.

In a conventional power supply, voltage is limited by connecting one or more zener diodes between supply line connecting a power supply to output terminals. The zener diodes limit voltage to V . Current limiting is provided by connecting a resistor having a resistance of R in series with a high potential output terminal. The resistor limits current to V/R . Power is controlled by the limiting of current and voltage.

The limiting components, i.e. the diodes and resistors, must be protected to prevent the components from exceeding published rating in the event of a fault. A fuse is typically added to the circuit to limit the amount of current that can be delivered to the components. A fuse is chosen that has a rating that ensures power dissipation ratings are not exceeded.

Although not required for intrinsic safety standards, a current limiting circuit is often added to the power supply circuit to prevent the fuse from blowing. There many current limiting topologies that may be employed on either a high potential or low potential side of a power supply. Most current limiting topologies include a
5 resistor to convert current to voltage in order to provide feedback that is proportional to current. A comparison to a reference voltage is performed. The impedance of a series element is adjusted in response to the comparison. A problem with adding a current limiting circuit is that the conversion of current to voltage adds to the total output resistance and causes additional voltage loss
10 beyond the voltage loss required to meet intrinsic safety standards.

Solution

The above and other problems are solved and an advance in the art is made by power supply having an integrated current source feedback and current limiting element in accordance with this invention. One advantage of an integrated current
15 source feedback and current limiting element is the voltage loss may be minimized to the voltage that must be limited for intrinsic safety standards. A second advantage is that the number of components of a power supply circuit are reduced which lowers the cost of producing a power supply.

In accordance with the present invention, the function of a current
20 conversion resistor in a power limiting circuit is combined with the function of barrier output resistance. This allows output resistance to be no more that the resistance required to prevent ignition of a hazardous material. The combination of function is provided by moving parts of the current limiting circuit to a point after the barrier resistance. In particular, a vary impedance device is moved to a point after the
25 barrier resistance. One example of a vary impedance device is a MOFSET transistor.

When an MOFSET transistor is moved, there are two new paths to the output terminals. A first is an op-amp control output and a feedback from a feedback from the barrier resistance. An input to an operational amplifier and the
30 gate for the MOFSET transistor are of high impedance and relatively large value resistors compared to a barrier resistor placed in each of these paths. The total barrier resistance in a combination of resistor placed in a path with inputs into the MOFSET gate and operational amp input. This limits the power supply to an output resistance which is negligibly lower than the barrier resistance alone.

An aspect of the invention comprises an intrinsically safe circuit configured for supplying power to a load connected to a first output terminal and to a second output terminal, said circuit comprising:

a power supply source;

5 a voltage limiter connected in parallel with said power supply source to limit the magnitude of the voltage generated by said power supply source;

a connection between a first side of said voltage limiter and said first output terminal;

10 a current limiter connected between a second side of said voltage limiter and said second output terminal, said current limiter comprises:

a barrier resistor;

a variable impedance;

a comparator;

characterized in that said current limiter further comprises:

15 said barrier resistor;

said variable impedance is connected between said second output terminal and a first side of said barrier resistor;

a second side of said barrier resistor is connected to said second side of said voltage limiter;

20 a reference voltage connected to an input of said comparator;

an output of said comparator connected to a control input of said variable impedance;

25 a signal applied by the output of said comparator to said input of said variable impedance controls the magnitude of the impedance of said variable impedance;

a connection between said first side of said barrier resistor and said input of said comparator for receiving a voltage representing the magnitude of current through said barrier resistor;

30 said comparator compares the magnitudes of said reference voltage and said voltage received from said barrier resistor to limit to a maximum current level the magnitude of current delivered to said load via said output terminals.

Preferably the intrinsically safe circuit further comprises a fuse connected

between a positive voltage side of the power supply source and the voltage limiting circuit.

Preferably the voltage limiter comprises a diode having a cathode connected to the positive side of the power supply source and an anode connected to the negative side of the power supply source.

Preferably the voltage limiter comprises a zener diode.

