

Description

This invention relates to a transmitter which senses a parameter, such as a pressure, and provides an output representative of the sensed parameter.

The transmitter comprises generating means coupled to sense the parameter. The generating means comprise reactance means coupled to the sensed parameter. The generating means generate a quantity of charge packets and provides a generator signal comprising the charge packets. The generator signal is responsive to the sensed parameter. The transmitter further comprises measurement means coupled to the generating means for measuring the generator signal as a function of the reactance means. The measurement means provide a measurement signal as a function of the reactance means. The transmitter further comprises feedback means coupled to the measurement means. The feedback means provide a feedback signal to the generating means as a function of the measurement signal. The feedback means provide an output signal representative of the quantities of charge packets generated in a measurement interval.

US-A-4054833 (Briefer) discloses a capacitance measuring system which includes a sensing network with two series capacitors, at least one of which is a sensor capacitor. A switching network and a feedback network are coupled to the sensing network. The feedback network generates a feedback signal representative of the difference in charge stored on the series capacitors from a predetermined value. A switching network connects the feedback and sensor networks with the feedback signal and externally applies reference potentials throughout a cycle, and the average charge stored in the series capacitors over each cycle is substantially equal to the predetermined value.

EP-A-0040996 (Bendix) discloses a digital pressure measuring system having a primary pressure transducer with a pressure sensitive capacitor and a pressure insensitive reference capacitor. Both of these capacitors are excited by out-phase signals and their outputs are combined at a summing junction, the output of which controls a counter. The counter output is converted to a non-linear negative feedback signal by a D to A converter which excites a second pressure sensitive capacitor and a second pressure insensitive capacitor with out-of-phase signals which are included in a feedback pressure transducer. A closed loop is formed by applying the non-linear negative feedback signal appearing at the output of the feedback pressure transducer to the summing junction. The counter is incremented in a direction to null the loops such that its output is representative of the measured pressure.

US-A-4181460 (Dauge et al) shows a capacitance measuring circuit in which there is a variable ca-

pacitor and a reference capacitor. The circuit selectively connects either the reference capacitor or the variable capacitor into a relaxation oscillator and compares a count of the number of pulses reduced by the relaxation oscillator during a measurement period with the number of pulses produce during a reference period.

US-A-4187459 (Wolfendale) shows a circuit for measuring a ratio of capacitances. Switches are provided to apply either a positive-going rectangular wave form or a negative-going rectangular wave form to one or the other of the capacitors. A chopped V+ is applied to one of the capacitors during a first stage, and demodulates a signal derived from that capacitor by operation of switches so that an integrated output is positive during the first stage. In a second stage, the V+ supply is supplied to the second capacitor. The demodulation is reversed so that the signal derived from that capacitor will tend to reduce the integrated output back towards zero. In a third stage, the V- supply is chopped by a switch and is supplied to the first capacitor. In stage four, the V- chopped supply is provided to a second capacitor. As with the first two stages, the demodulation provided by the switches is reversed so that the signal derived from the first capacitor causes the departure of the integrator signal from zero, and the signal derived from the second capacitor causes a return toward zero.

According to the present invention there is provided a transmitter for providing an output representative of a sensed parameter comprising generating means for providing a generator signal comprising a plurality of charge packets having a magnitude of charge which is a function of the sensed parameter, the generating means including reactance means for forming the charge packets in response to electrical excitation, measurement means coupled to the generating means for measuring the generator signal as a function of the reactance means and for providing a measurement signal as a function thereof, the generating means generating a number of first charge packets increasing the measurement of the generator signal in a first direction, and generating a number of second charge packets increasing the measurement of the generator signal in a second direction, opposite the first direction and feedback means coupled to the measurement means for providing a control signal to the generating means as a function of the measurement signal to provide the first and second charge packets so the measurement of the generator signal tends toward a charge balanced state and the feedback means providing an output signal representative of the numbers of charge packets, the transmitter characterized by the generating means including means for varying a level of the electrical excitation to the reactance means as a function of the control signal to alter magnitudes of the charge packets, and the feedback means including adjustment means

coupled to the generating means for providing the control signal to vary the level of the electrical excitation to the reactance means the adjustment means controlling the means for varying to adjust the electrical excitation to a first level so the reactance means provides charge packets having a magnitude as a function of the first level, the adjustment means controlling the means for varying to vary the electrical excitation from the first level to a second level so the reactance means provides the charge packets having a magnitude as a function of the second level, wherein the adjustment means controls variation in the electrical excitation so the measurement of the generator signal first converges on the charge balanced state more coarsely when the electrical excitation is at the first level and next converges on the charge balanced state more finely when the electrical excitation is at the second level, the output signal being representative of the numbers of charge packets provided to the measurement means.

