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G1N
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(54) **Two-wire differential pressure transmitter**

(57) A two-wire differential pressure transmitter comprises a pressure sensor 20 having a pressure-sensitive element 21, 22 for converting a change in a pressure into a resistance change to produce an electric signal indicative of the pressure change, a temperature detector 23 having a thermosensitive element 24 disposed in the vicinity of the pressure-senstive element for generating an electric signal indicative of a change in ambient temperature, a memory 31 for storing in advance data on relationships of the electric signal from the pressure sensor with respect to the pressure and the ambient temperature, an arithmetic and logic circuit 30 responsive to the electric signals from the pressure sensor and the temperature detector for reading corresponding data out of the memory to compute the pressure applied to the pressure-sensitive element, and a circuit 32 for converting an output signal from the arithmetic and logic circuit into an analog electric signal and delivering the latter over a two-wire transmission line.

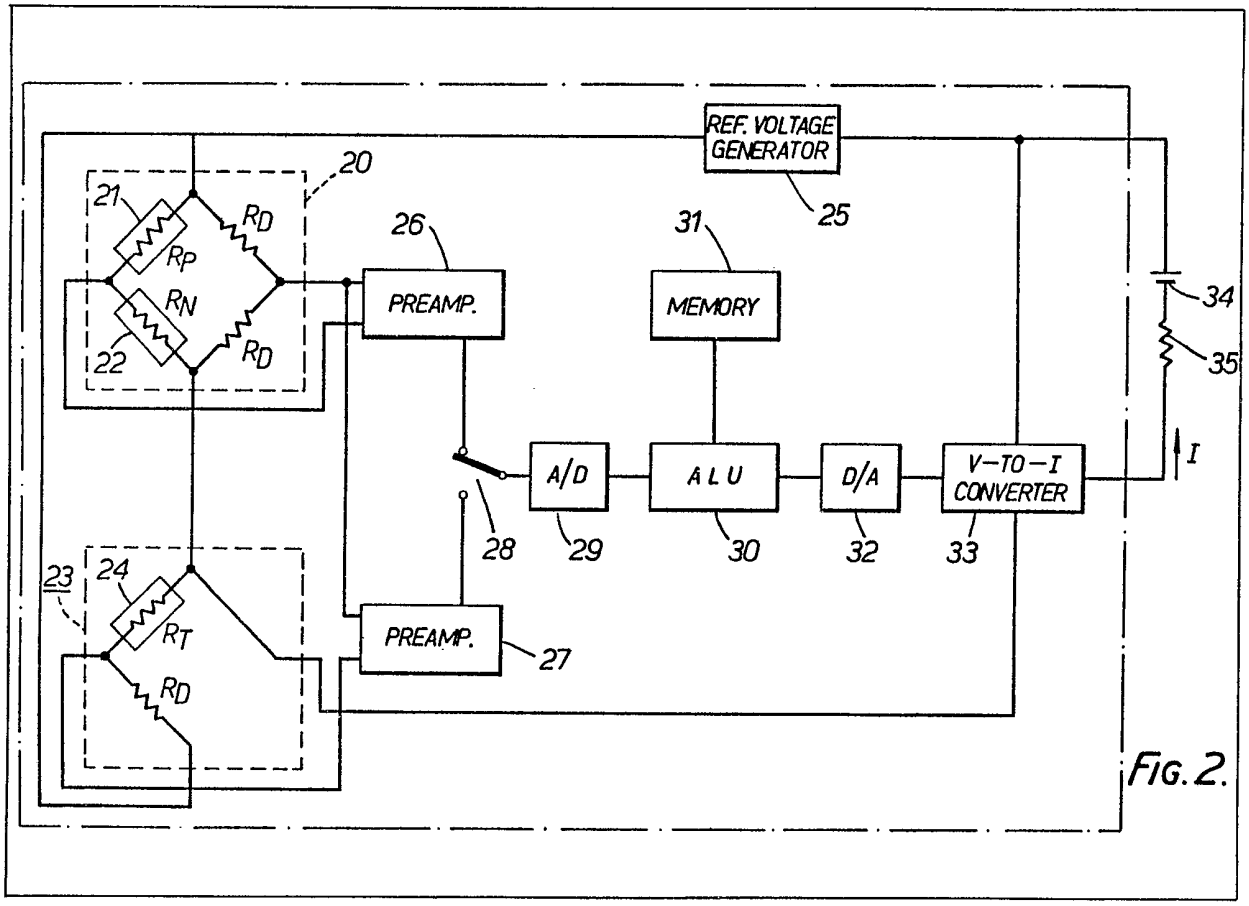

FIG. 2.