Preferably said variable impedance comprises a transistor connected between said first side of said barrier resistor and said second output terminal for controlling the magnitude of current delivered to the load;

said comparator is an operational amplifier (OA) that controls the impedance of the transistor;

said comparator has an output connected to a control input of the transistor;

said comparator further has a first input connected to a voltage representing the magnitude of said load current and further has a second input connected to said reference voltage; and

a voltage divider including said barrier resistor for generating a voltage representative of said load current, said voltage divider is connected to the first input of the operational amplifier and to the negative side of the power supply source.

Preferably the current limiter further comprises a resistor connected between the output of the operational amplifier and the control input of the transistor.

Preferably the transistor comprises a Metal Oxide Semiconductor Field Effect Transistor (MOSFET).

Preferably the voltage divider comprises:

a first resistor connected between the first input of the operational amplifier and the drain of the transistor; and

said barrier resistor having said first end connected to said drain and a second end connected to the negative side of the power supply source.

Preferably the intrinsically safe circuit characterized in that the load comprises electronics of the Coriolis flowmeter having a signal conditioner circuit for generating a drive signal and for receiving pick-off signals, said signal

conditioner circuit is connected to the first and second output terminals of the intrinsically safe circuit.

Preferably the signal conditioner circuit further comprising:

5 a drive circuit for generating said drive signal, said drive circuit is connected to the first and second output terminals of the intrinsically safe circuit; and

a conditioning circuit for receiving the pick-off signals, said conditioning circuit has an input connected to an output of the drive circuit.

10 Another aspect of the invention is a method of operating an intrinsically safe circuit for supplying power to a load via first and second output terminals, said method comprises the steps of:

connecting a voltage limiter in parallel with a power supply source to limit the magnitude of the voltage generated by said power supply source;

15 extending a connection between a first side of said voltage limiter and said first output terminal;

characterized in that said method comprises the further steps of:

connecting a first side of said barrier resistor in series with a variable impedance to said second output terminal;

20 connecting a second side of said voltage limiter to a second side of a barrier resistor;

operating a comparator to compare a reference voltage with the voltage across said barrier resistor representing the current delivered to said load via said output terminals;

25 extending a control signal from said output of said comparator to an input of said variable impedance;

operating said variable impedance in response to the receipt of said control signal to limit the maximum current extended through said barrier resistor and said variable impedance to said load.

30 Preferably the step of limiting the voltage level includes the step of operating a diode to limit said voltage.

Preferably the step of operating a diode includes the step of operating a zener diode.

Preferably the method further includes the steps of:

applying intrinsically safe power from said terminal to a drive circuit of a Coriolis flowmeter, and

generating a drive signal with the drive circuit in response to the reception of said power.

5 Preferably the method further includes the step of applying pick-off signals to a conditioning circuit of said Coriolis flowmeter in response to the reception of said power.

 Preferably the step of limiting the maximum current delivered to the load comprises the steps of:

10 operating a voltage divider to generate a voltage that is representative of the current delivered to said load through said barrier resistor;

 operating the operational amplifier to compare a reference voltage with said voltage representing the current delivered to the load; and

15 extending a signal from an output of the operational amplifier to a control input of a transistor defining said variable impedance for limiting the magnitude of current delivered to the load.

 Preferably the step of operating the transistor includes the step of operating a MOSFET.

20 Another aspect of the invention comprises an intrinsically safe circuit configured for supplying power to a load connected to a first output terminal and a second output terminal, said circuit comprising:

 a power supply source;

 a voltage limiter connected in parallel with said power supply source to limit a maximum voltage generated by said power supply source;

25 a connection between a first side of said voltage limiter and said first output terminal; and

 characterized in that said circuit comprises:

 a current limiter connected between a second side of said voltage limiter and a second output terminal;

30 said current limiter comprising:

 a reference voltage,

 a variable impedance,

 a barrier resistor, and

a second side of said voltage limiter is connected in series with said barrier resistor and said variable impedance to said second output terminal,

said current limiter limits a current delivered to said load via said terminals to a maximum current level in response to a comparison of said reference voltage with a voltage across said barrier resistor.