IN THE DRAWINGS:

FIG. 1 is a diagram of an embodiment of a transmitter according to this invention;

FIG. 2 is a diagram of a first embodiment of a feedback means according to this invention;

FIG. 3 is a timing diagram corresponding to the feedback means of FIG. 2;

FIG. 4 is a flow chart corresponding to the feedback means in FIG. 2;

FIG. 5 is a diagram of a second embodiment of a feedback means according to this invention;

FIG. 6 is a timing diagram corresponding to the feedback means of FIG. 5;

FIG. 7 is a flow chart corresponding to the feedback means of FIG. 5.

The circuitry described herein is an improvement to circuitry described in International Application WO-A-8 706 711 entitled "Measurement Circuit", and incorporated herein by reference.

In FIG. 1, an embodiment of a transmitter is indicated generally at 10. Generating means 11 in the transmitter 10 senses a parameter "P" indicated at 12 and generate quantities or packets of charge representative of the parameter P. The term "packet" refers to a discrete amount of electrical charge which flows to or from a capacitance when it is charged from a first potential to a second potential, different from the first potential. The amount of charge in a packet is proportional to the capacitance and the difference between the first and second potentials. The packets of charge are coupled on line 76 to measurement means 60 in the transmitter 10. The measurement means 60 accumulate the packets of charge coupled on line 76 and provides a measurement signal "Vs" on line 90 as a function of the accumulated charge. The measurement signal on line 90 is coupled to and controls feed-

back means 50 in the transmitter. The feedback means 50 couple feedback signals to the generating means 11 along lines 18, 30, 31, 56, 64, 70 and 74 for controlling the generation of charge packets by the generating means 11. The feedback means 50 comprise adjustment means 51 for controlling the magnitude of the charge packets coupled on line 76. The adjustment means 51 couple feedback signals CK5 and CK6 along lines 30 and 31 respectively to vernier networks 20 and 34 in the generating means 11. The adjustment means 51 control the vernier networks 20 and 34 to adjust levels of excitation and hence the magnitude of charge packets produced by generating means 11. During a first time interval, the adjustment means 51 control the generating means 11 such that the generating means 11 generate larger packets of charge. The charge packets generated during the first time interval provide a coarse adjustment of the amount of charge accumulated by the measurement means 60. During a second time interval, different from the first time interval, the adjustment means 51 control the generating means 11 such that the generating means 11 generate smaller packets of charge. The smaller charge packets generated during the second time interval provide a fine adjustment of the amount of charge accumulated by the measurement means 60. The generation of the larger packets of charge by the generating means 11 during a first time interval followed by the generation of smaller packets of charge during the second time interval causes the accumulated charge in measurement means 60 to converge to a finely adjusted level in a short cycle time. There is a charge balancing interaction between the generating means 11, the measurement means 60 and the feedback means 50. The quantities or numbers of larger and smaller charge packets are representative of the sensed parameter p. The feedback means 50 counts the numbers of smaller and larger charge packets coupled from the generating means 11 to the measurement means 60 and provide a signal representative of the numbers of smaller and larger charge packets to an output means 92 along line 94. The output means 92 couples an output signal representative of the parameter P on line 96 to readout means 98. Alternatively, the output means 92 can receive the output signal on line 94 and be a means for coupling an analog output, a serial digital output, or a combined analog and digital output to the readout means 98. The vernier adjustment of excitation amplitudes in the generating means 11 provides a preferred fast, accurate output on line 96.