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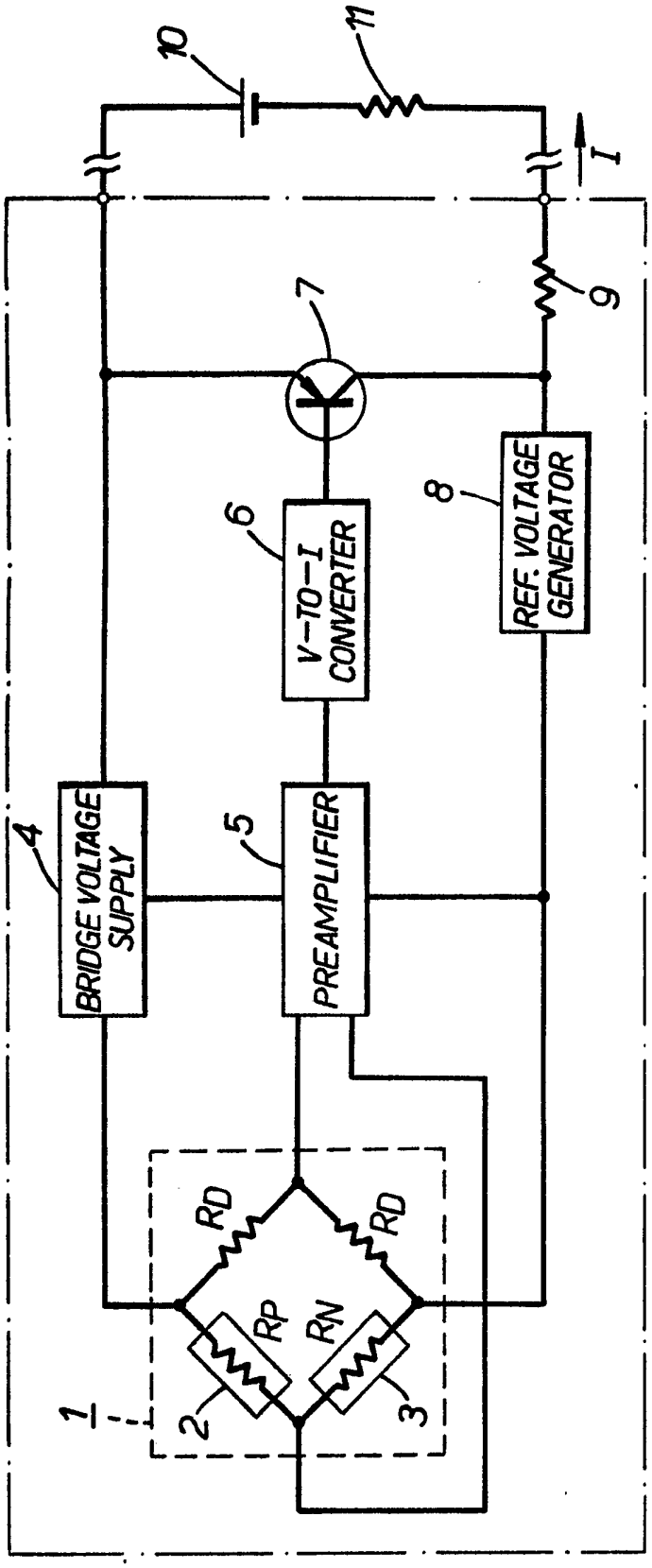
The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.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I
9
7
