

PATENT SPECIFICATION

(11) 1335 349

DRAWINGS ATTACHED

- (21) Application No. 49801/70 (22) Filed 20 Oct. 1970
 (31) Convention Application No. 869608 (32) Filed 27 Oct. 1969 in
 (33) United States of America (US)
 (44) Complete Specification published 24 Oct. 1973
 (51) International Classification G01R 15/00
 (52) Index at acceptance

G1U 5A2 5CX 5MX
 G1N 1A3A 1A3B 1D5 3S15 3S1B 3S6 4D 7C



(54) TRANSDUCER CIRCUITRY FOR CONVERTING AN INPUT PARAMETER TO A DC CURRENT SIGNAL

(71) We, ROSE MOUNT ENGINEERING COMPANY, a corporation of the State of Minnesota, United States of America, 12001 West 78th Street, Eden Prairie, State of Minnesota 55343 United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a transducer circuit for converting an input parameter to a DC circuit signal flowing through a direct current source and head. The input parameter controls a reactive impedance means. One embodiment provides an output from a capacitance type pressure sensor.

Capacitance sensing circuitry which provides a DC signal accurately proportional to capacitance has been described in British Patent Specification No. 1001806. Also, circuitry which provides a control of direct current through a remote transducer as a function of a DC signal is shown in Patent Application No. 39948/68 (Serial No. 1240493). Many industrial process indicators and controllers are in use which are made to respond to the current from a DC two-wire transmitter, so it has long been desirable to have a transducer which could convert a capacitance sensor output, such as from a capacitance pressure sensor or a capacitance liquid level sensor, to control a direct current supplied to the transducer. The required current control range is commonly required to be 4—20 milliamps, although both higher and lower ranges are also in use. The minimum current is usually of the order of 1—10 milliamps and the transducer voltage drop should generally be as low as possible so that high voltage and excessive power consumption can be avoided. The sensing devices frequently require mathematical operations to be performed on the output signal and this factor together with the requirement of an accurate current control under sometimes

adverse measurement environments has prevented previous solution of the problem.

According to this invention a transducer circuit for converting an input parameter to a DC current signal flowing through a direct current source and a load comprises a pair of excitation terminals for connection to the direct current source and the load, an AC reactive impedance means which varies in impedance as a function of a condition to be measured, an AC generating means energized by current drawn through the excitation terminals and having its output coupled to the AC reactive impedance means for applying an alternating current therethrough, rectification means in circuit with the AC generating means and AC reactive impedance means to provide a first DC signal dependent on the impedance of said AC reactive impedance means, a reference DC source energized through said excitation terminals which provides a second DC signal independent of the variable AC reactive impedance, a current control circuit including an amplifier energized through said excitation terminals and having input signal connection means and providing an output control signal at a level responsive to signals at its input signal connection means, said current control circuit controlling the current through said excitation terminals in response to said control signal, a network including resistances connected to provide arithmetic comparison of a current dependent on both first and second DC signals and the total direct current through the excitation terminals, and means connecting the network to input signal connection means of the amplifier so that a control signal is produced which adjusts the current through said excitation terminals to provide a prescribed relation between total direct current through said excitation terminals and the condition to be measured.

The sole figure is a schematic drawing of a circuit embodiment of the invention as used with a capacitance pressure sensor to provide a specialized computational function

[Price 25p]

Price 75p

and which is used to develop a control of the total circuit current as a desired function of the capacitance.

5 The drawing shows a schematic diagram of a circuit embodiment used in conjunction with a capacitance type differential pressure sensor shown at 10 and including a pair of variable capacitors C_1 and C_2 . In addition to being a particularly useful computation circuit for a capacitance pressure sensor, this circuit embodiment illustrates the detailed operation of converting a capacitance signal to a control signal for direct current supplied to the circuit whereby this direct current is dependent on the capacitance.