In FIG. 1, the parameter 12 such as a pressure is coupled to a capacitive pressure sensor in a generating means 11 comprising variable capacitor 14 having a capacitance C1 and variable capacitor 16 having a capacitance C2. The capacitances C1 and C2 vary as a function of the sensed parameter P. The feedback means 50 couple an excitation potential

CKO varying with time on line 18 through the vernier network 20 to the capacitors 14 and 16. The excitation potential CKO couples to a resistive voltage divider in the vernier network 20 comprising resistors 22 and 24 coupled in series between line 18 and a reference potential -V. The voltage divider generates a second excitation potential at the junction of resistors 22 and 24 and this second excitation potential thus varies with time in the same manner as excitation potential CKO, but it has a magnitude which is only a selected portion of the magnitude of the excitation signal CKO. Selection of the resistances of resistors 22 and 24 controls the magnitude of the second excitation potential. A switch 26 couples the excitation potential CKO from line 18 to the capacitors 14 and 16. A switch 28 couples the second excitation potential from the voltage divider comprising resistors 22 and 24 to the capacitors 14 and 16. The feedback means 50 couples a signal CK5 along a line 30 to the switch 26 to control switch 26. The feedback means 50 couples a signal CK6 along a line 31 to the switch 28 to control switch 28. The feedback means 50 controls the switches 26 and 28 to conduct in a non-overlapping manner such that either the excitation potential CKO or the second excitation potential is coupled to the capacitors 14 and 16 to provide excitation thereof. Switches are preferably MOS transmission gates. These MOS transmission gates are designed to have a structure which provides for very low leakage currents when they are open and which transfers a minimal amount of parasitic charge from the gate when switched. Desired MOS transmission gate characteristics are a leakage current of less than 1 pico ampere in an "off" state and a charge transfer of less than .05 pico coulombs when switched. Each of the switches is closed to couple signals by application of a high or "1" level, and is opened to stop coupling signals by application of a low or "0" level to the control input or gate of the switch. The vernier network 20 thus functions as a vernier to provide either a large, coarse excitation or a small fine excitation to the sensing capacitors 14 and 16. Larger packets of charge couple through capacitors 14 and 16 when switch 26 is closed; smaller packets of charge couple through capacitors 14 and 16 when switch 28 is closed. The feedback means 50 thus controls the magnitude of an excitation potential V_e at the junction of capacitors 14 and 16. The vernier adjustment of the excitation amplitude can be alternatively provided using a programmable gain operational amplifier, capacitive voltage divider or other means of providing coarse and fine excitation under the control of feedback means.

The excitation potential CKO further couples along line 18 to an inverter 30 which couples a third excitation potential $\overline{\text{CKO}}$ to line 32. The third excitation potential $\overline{\text{CKO}}$ is an inverse of the excitation potential CKO and is coupled along line 32 to a second vernier network 34. The second vernier network 34 includes

a second resistive voltage divider comprising resistors 36 and 38 coupled in series between line 32 and the reference potential -V. The voltage divider comprising resistors 34 and 36 generates a fourth excitation potential at the junction of resistors 34 and 36 and this fourth excitation potential varies with time in the same manner as the third excitation potential $\overline{\text{CKO}}$, but it has a magnitude which is only a selected portion of the magnitude of the third excitation potential $\overline{\text{CKO}}$. The excitation potentials CKO and $\overline{\text{CKO}}$ preferably have the same peak to peak magnitudes. The resistive voltage divider comprising resistors 22 and 24 preferably has a resistive divider ratio that is substantially the same as a divider ratio of the resistive voltage divider comprising resistors 34 and 36. The adjustment means 51 in the feedback means 50 couples the signal CK5 along the line 30 to a switch 40 for controlling switch 40. The switch 40 couples the third excitation potential $\overline{\text{CKO}}$ to a linearity correction capacitor 44 having a selected capacitance CL1 and a linearity correction capacitor 46 having a selected capacitance CL2. The adjustment means 51 in the feedback means 50 couples the signal CK6 along the line 31 to a switch 42 for controlling switch 42. The switch 42 couples the fourth excitation potential to linearity correction capacitors 44 and 46 along line 48. Capacitors 44 and 46 have selected capacitances which compensate the generating means 11 for stray capacitances associated with capacitors 14 and 16. The second vernier network 34 thus couples either a coarse or a fine adjusted excitation potential to the linearity correction capacitors 44 and 46.