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6
V–TO–I CONVERTER
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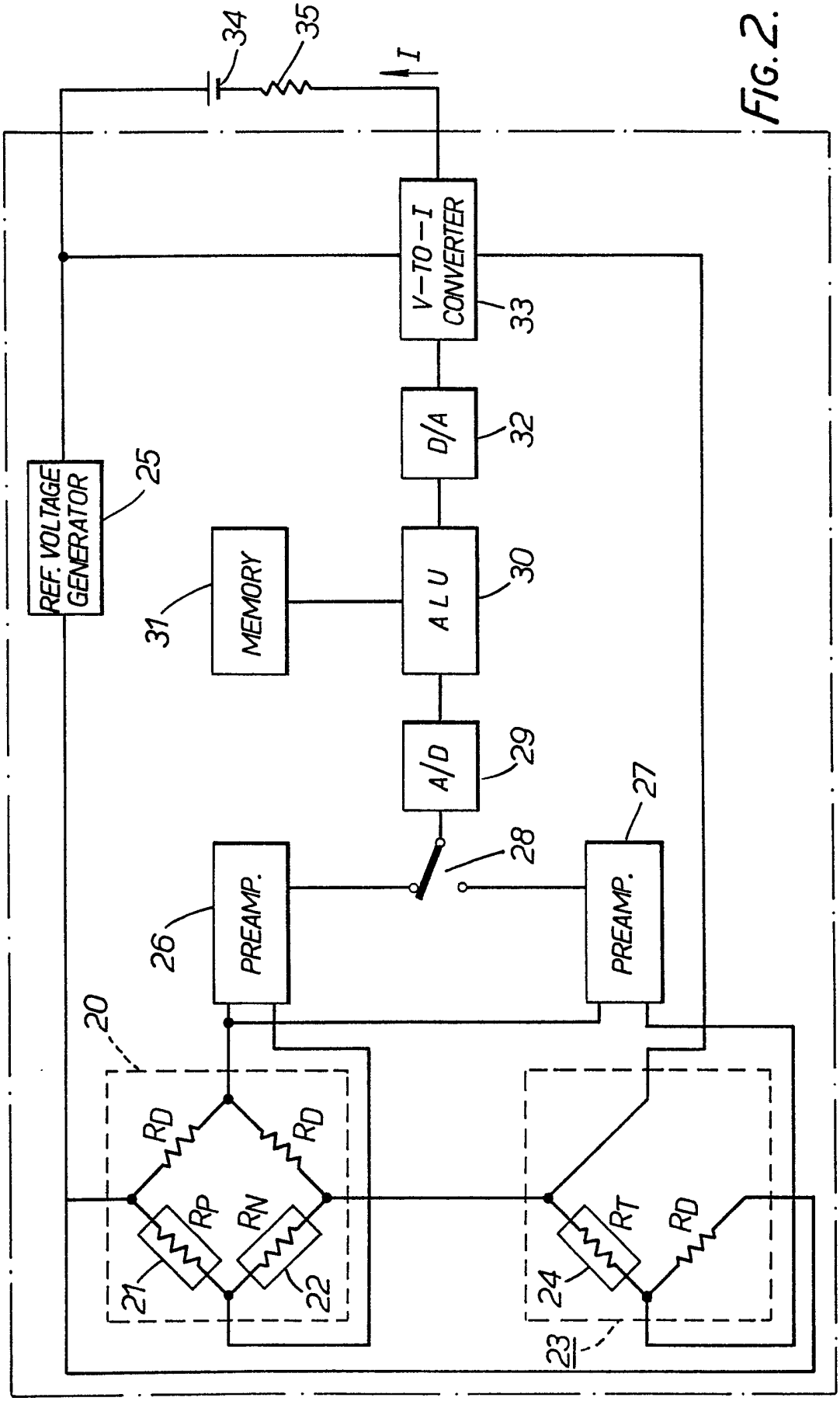
BRIDGE VOLTAGE SUPPLY
5
PREAMPLIFIER
RD
RD
RP
RN
1
2
3