Another aspect of the invention comprises a method of operating an intrinsically safe circuit for supplying power to a load, said method comprises the steps of:

connecting a voltage limiter connected in parallel with a power supply source to limit a maximum voltage generated by said power supply source; extending a connection between a first side of said voltage limiter and a first terminal;

connecting a second side of said voltage limiter in series with a barrier resistor and a variable impedance to a second output terminal; and limiting a current delivered to said load via said output terminals to a maximum current level in response to a comparison of a reference voltage with a voltage across said barrier resistor representative of the current delivered to said load via said barrier resistor and said output terminals.

Description of the Drawings

The above and other features in accordance with this invention can be understood from the Detailed Description and the following drawings:

FIG. 1 illustrating a prior art power supply for an intrinsically safe load;

FIG. 2 illustrating a power supply for an intrinsically safe load in accordance with this invention; and

FIG. 3 illustrating a Coriolis flowmeter incorporating a power supply in accordance with this invention into meter electronics.

Detailed Description

A power supply in accordance with this invention allows the total output resistance to be no more than is required to prevent ignition of volatile material in a hazardous environment. A typical intrinsically safe power supply 100 is illustrated in FIG. 1 to show the differences between a power supply in accordance with the present invention and a typical intrinsically safe power supply.

Prior Art intrinsically safe power supply 100 delivers sufficient power to a load to ensure that the load may operate properly while limiting the worst case voltage, current, and power to levels insufficient to cause ignition of a hazardous material. Voltage limiting circuitry 101 limits the voltage across the load. In power supply 100, voltage limiting circuitry 101 is a zener diode Z1 connected between paths 110 and 120. One skilled in the art will recognize that more than one zener diode may be connected between paths 110 and 120 to limit the voltage. For purposes of this discussion, voltage limiting circuitry 101 limits the magnitude of the voltage across a load (Not Shown) to V_z .

Instantaneous current limiting circuitry 102 limits instantaneous current applied to a load. In power supply 100, instantaneous current limiting circuitry includes resistor R_b which is connected in series with output terminals T1 and T2. In this embodiment, resistor R_b is connected between positive output terminal T1 and power source PS along path 110. This limits the instantaneous current to V_z/R_b where R_b is the resistance of resistor R_b . Power delivered to the load (Not Shown) is limited by the limits of voltage and current.

Fuse F1 is connected between power source Ps and positive output terminal T1 to protect voltage limiting circuitry 101 and instantaneous current limiting circuitry 102 in case of a fault in the circuit. Fuse F1 prevents voltage limiting circuitry 101 and instantaneous current limiting circuitry 102 from exceeding published rating of components.

Average current limiting circuit 103 prevents fuse F1 from blowing in the event that output terminals T1 and T2 are shorted. There are many well known current limiting topologies that can be used to provide average current limiting circuit 103. In power supply 100, average current limit circuit is provided by the following components. A source of transistor Q1 is connected to negative output terminal T2. A drain of transistor Q1 is connected to a resistor R_v . Resistor R_v converts the current through it to a voltage to provide a feedback voltage that is

proportional to current through it. An output of operational amplifier OA is connected to the gate of transistor Q1 and a signal is applied to the gate based on a comparison with voltage "REF" to adjust the impedance of transistor Q1. The current limit is set to $I_{lim} = V_{ref} / R_v$ where I_{lim} is the current limit, V_{ref} is the reference voltage, Ref, and R_v is the resistance of the resistor R_v .

One skilled in the art will recognize that values of components in power supply 100 are constrained by tables and formulas that characterize power and energy at which an ignition of a volatile material occurs. In normal operation, the load (not Shown) is connected to output terminals T1 and T2, draws current and voltage is lost across an output resistance. In order to maximize power transfer, it is desired to limit output resistance to that needed to prevent ignition of the volatile material.

It is a problem that adding average current limiting circuit 103 results in additional voltage loss beyond the voltage limits for preventing ignition. Voltage is lost because the voltage conversion resistance add to the total output resistance.

Power supply 200 illustrated in FIG. 2 solves this problem in accordance with the present invention. Power supply 200 is an intrinsically safe power supply that limits current, power and voltage delivered to a load (Not Shown). Voltage limiting circuitry 201 limits the voltage across the load. Voltage limiting circuitry 201 is a zener diode Z1 connected between paths 210 and 220. One skilled in the art will recognize that more than one zener diode may be connected between paths 210 and 220 to limit the voltage. For purposes of this discussion, voltage limiting circuitry 201 limits the voltage across a load (Not Shown) to V_z .