Pressure sensing capacitor 14 and linearity correction capacitor 44 couple along line 52 to a switch 54. Feedback means 50 couples a signal CK4 along line 56 to switch 54 to control the switch 54. Switch 54 couples capacitors 14 and 44 to a reference potential V_{ref} on line 58 such that controlled quantities or packets of charge are stored on capacitors 14 and 44. Capacitors 14 and 44 also couple along line 52 to a switch 62 which couples packets of charge stored on capacitors 14 and 44 to the measurement means 60 along line 76. Feedback means 50 couples a signal CK1 along line 64 to switch 62 for controlling switch 62.

Pressure sensing capacitor 16 and linearity correction capacitor 46 couple along a line 66 to a switch 68. Feedback means 50 couples a signal CK3 along line 70 to the switch 68 for controlling switch 68. Switch 68 couples capacitors 16 and 46 to the reference potential V_{ref} on line 58 such that controlled quantities or packets of charge are stored on capacitors 16 and 46. Capacitors 16 and 46 also couple along line 66 to a switch 72. Feedback means 50 couples a signal CK2 along line 74 to the switch 72 for controlling the switch 72. Switch 72 couples packets of charge stored on capacitors 16 and 46 to the measurement means 60 along the line 76.

Measurement means 60 comprises an integrator 78 which accumulates charge coupled from the generating means 11 along line 76. Integrator 78 comprises a capacitor 80 having a capacitance C_i coupled between an output and an inverting input of an amplifier 82. The integrator 78 couples a potential V_i representative of accumulated charge to an inverting input of a comparator 86 along line 84. A bias generator 88 in the measurement means 60 is energized from reference potentials $+V$ and $-V$ and is preferably a CMOS voltage divider. The bias generator 88 couples a reference potential V_{ref} along line 58 to a positive input of the comparator 86, to a positive input of amplifier 82 and to switches 54 and 68 in the generating means 11. The comparator 86 couples the measurement signal V_s on line 90 to the feedback means 50. The measurement signal V_s is indicative of a level of charge stored on capacitor 80 in integrator 78. The measurement signal V_s on line 90 controls the operation of the feedback means 50.

In FIG. 2, a first embodiment of the feedback means 50 of FIG. 1 is shown. The feedback means 50 comprises an oscillator 102 coupling an oscillator signal along a line 104 to an excitation logic circuit 106. The oscillator signal clocks circuitry in the excitation logic circuit 106 to provide timing. The excitation logic circuit 106 couples feedback signals to the generating means 11 on lines 56, 64, 70, 74 and 18 which are timed by the oscillator signal and controlled by the measurement output V_s on line 90 in a desired manner. The excitation logic circuit 106 comprises an adjustment means 51 which couples feedback signals to lines 30 and 31. Adjustment means 51 provides selection of larger or smaller charge packets as explained above in connection with FIG. 1. The excitation logic circuit 106 couples counter control signals on lines 108, 110 and 112 to pulse counters 114, 116 and 118 respectively in the feedback means 50. The counter control signals control the enabling and resetting of the counters 114, 116 and 118. Counter 114 is coupled to line 74 for counting the number of pulses N_2 on line 74 during the first time interval. Counter 116 is coupled to line 64 for counting the number of pulses N_1 on line 64 during the first time interval. Counter 118 is coupled to line 64 for counting the number of pulses N_3 on line 64 during the second time interval. The numbers of pulses counted, N_1 , N_2 and N_3 are together representative of the sensed parameter. Counters 114, 116 and 118 couple signals representative of the numbers N_2 , N_1 and N_3 along lines 120, 122 and 124 respectively to a circuit 126. Circuit 126 comprises a computing circuit 128 for computing a value of the sensed parameter P from the signals on lines 120, 122 and 124. The computing circuit 128 couples a signal representative of the computed value on line 132 to a circuit 130 comprising a shift register 131. Circuit 130 converts the parallel data signal on line 132 to a serial form and couples a serial signal representative

of the sensed parameter out on line 134. The feedback means 50 couples to a 5-line data bus 94 for interfacing with a microprocessor 91 in the output means 92. The 5-line data bus 94 couples energization potentials on lines 136 and 138 to the transmitter 10. The 5-line data bus couples a chip select signal on line 140 and a data clock signal on line 142 for synchronizing the operation of a shift register in circuit 130 with the microprocessor in the output means 92.