FIG. 1.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D/A
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REF. VOLTAGE GENERATOR
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PREAMP.
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PREAMP.
20
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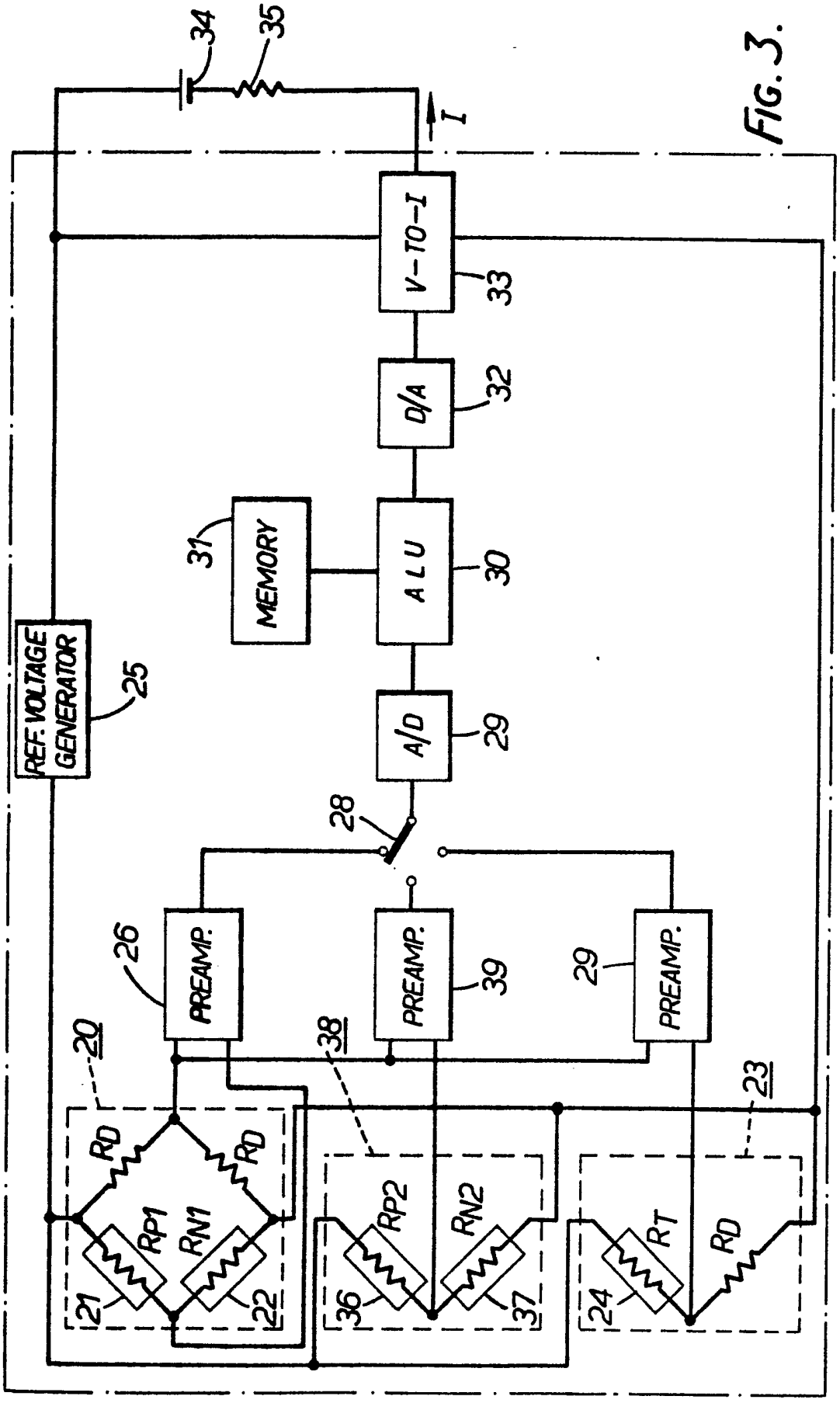
FIG. 2.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29
28
PREAMP.
26
PREAMP.
39
PREAMP.
29
20
38
23
RD
RD
RP1
RN1
21
22
RP2
RN2
36
37
RT
RD
24