In accordance with the present invention, the functions of limiting the instantaneous and average current are combined into one circuit. The use of one circuit for both functions allows the total output resistance to be reduced to the amount of resistance required to prevent ignition of a volatile material. This is accomplished by moving components of the average current limiting circuits to a point after the instantaneous current limiting circuitry. In particular, the variable impedance device, transistor Q1 is moved to a point after the barrier circuitry. The location of the variable impedance device creates two new paths to output terminals T1 and T2. The new paths are the operational amplifier OA output and the feedback from a conversion resistor. The total output resistance is a parallel

combination of resistors along the two new paths and path 210 to power source PS.

In power supply 200, the current limiting circuit 202 in accordance with the present invention is provided in the following manner. A source of Metal-Oxide
5 Semiconductor Field-Effect Transistor, or MOSFET, transistor Q1 is connected to negative output terminal T2. A barrier resistor R3 is connected along path 220 between transistor Q1 and power source PS. A second resistor R2 is connected between a drain of transistor Q1 and an input of operational amplifier OA to generate a comparison voltage. Operational amplifier OA has a lower input
10 connected to resistor R2 and it receives a reference voltage Ref on its upper input. Operational amplifier performs a comparison and applies a current to a gate of transistor Q1 to adjust the impedance of transistor Q1. Resistor R1 is connected between the output of operational amplifier OA and the gate of transistor Q1. Those skilled in the art will recognize that the values of Resistors R1, R2, and R3
15 may be large and that the total output resistance is a combination of the three resistors in parallel which is negligibly smaller than the value of the barrier resistance. Thus power transfer is optimized.

One device where power supply 200 is needed is a power supply for electronics in a Coriolis flowmeter operating in a hazardous environment. FIG. 3
20 illustrates a Coriolis flowmeter 300 incorporating power supply 200. Coriolis flowmeter 300 includes a flowmeter assembly 310 and meter electronics 350. Meter electronics 350 are connected to a meter assembly 310 via leads 320 to provide for example, but not limited to, density, mass-flow-rate, volume-flow-rate, and totalized mass-flow rate information over a path 375. A Coriolis flowmeter
25 structure is described although it should be apparent to those skilled in the art that the present invention could be practiced in conjunction with any apparatus having intrinsically safe circuits requiring an intrinsically safe power supply.

A Coriolis flowmeter structure is described although it should be apparent to those skilled in the art that the present invention could be practiced in conjunction
30 with any apparatus having a vibrating conduit to measure properties of material flowing through the conduit. A second example of such an apparatus is a vibrating tube densitometer which does not have the additional measurement capability provided by a Coriolis mass flowmeters.

Meter assembly 310 includes a pair of flanges 301 and 301', manifold 302 and conduits 303A and 303B. Driver 304, pick-off sensors 306 and 306' and temperature sensor 307 are connected to conduits 303A and 303B. Brace bars 305 and 305' serve to define the axis W and W' about which each conduit
 5 oscillates.

When Coriolis flowmeter 300 is inserted into a pipeline system (not shown) which carries the process material that is being measured, material enters flowmeter assembly 310 through flange 301, passes through manifold 302 where the material is directed to enter conduits 303A and 303B. The material then flows
 10 through conduits 303A and 303B and back into manifold 302 from where it exits meter assembly 310 through flange 301'.

Conduits 303A and 303B are selected and appropriately mounted to the manifold 302 so as to have substantially the same mass distribution, moments of inertia and elastic modules about bending axes W-W and W'-W', respectively. The
 15 conduits 303A-303B extend outwardly from the manifold in an essentially parallel fashion.

Conduits 303A-303B are driven by driver 304 in opposite directions about their respective bending axes W and W' and at what is termed the first out of phase bending mode of the flowmeter. Driver 304 may comprise any one of many well
 20 known arrangements, such as a magnet mounted to conduit 303A and an opposing coil mounted to conduit 303B and through which an alternating current is passed for vibrating both conduits. A suitable drive signal is applied by meter electronics 350 to driver 304 via path 312.