10 As shown, the sensor is indicated generally at 10, and in this specific embodiment the measurement circuit includes three capacitors, C_1 , C_2 , and C_3 . In this case the required output is a function of the three capacitances. However, it should be clear that for some measurement applications the sensor may have only one active capacitor and in other instances there may be many more than three capacitors involved in the measurement. Capacitors C_1 , C_2 and C_3 are connected to a charging circuit including secondary transformer windings 11, 12, 13 and 14 which are all closely coupled in phase and amplitude and which are in circuit with the respective diodes 15, 16, 17, 18, 19 and 20. As will be explained later, each capacitor is alternately charged to one polarity and the opposite polarity. Capacitors 22, 23, 24 and 25 provide AC coupling to the capacitors C_1 and C_2 while maintaining DC isolation where required; the capacitors 23 and 25 have also a filtering and smoothing function to be described later. Each of the capacitors C_1 , C_2 and C_3 has a pair of diodes associated with it where one diode allows a charging current to flow to the capacitor in one direction, or polarity, only and the other of the two diodes allows a charging current to flow to the capacitor in an opposite direction, or polarity, only. The charging currents associated with an individual capacitor are then DC signals having an average current amplitude directly proportional to the product of applied peak voltage, frequency, and capacitance so long as the peak voltages of the signals are of sufficient duration to substantially fully charge the capacitors each cycle and neglecting the forward volt drop of the diodes. The polarity of the charging currents are defined by the diodes. Such circuitry has been previously described in British Patent Specification No. 1001806. The currents from the capacitors C_1 , C_2 and C_3 may be filtered and smoothed for example by capacitors 23 and 25 across their resistors 45 and 44, respectively, and the currents may then be subjected to prescribed arithmetical operations such as addition, subtraction, multiplication and division. Several examples of possible

functions are given in the referenced patents, but the circuits disclosed herein show additional improvements as described more fully below. For this description it is necessary to realize that each combination of an AC excitation means (shown herein as transformer windings 11, 12, 13 and 14, respectively) and its associated diode and sensor capacitance provides a DC signal proportional to that capacitance. As shown, two currents flow proportional to capacitor C_1 , one of which is a charge current having a first polarity and passing in one direction through line 11A, winding 11 and diode 17 to capacitor C_1 and the other having a second, opposite polarity and passing from capacitor C_1 through winding 12 and line 12A. Similar action occurs with respect to capacitor C_2 where line 13A connects to winding 13 and line 14A connects to winding 14. With respect to capacitor C_3 a current having a first polarity flows from winding 14 through line 15A and diode 15 to capacitor C_3 , and a second current of opposite polarity flows through winding 11, line 16A and diode 16. Excitation of the secondary windings 11-14 and thus the repetitive or cyclic charging of C_1 , C_2 and C_3 is provided by the oscillator shown generally at 30 which has a primary winding 31. A feedback winding 32 and parallel connected capacitor 33 are shown in a conventional oscillator circuit arrangement with the phase shift components, resistor 34 and capacitor 35. The primary winding 31 is in series with the collector of transistor 36 and the output of amplifier 40. The phase shift network 34, 35 and the regenerative loop 32, 33 connect between one end of the primary winding and the base of transistor 36 for providing regenerative action for the oscillator. The frequency of this oscillator circuit is defined primarily by the output circuits comprising the transformer secondary windings and the capacitances associated therewith. In this embodiment the oscillator amplitude is controlled by amplifier 40 which is referred to as the oscillator control amplifier and which responds to direct current input signals, at least one of which comes from one of the capacitors C_1 , C_2 and C_3 .

Amplifier 40 is simply a high gain operational amplifier which delivers an output current to the oscillator in response to a differential input signal between input terminals 42 and 43. Power is supplied from a line 55 from a current source 70. Capacitor 41 connects between the output of amplifier 40 and the degenerative input terminal 42 to provide dynamic stability. In operation, a differential input signal to amplifier 40 is derived from at least one capacitor which is excited by the oscillator output. Accordingly, a differential input signal causes a change of voltage level to the oscillator circuit

thereby changing the amplitude of the oscillator output and hence modifying the DC signal current from the driven capacitor. This "loop" is made degenerative so that the oscillator amplitude is closely controlled as a function of the capacitor. Since the DC signal which controls the amplifiers output is proportional to the product of oscillator voltage and frequency and the capacitor, the resulting amplitude control is therefore a function of frequency and capacitance as well as any other DC input signal applied to the amplifier input terminals 42 and 43. In a simple case of oscillator control, for example, it might be required to simply stabilize the oscillator output against drifts in amplitude or frequency. Such an example of oscillator control is described in British Patent No. 1001806 and similar control could be obtained by the circuit described herein with only slight modification. Note that Zener diode 46 and series resistor 49 introduces a positive current to junction 52 which connects to amplifier input terminal 43 while Zener diode 47 and series resistor 48 introduces a negative current to junction 51 which connects to amplifier input terminal 42. Then C_3 could be employed to supply the stabilizing signal if the polarity of diodes 15 and 16 were reversed so that the positive current from capacitor C_3 would be introduced to junction 51 and the negative current would be introduced to junction 52. (The currents derived from capacitor C_1 and C_2 are assumed to be disconnected from input terminals 42 and 43 for this simple example.) Then the polarities would be such that the product of oscillator frequency and amplitude would be maintained at a constant value by the amplifier control action as a function of capacitor C_3 and reference currents derived from Zeners 46 and 47.