FIG. 3.

SPECIFICATION

Two-wire differential pressure transmitter

The present invention relates to a two-wire differential pressure transmitter for transmitting over a two-wire transmission path an electric output signal indicative of a pressure detected by pressure-sensitive elements.

Figure 1 of the accompanying drawings illustrate a conventional two-wire differential pressure transmitter. The transmitter includes a two-active-arm bridge circuit 1 which constitutes a central portion of a pressure sensor and has in its two active arms semiconductor pressure-sensitive elements 2, 3 for converting a pressure change into a resistance change. Each of semiconductor pressure-sensitive elements 2, 3 may for example be composed of a piezoresistance element formed on a silicon monocrystal plate and having a resistance variable with pressure applied due to piezoresistance effect. The semiconductor pressure-sensitive elements are attached to diaphragms, for example, of the differential pressure transmitter for detecting a differential pressure resulting from a pressure change. Arrangements for such pressure-sensitive elements are known and described in detail in various publications such as Japanese Patent No. 1024493 (Japanese Patent Publication No. 55—2742) and Japanese Patent No. 1008719 (Japanese Patent Publication No. 54—41309).

Although in Figure 1 the pressure-sensitive elements 2, 3 are in the two legs of the bridge, a full or four-active-arm bridge arrangement may be employed in which pressure-sensitive elements are placed respectively in all bridge arms. In Figure 1, the two other arms have reference resistors R_D, and internal resistances of the pressure-sensitive elements 2, 3 are indicated as R_P, R_N, respectively. The bridge circuit 1 is supplied with a voltage from a bridge voltage supply circuit 4. An output signal from the bridge circuit 1 is amplified by a preamplifier 5, and an amplified signal generated by the preamplifier 5 is converted into a current by a voltage-to-current converter 6. A current control element 7 is controllable by a current supplied from the voltage-to-current converter 6. The differential pressure transmitter also includes a reference voltage generator 8 and a resistor 9 connected thereto, and is connected to an external reference power supply 10 for normally producing a voltage of DC 24 V and an external load resistor which normally has a resistance of 500 ohms at maximum.

Operation of the differential pressure transmitter of Figure 1 is as follows:

Electric power supplied from the external reference power supply 10 is converted by the reference voltage generator 8 into a fixed voltage for energising the pressure detector. The voltage is applied to the bridge circuit 1 through the bridge voltage supply circuit 4. The bridge circuit 1 is kept in balance as long as no pressure is applied thereto, and no output is fed therefrom to the preamplifier 5.

When a pressure is exerted on the pressure-sensitive elements 2, 3, the bridge circuit 1 is brought out of balance and generates an output voltage which is amplified by the preamplifier 5 and then converted by the voltage-to-current converter 6 into a current I (in the range of from 4 to 20 mA DC) which is proportional to the pressure imposed and passed through a two-wire signal line in the direction of the arrow.

The two-wire differential pressure transmitter as shown in Figure 1 is quite simple in construction and inexpensive to fabricate provided the output voltage from the bridge circuit is variable linearly with pressure and the pressure-sensitive elements 2, 3 are completely free from thermal effects. Strictly speaking, however, the prior differential pressure transmitter actually suffers from small degrees of non-linearity in the output voltage characteristics of the bridge circuit with respect to the pressure. In order to effect pressure detection with high precision, it has been necessary that a circuit arrangement be made to compensate for the non-linear output voltage, or the pressure-sensitive elements be fabricated with high precision by way of sophisticated technology.

Where semiconductor pressure-sensitive elements are incorporated, a temperature compensation circuit is required as such pressure-sensitive elements are easily affected by temperature changes. Various temperature compensation circuits have heretofore been proposed. In any case, however, circuit elements should be selected dependent on the characteristics of the pressure-sensitive elements, or an adjustment should be made as by a variable resistor. Accordingly, the compensation circuit has been complex, and many steps of compensation have been required. There is one known system in which the outputs from a plurality of pressure sensors are supplied to and corrected by a large-size computer. This system however has proven unsatisfactory in that it is adversely affected by interference between the pressure sensors and is influenced by the signal transmission paths.

Therefore, the present invention seeks to provide a two-wire differential pressure transmitter of high precision which requires a simplified compensation process.