In FIG. 3, a timing diagram 200 is shown which corresponds to the first embodiment of the feedback means 50 shown in FIG. 2. During a first time interval shown in FIG. 3 the feedback signal CK_5 at 201 is at a high or "1" level, closing switches 26 and 40, and the feedback signal CK_6 at 202 is at a low or "0" level, opening switches 28 and 42. The vernier network 20 thus provides an excitation potential V_e at a higher magnitude as shown at 204. The excitation level from vernier network 34 is likewise at a higher magnitude during the first time interval. The feedback signal CK_3 is actuated as shown at 206 to close switch 68, thus storing packets of charge on capacitors 16 and 46. After the excitation signal V_e changes polarity, the feedback signal CK_4 is actuated as shown at 208, thus closing switch 54 and storing packets of charge on capacitors 14 and 44. After the excitation potential V_e again changes polarity, the feedback signal CK_1 is actuated as shown at 212 to close switch 62 and couple a packet of charge on line 76 to the integrator 78. The integrator signal V_i responds to the packet of charge as shown at 210 in FIG. 3. After the excitation potential V_e again changes polarity, the feedback signals CK_2 and CK_4 are actuated as shown at 214. The actuation of signal CK_4 at 214 stores new packets of charge on capacitors 14 and 44; the actuation of signal CK_2 at 214 couples charge packets from capacitors 16 and 46 to the integrator 78. The integrator output V_i responds to these packets of charge as shown at 216 in FIG. 3. Charge packets from capacitors 16 and 46 are then repetitively coupled from capacitors 16 and 46 to the integrator 78 until the integrator output V_i falls below the reference level V_{ref} as shown at 218. The comparator 86 senses the integrator output change shown at 218 and couples a pulse shown at 220 to the feedback means along line 90. The feedback means senses the level change on line 90 and couples a second charge packet from capacitors 14 and 34 as shown at 222. The feedback means 50 next controls switches in the feedback means such that charge packets from the capacitor 16 and 46 are again repetitively applied to the integrator until the integrator output falls below the reference level as shown at 224. After a selected number ($N_1 + N_2$) of charge packets from capacitors 14, 16, 44 and 46 have been coupled to the integrator 78 the quantity of charge coupled to the integrator 78 is coarsely balanced. The feedback means then actuates the feedback signal CK_6 thus ending the first time interval

and starting the second time interval as shown at 228.

During the second time interval, switches 28 and 42 are closed and hence a lower magnitude of excitation V_e as shown at 230 is coupled to the sensing capacitor 14 and 16 from the vernier network 20. The excitation provided by vernier network 34 is likewise at a lower magnitude. In the example shown in FIG. 3, the lower magnitude of excitation is shown at 230 to be about 1/8 of the higher level of excitation at 204. During the second time interval, a number N_3 of lower magnitude packets of charge are coupled from the capacitors 14 and 44 as shown at 232 until the charge on the integrator is finely balanced to near the reference level as shown at 234.

The balancing of charge at the integrator 78 during the first and second time intervals results in a relationship as shown in Equation 1 below:

$$(N_1)(C_a)(V_e) + (N_3)(C_a)(V_e)/N = (N_2)(C_b)(V_e)$$

Equation 1

where:

- N_1 = the number of larger charge packets coupled from capacitors 14 and 44 during the first time interval;
- N_2 = the number of larger charge packets coupled from capacitors 16 and 46 during the first time interval;
- N_3 = the number of smaller charge packets coupled from capacitors 14 and 44 during the second time interval;
- N = the divider ratio of the higher to the lower excitation magnitudes;
- C_a = $C_1 - CL_1$, a value of C_1 corrected for linearity;
- C_b = $C_2 - CL_2$, a value of C_2 corrected for linearity;
- V_e = the higher excitation magnitude.

A long term average value of the numbers of charge packets tends toward an accurate value representative of the sensed parameter because small accumulations of charge packets in the measurement means 60 are not zeroed out and lost at the end of a measurement period, but are instead carried forward to affect a succeeding measurement interval.

Equation 1 can be simplified to form Equation 2 below:

$$\frac{C_b}{C_a} = \frac{(N_1) + (N_3)/N}{N_2}$$

Equation 2

In a dual plate capacitive pressure transducer, the sensed pressure P is related to the corrected sensor capacitances Equation 3:

$$P = \frac{K(1 - (C_b/C_a))}{1 + (C_b/C_a)}$$

Equation 3

where K is a scaling factor. Equations 2 and 3 can be combined to form Equation 4:

$$P = K \frac{(N_2) - (N_1) - (N_3/N)}{(N_2) + (N_1) + (N_3/N)}$$

Equation 4

Hence it can be seen that the pressure P is dependent on the numbers N_1 , N_2 , N_3 and N and can be substantially independent of the reference poten-

tials and ambient temperature of the transmitter over an operating range.