The more complex embodiment shown in detail herein uses an arithmetical combination of currents from C_1 , C_2 , C_3 and from the reference supply derived from Zener diodes 46 and 47. This combination is particularly useful with a differential capacitance sensor such as the oil-filled pressure sensor which is shown in Patent Application No. 49768/70 (Serial No. 1318980) and is shown schematically in this application. Pressures P_1 and P_2 are indicated on opposite sides of a diaphragm 21. Movement of diaphragm 21 under an increase in pressure P_2 causes capacitance C_2 to decrease and capacitance C_1 to increase. If the stationary capacitor plates are small compared to the diaphragm or if the plates are formed somewhat as shown to conform to the shape of a deflecting diaphragm, the differential pressure $P_2 - P_1$ is substantially linearly proportional to the ratio of $(C_1 - C_2)/(C_1 + C_2)$. Since capacitance is directly proportional to dielectric constant and inversely proportional to spacing

between plates, it may be seen that this expression is exactly linear with respect to diaphragm motion and is dependent on the dielectric constant. It has further been found that because of slight nonlinearities which are primarily attributed to capacitance shunts of substantially constant value, the measured differential pressure is even more closely linear to the function $(C_1 - C_2)/(C_1 + C_2 - 2C_3)$ where C_3 is independent of C_1 and C_2 . For this reason the capacitor C_3 is used in the present embodiment, its capacitance being chosen to have the appropriate value such as gives this closer approximation so a linear function. Since each of the excitation windings 11, 12, 13 and 14 together with its associated diode and capacitor provides a DC signal proportional to $1 \pm CV$ depending on the relative polarity of the respective diode, it may be seen from the drawing that the current i_1 delivered to line 50 is proportional to $(C_1 - C_2)fV$. Similarly it may be seen that a zero differential input to amplifier 40 requires that

$$\frac{2E}{R_1} \text{ is proportional to } fV(C_1 + C_2 - 2C_3) \quad 90$$

where E is the voltage across each of the Zeners 46 and 47 and R_1 is the resistance of each of the resistors 48 and 49 and V is the peak-to-peak voltage. The proportionality factors are the same in these expressions for i_1 and

$$\frac{2E}{R_1}$$

and hence the current i_1 on line 50 is found to be

$$i_1 = \frac{2E}{R_1} \left(\frac{C_1 - C_2}{C_1 + C_2 - 2C_3} \right) \quad 100$$

which is the desired function for the differential pressure sensor application. Obviously, any one of a variety of different functions of capacitance may be obtained through different combinations of the individual current sources. It may be noted that as shown all the power required for operation of amplifier 40, oscillator 30, and the Zener reference circuits is derived solely from across lines 55 and 56.

Thus far in the description of the circuit there is provided a resultant current i_1 which is proportional to a particular function of a reactive impedance, (the reactive impedance comprising capacitors C_1 , C_2 and C_3 in the preferred embodiment) and a reference current which is derived from a pair of Zeners 46 and 47 of equal value E and

resistors 49 and 48 of equal value R_1 . Although a capacitor specifically has been illustrated above it is also possible to obtain a DC current as a function of a varying inductor with similar techniques.

For common industrial measurement applications it is desirable to provide a current transmitter which is energized remotely from a DC power supply and which transmitter modifies or controls the total current flowing therethrough to be precisely proportional to a condition being measured. In this case the condition being measured is characterized by a varying capacitance and it has been shown above how this capacitance signal is converted to a current signal of desired proportionality.