The present invention also seeks to provide a differential pressure transmitter having means for compensating for non-linear output characteristics with respect to pressure such that the transmitter will produce the same pressure signal for the same pressure difference irrespective of a pressure measurement range selected.

The present invention also seeks to provide a differential pressure transmitter having all circuit sections accommodated in a single casing.

According to the present invention, there is provided a differential pressure transmitter having a temperature detector and a line-pressure sensor in the vicinity of the pressure-sensor of the transmitter for compensating the output signal from the pressure sensor by means of output

signals from the temperature detector and the line-pressure sensor.

A preferred form of two-wire differential pressure transmitter according to the invention comprises a pressure sensor having a pressure-sensitive element for converting a change in a pressure into a resistance change to produce an electric signal indicative of the pressure change, a temperature detector having a thermosensitive element disposed in the vicinity of the pressure-sensitive element for generating an electric signal indicative of the ambient temperature in the vicinity of the pressure-sensitive element, a memory for storing in advance data on relationships of the electric signal from the pressure sensor with respect to the pressure and the ambient temperature, an arithmetic and logic circuit responsive to the electric signals from the pressure sensor and the temperature detector for reading corresponding data out of the memory to compute the pressure applied to the pressure-sensitive element, and a circuit for converting an output signal from the arithmetic and logic circuit into an analog electric signal and delivering the latter over a two-wire transmission line.

Some embodiments of the present invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a circuit diagram, partly in block form, of a conventional two-wire differential pressure transmitter as described above;

Figure 2 is a circuit diagram, partly in block form, of a two-wire differential pressure transmitter according to an embodiment of the present invention; and

Figure 3 is a circuit diagram, partly in block form, of a two-wire differential pressure transmitter according to another embodiment of the present invention.

The two-wire differential pressure transmitter of Figure 2 includes a bridge circuit 20 which constitutes a pressure sensor and which comprises a pair of pressure-sensitive elements 21, 22 and a pair of reference resistors R_D, R_D. The pressure-sensitive elements 21, 22 preferably comprise semiconductor pressure-sensitive elements bonded on a single chip and attached to transmitter diaphragms. A temperature detector 23 comprises a bridge circuit having in one arm thereof a thermosensitive element 24 disposed adjacent to the pressure-sensitive elements 21, 22. The pressure-sensitive elements 21, 22 and the thermosensitive elements 24 may be separately formed or fabricated on one semiconductor substrate. The bridge circuits 20, 23 and other circuit components are supplied with a voltage from a reference voltage generator 25. Output signals from the bridge circuits 20, 23 are amplified respectively by preamplifiers 26, 27 of a known arrangement each composed of a plurality of operational amplifiers. The preamplifiers 26, 27 are selected one at a time by a multiplexer 28 which is connected to an A/D converter 29 for converting an analog signal from the multiplexer 28 into a digital signal. The digital signal from the A/D converter 29 is processed into a predetermined signal by an arithmetic and logic circuit 30 comprising a microcomputer. The signal from the arithmetic and logic circuit 30 is stored in a memory 31 and also converted by a D/A converter 32 into an analog signal. The circuits 29 through 32 are of a known construction. The multiplexer 28 is controlled by an output port of the arithmetic and logic circuit 30. A voltage-to-current converter 33 of a known circuit arrangement serves to convert an output from the D/A converter 33 into a current signal in the range of from 4 to 20 mA DC, for example, which is proportional to a pressure applied to the pressure sensor, and also serves to deliver out the current signal to a two-line transmission line. An external power supply 34, which normally supplies DC 24 V, and an external load resistor 35, which is normally up to 500 ohms at maximum, are connected in series to the differential pressure transmitter. A voltage developed across the load resistor 35 is indicative of the differential pressure or the pressure imposed on the pressure sensor. All the circuit components described above except the reference power supply 34 and the load resistor 35 are housed in a single transmitter casing to facilitate use, maintenance and servicing.