Computing means 128 calculates a signal representative of pressure according to Equation 4 and couples the signal representative of pressure on line 132 to circuit 130.

In FIG. 4, a flow chart 250 illustrates an exemplary sequence of operation for a transmitter 10 comprising the feedback means 50 as shown in FIG. 2 and corresponding to the timing diagram of FIG. 3. At power up or START at 252, the coarse excitation mode is first selected as shown at 254. The excitation logic circuit then controls the generating means 11 so that it repetitively couples charge packets from capacitance C_b as shown at 254 until the measurement signal V_s changes as shown at 256. If the number $(N_1 + N_2)$ is less than a preselected number M , the excitation logic circuit 106 then leaves a right loop 258 and starts a left loop 260. In the left loop 260, the excitation logic circuit 106 controls the generating means 11 to repetitively couple charge packets from capacitance C_a until the measurement output V_s changes as shown at 262.

The excitation logic circuit 106 controls the generating means 11 so that the generating means 11 alternates between coupling charge packets from C_a and coupling charge packets from capacitance C_b until the quantity $(N_1 + N_2)$ equals or exceeds M as shown at 264, at which time the excitation logic circuit 106 switches from the coarse excitation mode (first time interval) to the fine excitation mode (second time interval) as shown at 266.

During the second time interval, the excitation logic circuit 106 controls the generating means 11 such that smaller charge packets are coupled from capacitance C_a to the measurement means 60 as shown at 268 until the measurement output V_s changes as shown at 270. The numbers N_1 , N_2 , N_3 which are obtained in this sequence are coupled to computing circuit 128 and then this sequence is repeated again starting at 272.

In the embodiment illustrated in FIG. 3, the number M of FIG. 4 is set to 8, and the divider ratio N is also set to 8. This arrangement provides a 6-bit resolution in only 10 cycles of the excitation waveform whereas a similar transmitter without the vernier feature requires more than 66 cycles of the excitation waveform to achieve this same 6-bit resolution. The speed of the capacitance-to-digital conversion is thus enhanced by a factor of more than 6 when M and N are 8. Much larger values of M and N can also be selected to achieve even greater resolution. In a practical circuit, M can be set to 256 and N can be set to 256 to achieve 16 bit resolution in 512 cycles of the excitation waveform using the vernier arrangement, giving a factor of 128 improvement over a similar circuit without a vernier.

The transmitter circuitry preferably comprises a

MOS integrated circuit coupling to an output circuit to provide a preferred low power consumption. The transmitter circuitry has a preferred low power consumption and can be used in a two-wire, intrinsically safe 4-20 mA loop powered transmitter.

In FIG. 5, a second embodiment of the feedback means 50 of FIG. 1 is shown. An oscillator 102 couples an oscillator signal along a line 104 to an excitation logic circuit 300. The oscillator signal clocks logic circuitry in the excitation logic circuit 300 to provide timing. The excitation logic circuit 300 couples feedback signals on lines 56, 64, 70, 74 and 18 which are timed by the oscillator signal and controlled by the measurement output Vs on line 90 in a desired manner. The excitation logic circuit comprises an adjustment means 302 which couples feedback signals to lines 30 and 31. Adjustment means 302 provides selection of larger or smaller charge packets as explained above in connection with FIG. 1. The excitation logic circuit 300 couples counter control signals on lines 304, 306 to a counter circuit 308 in a serial output circuit 310. Counter circuit 308 is coupled to lines 64 and 74 for counting numbers of pulses on lines 64 and 74 under the control of counter control signals on lines 304 and 306. The counter circuit 308 couples signals representative of the numbers of pulses counted along lines 312 to a parallel input of a shift register circuit 314 in the serial output circuit 310. The shift register circuit 314 is controlled by a chip select signal on line 140 and a data clock signal on line 142 to couple a serial output to line 134. The serial output on line 134 comprises a signal representative of the numbers of pulses counted on lines 64 and 67. The feedback means 50 of FIG. 5 couples to a 5-line data bus 94 for interfacing with a microprocessor in the output means 92. The 5-line data bus 94 couples energization potentials on lines 136 and 138 to the transmitter 10. A non-volatile memory 313 can comprise constants which are representative of the characteristics of sensing capacitors 14 and 16. The constants in memory 313 can be coupled along a line 315 to the counter circuit 308 to pre-load the counter circuit 308 with constants so that counting of pulses by counter circuit 308 is adjusted for manufacturing tolerances of the sensing capacitors 14 and 16.