Pick-off sensors 306 and 306' are affixed to at least one of conduits 303A and 303B on opposing ends of the conduit to measure oscillation of the conduits.
 25 As the conduit 303A-303B vibrates, pick-off sensors 306-306' generate a first pick-off signal and a second pick-off signal. The first and second pick-off signals are applied to paths 311 and 311'. The driver velocity signal is applied to path 310.

Temperature sensor 307 is affixed to at least one conduit 303A and/or 303B.
 30 Temperature sensor 307 measures the temperature of the conduit in order to modify equations for the temperature of the system. Path 311" carries temperature signals from temperature sensor 307 to meter electronics 350.

Meter electronics 350 receives the first and second pick-off signals appearing on paths 311 and 311', respectively. Meter electronics 350 processes

the first and second velocity signals to compute the mass flow rate, the density, or other property of the material passing through flowmeter assembly 10. This computed information is applied by meter electronics 350 over path 375 to a utilization means (not shown).

5 It is known to those skilled in the art that Coriolis flowmeter 300 is quite similar in structure to a vibrating tube densitometer. Vibrating tube densitometers also utilize a vibrating tube through which fluid flows or, in the case of a sample-type densitometer, within which fluid is held. Vibrating tube densitometers also employ a drive system for exciting the conduit to vibrate. Vibrating tube
10 densitometers typically utilize only single feedback signal since a density measurement requires only the measurement of frequency and a phase measurement is not necessary. The descriptions of the present invention herein apply equally to vibrating tube densitometers.

 In Coriolis flowmeter 300, the meter electronics 350 are physically divided
15 into 2 components a host system 370 and a signal conditioner 360. In conventional meter electronics, these components are housed in one unit.

 Signal conditioner 360 includes drive circuitry 363 and pick-off conditioning circuitry 361. One skilled in the art will recognize that in actuality drive circuitry 363 and pick-off conditioning circuitry 361 may be separate analog circuits or may be
20 separate functions provided by a digital signal processor or other digital components. Drive circuitry 363 generates a drive signal and applies the drive signal to driver 304 via path 312 of path 320. In actuality, path 312 is a first and a second lead. Drive circuitry 363 is communicatively connected to pick-off signal conditioning circuitry 361 via path 362. Path 362 allows drive circuitry to monitor
25 the incoming pick-off signals to adjust the drive signal. Power to operate drive circuitry 363 and pick-off signal conditioning circuitry 361 is supplied from host system 370 via a first wire 373 and a second wire 374. First wire 373 and second wire 374 may be a part of a conventional 2-wire, 4-wire cable, or a portion of a multi-pair cable.

30 Pick-off signal conditioning circuitry 361 receives input signals from first pick-off 305, second pick-off 305', and temperature sensor 307 via paths 311, 311' and 311". Pick-off circuitry 361 determines the frequency of the pick-off signals and may also determine properties of a material flowing through conduits 303A-303B. After the frequency of the input signals from pick-off sensors 305-305' and

properties of the material are determined, parameter signals carrying this information are generated and transmitted to a secondary processing unit 371 in host system 370 via path 376. In a preferred embodiment, path 376 includes 2 leads. However, one skilled in the art will recognize that path 376 may be carried
5 over first wire 373 and second wire 374 or over any other number of wires.

Host system 370 includes a power supply 372 and processing system 371. Power supply 372 receives electricity from a source and converts the received electricity to the proper power needed by the system. Processing system 371 receives the parameter signals from pick-off signal conditioning circuitry 361 and
10 then may perform processes needed to provide properties of the material flowing through conduits 303A-303B needed by a user. Such properties may include but are not limited to density, mass flow rate, and volumetric flow rate.

In this embodiment, power supply 372 includes the circuitry of power supply 200 shown in Fig. 2. This allows power supply 372 to provide power meeting
15 intrinsically safe limits to signal conditioner 360 which includes circuitry meeting intrinsically safe standards.