The two-wire differential pressure transmitter thus constructed will operate as follows:

Electric power is supplied from the reference power supply 34 to drive the bridge circuits 20, 23 through the reference voltage generator 25. When a pressure is applied to the pressure-sensitive elements 21, 22 in the bridge circuit 20, their resistances are changed to cause a bridge unbalance, whereupon the bridge 20 produces an output voltage which is amplified by the preamplifier 26. As shown in Figure 2, the pressure-sensitive elements 21, 22 in the corresponding arms of the bridge circuit 20 are arranged such that an increase in the resistance of one of the pressure-sensitive elements 21, 22 will result in an equivalent reduction in the resistance of the other pressure-sensitive element for linearising the output voltage variation with respect to the resistance variation.

When the ambient temperature changes, the resistance of the thermosensitive element 24 in the bridge circuit 23 varies to bring the latter out of balance. The bridge circuit 23 thus generates an output voltage dependent on a variation in the ambient temperature, and the output voltage from the bridge circuit 23 is amplified by the preamplifier 27.

Since the output voltage from the bridge circuit 20 varies with the pressure applied at a rate determined solely by the characteristics of the pressure-sensitive elements 21, 22, the output voltage is subjected to the same change for a given pressure imposed as long as the ambient temperature remains unchanged. The characteristics with which the output voltage from the bridge circuit 20 will vary with pressure are determined in advance at the manufacturing

stage, and the data on the pressure-dependent output voltage variation curve is stored in the memory 31 by virtue of approximation using line segments. The data is stored as a two-dimensional table in a RAM of the memory 31 and serves as a program for corrective arithmetic operations. Likewise, the characteristics with which the output voltage from the bridge circuit 20 will vary with temperature are determined in advance at the manufacturing stage, and the data on the temperature-dependent output voltage variation curve is stored in the memory 31.

To detect the pressure imposed on the bridge circuit 20, the contents of the memory 31 are read out by the arithmetic and logic circuit 30 under the command of a read signal indicative of the output voltage of the bridge circuit 20 and information on an ambient temperature, which is provided by the bridge circuit 23 that produces an output signal responsive to the ambient temperature.

The outputs from the preamplifiers 26, 27 are switched by the multiplexer 28 so as to be supplied to the arithmetic and logic circuit 30, which reads out a pressure-indicative electric signal corresponding to the supplied signals to effect corrective arithmetic operations for computing the pressure applied to the bridge circuit 20. The A/D converter 29 serves to convert the analog signals from the preamplifiers 26, 27 into digital signals for allowing digital processing of such corrective arithmetic operations. The arithmetic and logic circuit 30 and the memory 31 are preferably in the form of a microcomputer programmed for obtaining desired data on corrected pressures.

An output signal from the arithmetic and logic circuit 30 is converted by the D/A converter 32 into an analog signal which is then converted by the voltage-to-current converter 33 into a current output signal in the range of from 4 to 20 mA DC.

The components incorporated in the foregoing circuit arrangement should preferably have low power consumption. For example, where the reference power supply 34 generates a DC voltage of 24V and the load resistor 35 has a resistance of 500 ohms at most to provide an output current ranging from 4 to 24 mA DC, the circuit components should be selected so as to consume about 50 mW or less altogether.

Figure 3 illustrates a two-wire differential pressure transmitter according to another embodiment of the invention. Identical parts shown in Figure 3 are denoted by identical reference characters in Figure 2, and will not be described in detail. The differential pressure shown in Figure 2 is designed to detect the absolute value of a pressure applied. When a pressure difference between line pressures is to be detected, it is necessary to compensate for an error resulting from the line pressures. For instance, the difference between pressures of 50 kPa and 51 kPa is equal to the difference between pressures of 300 kPa and 301 kPa, that is 1 kPa. However, actual measurements suffer from an error due to the difference between the line pressures of 50 kPa and 300 kPa. To compensate for such an error, the differential pressure transmitter of Figure 3 includes a second pressure sensor 38 disposed adjacent to the pressure-sensitive elements 21, 22 and composed of second pressure-sensitive elements 36, 37 for producing an output signal which will be utilised to correct the output from the first pressure sensor 20.