The current control portion of the circuit is energized from a remote circuit comprising a DC power supply 60 and series connected load 61. Load 61 is typically a recorder, indicator, or controller, or combination thereof. A DC current is then delivered to circuit means within the dotted lines 70 which is termed a current source since its function is to supply certain parts of the transmitter circuit with a current constrained to a certain maximum level while allowing a variable bypass current to flow to a current control stage designated at 80. Current control stage 80 is regulated by the output of a differential input operational amplifier 90 which responds to a combination of current input signal i_i and the total transmitter current i_T . This combining of currents to provide a resultant signal as a function of i_i and i_T is accomplished within the network designated generally at 53.

Current source 70 comprises a resistor 71 series connected between power supply terminal 72 and the emitter of a transistor 73. The collector of transistor 73 connects to line 55, which supplies current for the aforementioned amplifiers 40 and 90 and thus also for oscillator 30. Capacitor 74 is connected between the base and collector of transistor 73 for dynamic stability and the base of transistor 73 connects to a current bypass line 75. A series combination of Zener diode 77 and diode 78 connect from input terminal 72 to line 75. In operation Zener diode 77 maintains a substantially constant voltage across resistor 71 and hence a substantially constant current to line 55. Diode 78 provides compensation for the base to emitter voltage drop change with temperature of transistor 73.

Current control stage 80 comprises transistor 81 which has its base connected through a resistor 85 to the output of control amplifier 90. The collector to emitter circuit connects through a resistor 82 and a Zener diode 83 to line 56. A resistor 84 is connected between the collector and emitter of transistor 81 to ensure a minimal amount

of current flow through line 75 even when transistor 81 is cut off. The Zener diode 83 maintains the emitter of transistor 81 at a reasonable desired voltage above line 56.

The control amplifier 90 has its negative input terminal 91 connected to a voltage reference junction between substantially equal value resistors 92 and 93 which are series connected between lines 55 and 56. A capacitor 94 is connected between the output of amplifier 90 and input terminal 91 to give dynamic amplifier stability. The amplifier positive input terminal 96 is connected to a junction 97 between the resistors 98 and 99. Resistor 98 connects to line 55 and resistor 99 connects to one end of a resistor 100. The other end of resistor 100 connects to line 56. Resistor 100 has a variable tap 101 which connects to the power return terminal 62. Resistor 98 is also shown as a variable resistor which can be used to adjust the "zero" for the circuit. The variable tap 101 on resistor 100 may be used to adjust the "gain" or "scaling" of the output equation. Line 50 which carries signal current i_i also connects to junction 97.

In operation, the potential of terminal 91 is selected to be very nearly one-half of the potential between lines 55 and 56. The potential at junction 97 and hence also at the positive input terminal 96 is increased for an increasing current i_i . Consider the effect of an increase in pressure P_2 relative to P_1 . This pressure signal moves diaphragm 21 away from the P_2 side giving an increased C_1 and a decreased C_2 thus giving rise to a positive current i_i and positive going signal at junction 97. A positive signal at junction 97 gives a similar signal at terminal 96 which results in a positive signal at the base of current control transistor 81 and subsequent increased current through Zener 83 and a lower portion (between tap 101 and line 56) of resistor 100 (designated R_4). This has the effect of lowering the potential at junction 97 thereby forcing the terminal 96 to the same potential as the reference at terminal 91. The resulting relation between total current i_T and current i_i at balanced conditions then may be readily derived and is

$$i_T = 1/R_4 [(i_i + E/R_3)(R_3 + R_4) - E]$$

where R_3 is the upper portion (between tap 101 and resistor 99) of resistor 100 plus resistor 99. The total output current i_T then is linearly related to the current signal i_i which is in turn a prescribed function of the capacitance to be measured as described above.

As a specific example of operation of the circuitry disclosed herein, circuit components were selected for use with a differential pressure sensor having a change in capacitance of about 300pf representing a full scale pres-

sure signal. Capacitors C_1 and C_2 individually were approximately 150 pf when diaphragm 21 was at its normal at-rest position. Capacitor C_3 was approximately 5 pf and was used to compensate for fixed shunting in the sensor leads. The individual circuit component values are given in Table 1 below.

In addition to the values given in Table 1 three capacitors 65, 66 and 67, each having a value of 0.01 μ f, were connected between the diode sides of windings 11, 12, 13 and 14, respectively, to provide close AC tracking of those excitation windings with respect to both phase and amplitude.