What is claimed is:

1. An intrinsically safe circuit (200) configured for supplying power to a load connected to a first output terminal (T1) and a second output terminal (T2), said circuit
 5 comprising:

a power supply source (PS);

a voltage limiter (Z1) connected in parallel with said power supply source to limit a maximum voltage generated by said power supply source;

a connection between a first side of said voltage limiter and said first terminal;

10 and

a current limiter (202) comprising:

a reference voltage;

a variable impedance;

a barrier resistor; and

15 a second side of said voltage limiter is connected in series with said barrier resistor and said variable impedance to said second output terminal;

said current limiter limits a current delivered to said load via said terminals to a maximum current level in response to a comparison of said reference voltage with a voltage across said barrier resistor representative of the current delivered to said load.

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2. The intrinsically safe circuit of claim 1 further comprises a fuse (F1) connected between a positive voltage side of the power supply source and the voltage limiting circuit.

25 3. The voltage limiter of claim 1 comprises a diode that has a cathode connected to the positive side of the power supply source and further has an anode connected to the negative side of the power supply source.

4. The voltage limiting circuit of claim 3 characterized in that the diode
 30 comprises a zener diode.

5. The current limiter and variable impedance of claim 1 comprises:
 said variable impedance comprises a transistor for controlling the current level through the load, said transistor is connected to the second output terminal;

an operational amplifier (OA) that controls the impedance of the transistor and has an output connected to a gate of the transistor, and further has a first input connected to a voltage representing said load current and further has a second input connected to said reference voltage; and

- 5 a voltage divider including said barrier resistor for generating a voltage level that is representative of said load current, said voltage divider is connected to the first input of the operational amplifier, and to the negative side of the power supply source.

6. The current limiter of claim 5 further comprises a resistor (R1) connected
10 between the output of the operational amplifier and the gate of the transistor.

7. The current limiting circuit of claim 5 in which the transistor comprises a Metal Oxide Semiconductor Field Effect Transistor (MOSFET).

- 15 8. The current limiter of claim 5 in which the voltage divider comprises:
 a first resistor (R2) connected between the first input of the operational amplifier and drain of the transistor; and
 a second resistor (R3) having one end connected to said drain and a second
 end connected to the negative side of the power supply source.

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9. The intrinsically safe circuit of claim 1 characterized in that the load
comprises electronics of the Coriolis flowmeter having a signal conditioner circuit for
generating a drive signal and for receiving pick-off signals, said signal conditioner
circuit is connected to the first and second output terminals of the intrinsically safe
25 circuit.

10. The signal conditioner circuit of claim 9 further comprising:
 a drive circuit for generating said drive signal, said drive circuit is connected to
the first and second output terminals of the intrinsically safe circuit; and
30 a conditioning circuit for receiving the pick-off signals, said conditioning circuit
has an input connected to an output of the drive circuit.

11. A method of operating an intrinsically safe circuit for supplying power to a
load, said method comprises the steps of:

connecting a voltage limiter connected in parallel with a power supply source to limit a maximum voltage generated by said power supply source;

extending a connection between a first side of said voltage limiter and a first terminal;

5 connecting a second side of said voltage limiter in series with a barrier resistor and a variable impedance to a second output terminal; and;

limiting a current delivered to said load via said terminals to a maximum current level in response to a comparison of a reference voltage with a voltage across said barrier resistor representative of the current delivered to said load.

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12. The method of claim 11 characterized in that the step of limiting the voltage level includes operating a diode to limit said voltage.

13. The method of claim 12, in which the step of operating a diode includes
15 the step of operating a zener diode.

14. The method of claim 11 further comprises the steps of:

applying intrinsically safe power from said terminal to a drive circuit of a Coriolis flowmeter; and

20 generating a drive signal with the drive circuit in response to the reception of said power.

15. The method of claim 14 further comprises the step of applying pick-off signals to a conditioning circuit of said Coriolis flowmeter in response to the reception
25 of said power.

16. The method of claim 11 characterized in that the step of limiting the current comprises the steps of:

operating a voltage divider to generate a voltage level that is representative of
30 the load current;

operating the operational amplifier to compare a reference voltage with said voltage level representing the load current; and

extending a signal from an output of the operational amplifier to a control input of a transistor for limiting a current to a maximum level through the load.

17. The method of claim 16 characterized in that the step of actuating the transistor includes the step of operating a MOSFET.