The relationship between outputs from the first pressure sensor 20 and line pressures acting thereon is determined and stored beforehand in the memory 31. In operation, pressure information corresponding to an output from the bridge circuit 38 as amplified by the preamplifier 39 is read out of the memory 31 by the arithmetic and logic circuit 30 to effect a corrective arithmetic operation on an output produced by the first pressure sensor 20 in the arithmetic and logic circuit 30, so that an output signal free from any error which would otherwise be caused by line pressure can be produced.

While in the embodiments shown in Figures 2 and 3 the pressure sensors and the temperature detector have been shown as being composed of bridges, they are not limited to the illustrated bridge circuits, but may be of other circuit arrangements.

In the preferred arrangements of the present invention, the thermosensitive element and additionally the line-pressure-sensitive element are disposed in the vicinity of the pressure-sensitive elements for producing outputs to correct an output from the primary pressure sensor in accordance with stored correction data, and the corrected output is delivered as an analog electric signal over a two-wire transmission line. This eliminates the need for linearising the output characteristics with respect to the pressure applied and compensating for temperature changes by selecting and adjusting circuit components. Accordingly, the process for linearisation and compensation can be simplified.

With the good ability of the pressure-sensitive elements and the thermosensitive element to produce output signals repeatedly at required levels, the preferred form of differential pressure transmitter is capable of generating proper output signals which are corrected at all times during a long period of use. In the conventional transmitter circuits, the pressure-sensitive elements which widely differ as to characteristics cannot be compensated for, and hence cannot be put to use. The transmitter of the invention is advantageous in this respect in that correct compensation is possible to match the characteristics of any particular pressure-sensitive element, and for this reason the yield of pressure-sensitive elements fabricated is increased.

All of the circuit parts of the transmitter according to the present invention are preferably housed in a single casing for facilitated use, maintenance and servicing of the transmitter. With the compensation circuit contained in the

transmitter, the latter can directly be connected to a recorder or warning device, and there is no need to connect the transmitter to a large-size computer for compensation and then to the recorder or warning device, as would heretofore be necessary.

Although certain preferred embodiments have been shown and described, it should be understood that many changes and modifications may be made therein without departing from the scope of the appended claims.

CLAIMS

1. A two-wire differential pressure transmitter comprising:

a first pressure sensor having a first pressure-sensitive element for converting a change in a pressure into an electric signal indicative of the pressure change;

a temperature detector having a thermosensitive element disposed in the vicinity of said pressure-sensitive element for generating an electric signal indicative of the ambient temperature in the vicinity of said pressure-sensitive element;

a memory for storing in advance, data in respect of the relationships of said electric signal from said pressure sensor with respect to said pressure and said ambient temperature;

an arithmetic and logic circuit responsive to said electric signals from said pressure sensor and said temperature detector for reading corresponding data out of said memory to compute the pressure applied to said pressure-sensitive element and

a circuit for converting an output signal from said arithmetic and logic circuit into an analog electric signal and delivering the latter over a two-wire transmission line.

2. A two-wire differential pressure transmitter according to claim 1, wherein said pressure sensor comprises a bridge circuit having said pressure-sensitive element in at least one arm thereof.

3. A two-wire differential pressure transmitter according to claim 1 or claim 2 further comprising a second pressure sensor having a second pressure-sensitive element disposed in the vicinity of said first pressure-sensitive element for producing an electric signal indicative of a line pressure, the said memory being adapted to additionally store data with respect to the relationship of said electric signal from said first pressure sensor with respect to said line pressure, and

said arithmetic and logic circuit being responsive to said electric signals from said first and second pressure sensors and said temperature detectors for reading corresponding data out of said memory to compute the pressure applied to said first pressure-sensitive element.

4. A two-wire differential pressure transmitter according to claim 3, wherein said first and second pressure sensors comprise bridge circuits having said first and second pressure-sensitive elements in at least one arm thereof.

5. A two-wire differential pressure transmitter according to any preceding claim further comprising a casing housing said pressure sensor or sensors, said temperature detector, memory, and circuits.

6. A two-wire differential pressure transmitter substantially as herein described with reference to Figure 2 or Figure 3 of the accompanying drawings.

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