With the specific component values shown and a minimum voltage supply about 22 volts between terminals 62 and 72, the total current i_T can be 4–20 milliamps for a full scale pressure excursion. The current delivered by the transistor 73 to line 55 is in

the order of 3.7 milliamps and is relatively independent of applied voltage at terminal 72. The instrument "zero" may be adjusted over a wide range by means of variable resistor 98 (R_2) and the scale factor or "span" of the instrument may be adjusted by means of tap 101 on resistor 100 which changes the relative value of R_3 and R_4 . Slight corrections in the output function between differential pressure and current i_1 can be modified by choice of value of capacitor C_3 as was discussed in the circuit description for that part of the circuitry. Power supply 60 and load resistor 61 may be located remotely from the remainder of the system with the only real restriction being that load 61 is restricted to approximately 550 Ω maximum for a 20-volt DC supply at 60. These values are for a total output current of 4–20 milliamps and the overall circuit may be readily scaled for different values of current if desired.

TABLE 1

	Symbol	Value and/or Type
45	Capacitors: 22, 23, 24, 25, 35	0.1 μ f
	34	0.0056 μ f
	41, 74, 94	0.022 μ f
	Resistors: 34	220K
	44, 45	500 Ω
50	48, 49	40K
	61, 100	100 Ω
	71	1.3K
	82	50 Ω
	84	470K
55	85	10K
	92, 93	100K
	98	15K
	99	9K
	Diodes: 15, 16, 17, 18, 19, 20, 78	1N914
60	46, 47	1N4571 (6.4V)
	77	1N705A8 (5V)
	83	1N4678 (1.8V)
	Transistors: 36	2N718
	73	2N5322
65	81	2N3440
	Amplifiers: 40, 90	Fairchild 741 I.C. Operational Amplifiers
61	Transformer 31	Primary—50 turns
	Windings: 32	Feedback—2 turns
70	11, 12, 13, 14	Secondaries—250 turns, quadfiler wound Core—18mm A400 3B7—Ferroxcube

In our aforementioned Patent No. 1240493, there is claimed a signal transmitting device for connection to a single pair of wires connected to a load and current supply means in series so that the load current that flows through said load also flows through

said wires, said transmitting device including means for adjusting the flow of current through said load, means providing first and second voltages, the difference between said voltages tending to change in accordance with variation in the magnitude of a variable con-

dition, voltage responsive means to which the first and second voltages are applied for controlling said current flow adjusting means in accordance with the magnitude of the variable condition; resistance means through which at least a portion of the load current flows to provide a voltage that depends on the value of load current, and means connecting said resistance means with said voltage providing means in such a way that the tendency of the difference between said first and second voltages to change is counteracted by variation of the magnitude of said voltage provided by said resistance means, whereby the adjusted load current flowing through said wires and load is representative of the magnitude of said variable condition.

In our aforementioned Patent, there is also claimed a signal transmitting device comprising a pair of current terminals for connection to one end of a pair of wires having a load and current supply means connected in series across the other end thereof so that all of the load current provided by said supply means flows through said load and said current terminals, the transmitting device comprising a controller energized solely from said current terminals including a voltage responsive means and a current adjusting means in circuit with said current terminals controlled by said voltage responsive means, means connected to said voltage responsive means for applying a direct current voltage to said voltage responsive means that tends to change in value in response to a change in magnitude of a variable condition so as to adjust the current through said adjusting means in accordance with the change in magnitude, resistance means in circuit with said current adjusting means so that the current flowing through said adjusting means determines the current flowing through said resistance means and the voltage thereacross, means connecting said resistance means with said voltage applying means to utilize the voltage across said resistance means as determined by the current there-through to counteract the tendency of the value of voltage applied to said voltage responsive means to change, whereby an adjustment in the value of current flowing through said current adjusting means will appear as a change in value of load current which is representative of the change in magnitude of said variable condition.

In our aforementioned Patent, there is also claimed a signal transmitting system comprising current supply means, a load, a pair of wires, said current supply means being connected in series with the load across said pair of wires at one end thereof, a transmitter connected across said wires at the other end thereof, the load current flowing through said wires serving to supply power to the transmitter as well as serving, at the

load, to represent the information transmitted from said transmitter, the transmitter including a voltage responsive current controller for adjusting the current through said wires in response to a voltage derived from an input circuit which tends to change in accordance with the magnitude of a variable condition constituting the information to be transmitted, said input circuit including a resistor connected so at least a portion of load current flows therethrough to provide a voltage thereacross depending on the magnitude of said load current for use by said circuit in maintaining the voltage to the current controller substantially constant, whereby the adjusted load current flowing through said wires and load is representative of the magnitude of said variable condition.

WHAT WE CLAIM IS:—

1. A transducer circuit for converting an input parameter to a DC current signal flowing through a direct current source and a load comprises a pair of excitation terminals for connection to the direct current source and the load, an AC reactive impedance means which varies in impedance as a function of a condition to be measured, an AC generating means energized by current drawn through the excitation terminals and having its output coupled to the AC reactive impedance means for applying an alternating current therethrough, rectification means in circuit with the AC generating means and AC reactive impedance means to provide a first DC signal dependent on the impedance of said AC reactive impedance means, a reference DC source energized through said excitation terminals which provides a second DC signal independent of the variable AC reactive impedance, a current control circuit including an amplifier energized through said excitation terminals and having input signal connection means and providing an output control signal at a level responsive to signals at its input signal connection means, said current control circuit controlling the current through said excitation terminals in response to said control signal, a network including resistances connected to provide arithmetic comparison of a current dependent on both the first and second DC signals and the total direct current through the excitation terminals, and means connecting the network to input signal connection means of the amplifier so that a control signal is produced which adjusts the current through said excitation terminals to provide a prescribed relation between total direct current through said excitation terminals and the condition to be measured.

2. A transducer circuitry as claimed in Claim 1 characterized in that the AC reactive impedance means includes a first capacitor



dition, voltage responsive means to which the first and second voltages are applied for controlling said current flow adjusting means in accordance with the magnitude of the variable condition, resistance means through which at least a portion of the load current flows to provide a voltage that depends on the value of load current, and means connecting said resistance means with said voltage providing means in such a way that the tendency of the difference between said first and second voltages to change is counteracted by variation of the magnitude of said voltage provided by said resistance means, whereby the adjusted load current flowing through said wires and load is representative of the magnitude of said variable condition.

In our aforementioned Patent, there is also claimed a signal transmitting device comprising a pair of current terminals for connection to one end of a pair of wires having a load and current supply means connected in series across the other end thereof so that all of the load current provided by said supply means flows through said load and said current terminals, the transmitting device comprising a controller energized solely from said current terminals including a voltage responsive means and a current adjusting means in circuit with said current terminals controlled by said voltage responsive means, means connected to said voltage responsive means for applying a direct current voltage to said voltage responsive means that tends to change in value in response to a change in magnitude of a variable condition so as to adjust the current through said adjusting means in accordance with the change in magnitude, resistance means in circuit with said current adjusting means so that the current flowing through said adjusting means determines the current flowing through said resistance means and the voltage thereacross, means connecting said resistance means with said voltage applying means to utilize the voltage across said resistance means as determined by the current there-through to counteract the tendency of the value of voltage applied to said voltage responsive means to change, whereby an adjustment in the value of current flowing through said current adjusting means will appear as a change in value of load current which is representative of the change in magnitude of said variable condition.

In our aforementioned Patent, there is also claimed a signal transmitting system comprising current supply means, a load, a pair of wires, said current supply means being connected in series with the load across said pair of wires at one end thereof, a transmitter connected across said wires at the other end thereof, the load current flowing through said wires serving to supply power to the transmitter as well as serving, at the

load, to represent the information transmitted from said transmitter, the transmitter including a voltage responsive current controller for adjusting the current through said wires in response to a voltage derived from an input circuit which tends to change in accordance with the magnitude of a variable condition constituting the information to be transmitted, said input circuit including a resistor connected so at least a portion of load current flows therethrough to provide a voltage thereacross depending on the magnitude of said load current for use by said circuit in maintaining the voltage to the current controller substantially constant, whereby the adjusted load current flowing through said wires and load is representative of the magnitude of said variable condition.

WHAT WE CLAIM IS:—

1. A transducer circuit for converting an input parameter to a DC current signal flowing through a direct current source and a load comprises a pair of excitation terminals for connection to the direct current source and the load, an AC reactive impedance means which varies in impedance as a function of a condition to be measured, an AC generating means energized by current drawn through the excitation terminals and having its output coupled to the AC reactive impedance means for applying an alternating current therethrough, rectification means in circuit with the AC generating means and AC reactive impedance means to provide a first DC signal dependent on the impedance of said AC reactive impedance means, a reference DC source energized through said excitation terminals which provides a second DC signal independent of the variable AC reactive impedance, a current control circuit including an amplifier energized through said excitation terminals and having input signal connection means and providing an output control signal at a level responsive to signals at its input signal connection means, said current control circuit controlling the current through said excitation terminals in response to said control signal, a network including resistances connected to provide arithmetic comparison of a current dependent on both the first and second DC signals and the total direct current through the excitation terminals, and means connecting the network to input signal connection means of the amplifier so that a control signal is produced which adjusts the current through said excitation terminals to provide a prescribed relation between total direct current through said excitation terminals and the condition to be measured.

2. A transducer circuitry as claimed in Claim 1 characterized in that the AC reactive impedance means includes a first capacitor

which varies as a function of the condition to be measured.

3. A transducer circuit as claimed in Claim 2 further characterized in that there is provided a second capacitor, means for feeding an alternating current through the second capacitor from the output of the AC generating means, separate current rectification means in circuit with the AC generating means and second capacitor to provide a third DC signal representative of the magnitude of the second capacitor, reference means providing a fourth signal, a second resistance network means for arithmetic comparison of the third and fourth signals, a control amplifier for said AC generating means energized solely by current drawn through the excitation terminals and having an output in response to signals at its input, the control amplifier input being coupled to receive the signal from the second resistance network so that the control amplifier output signal is a function thereof, and means coupling the output of the control amplifier to the AC generating means so that the AC generating means is controlled as a function of the third and fourth signals.

4. The transducer circuit as claimed in Claim 3 further characterized in that a current regulator providing a substantially constant value of current therethrough is connected to one of the pair of excitation terminals to provide a power supply for the amplifier in the current control circuit and for said control amplifier.

5. The transducer circuit as claimed in Claim 4 further characterized in that the current source comprises a transistor having an emitter, collector and base, a control resistor in series with the transistor emitter and a current source terminal wherein substantially all the current delivered by the current source flows through the control resistor, and a Zener diode connected between the current source terminal and the transistor base to effect a substantially fixed voltage drop across the control resistor.

6. The transducer circuit as claimed in Claim 2 further characterized in that the AC generating means and rectification means feed repetitive current pulses of opposite polarity, alternately to the first capacitor, and feed repetitive current pulses of opposite polarity alternately to a second capacitor, the generating means and rectification means providing charge currents to charge the first and second capacitors respectively to a first polarity during each positive pulse, and to

a second opposite polarity during each negative pulse, said rectification means providing separate unidirectional current paths for the respective currents of opposite polarity to the first and second capacitors so that the respective charge currents are separately measured or combined in a prescribed manner to give a resultant unidirectional current signal which is a function of the capacitance of the first and second capacitors and of the frequency and amplitude of the AC generating means.

7. The transducer circuit as claimed in Claim 6 further characterized in that the AC generating means comprises an oscillator controlled so that the product of the oscillator amplitude and frequency is a function of the magnitude of the first and second capacitors and the second DC voltage.

8. The transducer circuit as claimed in Claim 7 further characterized in that the AC generating means are coupled to the reactive impedance means by four separate secondary transformer windings each in series circuit with a separate current rectifier, each of the first and second capacitors having separate windings for providing pulses of opposite polarity.

9. The transducer circuit as claimed in Claim 7 further characterized in that the oscillator output is controlled to be directly proportional to the second reference DC voltage and inversely proportional to a magnitude including the sum of the capacitances of the first and second capacitors, and that there is provided second means to provide a third voltage signal proportional to the difference of currents from the first and second capacitors respectively so that the third voltage signal is directly proportional to the difference in magnitude of the first and second capacitors and is inversely proportional to a magnitude including the sum of capacitance of the first and second capacitors.

10. The transducer circuit as claimed in Claim 9 characterized in that there is provided a third capacitor and means coupling said third capacitors to said AC generating means to provide direct currents proportional to the capacitance of the third capacitor, and means to combine a direct current proportional to the capacitance of the third capacitor with the currents proportional to the capacitances of the first and second capacitors to provide a modified first voltage signal which is proportional to the magnitude of the first capacitor plus the magnitude of the



second capacitor minus twice the magnitude of the third capacitor.

11. A transducer circuit substantially as hereinbefore described with reference to the accompanying drawing.
- 5

BOULT, WADE & TENNANT,
111 & 112 Hatton Garden,
London, E.C.1.
Chartered Patent Agents,
Agents for the Applicant(s).

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1973.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