In FIG. 6, an exemplary timing diagram 320 is shown which corresponds to the second embodiment of the feedback means 50 shown in FIG. 5. During a first time interval shown in FIG. 6, the feedback signal CK5 at 322 is at a high or "1" level, closing switches 26 and 40, and the feedback signal CK6 at 324 is at a low or "0" level, opening switches 28 and 42. The vernier network 20 thus provides an excitation potential Ve at a higher magnitude as shown at 326 during the first time interval. The excitation level from vernier network 34 is likewise at a higher magnitude during the first time interval. The feedback signal CK4 is actuated as shown at 328 to close switch 54, thus

storing packets of charge on capacitors 14 and 44. The feedback signal CK1 is then actuated at 330 closing switch 62. The excitation signal Ve changes polarity at 332 thus coupling a packet of charge from capacitors 14 and 44 to the measurement means 60 along line 76. The integrator signal Vi increases past the reference voltage Vref in response to this packet of charge as shown at 334. The comparator 86 senses that the integrator signal Vi has increased past the reference potential Vref and the measurement output Vs changes from a "1" to a "0" as shown at 336. The change in the measurement output Vs is coupled along line 90 to the feedback means 50 and the feedback means 50 senses the change and stops coupling charge packets of a first polarity from capacitors 14 and 44 and starts coupling charge packets of opposite polarity from capacitors 16 and 46 to the measurement means 60. The response of the integrator 78 to the charge packets coupled from capacitors 16 and 46 is shown at 338 in FIG. 6. The generating means continues to provide charge packets from capacitors 14 and 44 and from capacitors 16 and 46 as shown in FIG. 6 until a predetermined number M1 of charge packets from both capacitors 14 and 44 and capacitors 16 and 46 have been produced. After the number M1 of charge packets has been produced, the feedback means 50 ends the first time interval and starts the second time interval by changing feedback signal CK5 from a "1" to a "0" and changing feedback signal CK6 from a "0" to a "1" as shown at 340. During the second time interval, the capacitors 14, 44, 16, 46 receive a lower or fine excitation level from vernier circuits 20 and 34 as shown at 342. During the second time interval, the feedback means 50 of FIG. 5 controls the generating means 11 to couple smaller charge packets to the measurement means 60 as shown at 344 in a manner similar to the coupling of larger charge packets during the first time interval. After a predetermined number M2 of smaller charge packets are coupled during the second time interval, the feedback means 50 of FIG. 5 controls the generating means 11 to couple charge packets to the measurement means 78 until the measurement output Vs changes. The integrator output Vi is thus balanced to near the reference level such that the integrator 78 is ready for another measurement sequence. Numbers of charge packets coupled to the measurement means 60 are counted during the measurement interval by the counter circuit 308. The balancing of charge during the measurement interval made up of a first and second time interval results in a relationship as shown in Equation 5 below.

$$P = K \frac{(N2 - N1) + (N4 - N3)/2^N}{(N1 + N2) + (N4 + N3)/2^N} \quad \text{Equation 5}$$

where

P is a pressure related to corrected sensor capacitances as shown in Equation 3 above;

N1 is the number of larger charge packets cou-

- pled from capacitors 14 and 44 during a measurement interval;
- N2 is the number of larger charge packets coupled from capacitors 16 and 46 during a measurement interval;
- N3 is the number of smaller charge packets coupled from capacitors 14 and 44 during a measurement interval;
- N4 is the number of smaller charge packets coupled from capacitors 16 and 46 during a measurement interval;
- 2^N is the divider ratio of the higher to the lower excitation magnitudes; and
- K is a scaling factor.

In a preferred embodiment the preselected numbers M1 and M2 and the divider ratio N are selected fixed numbers, and hence the denominator of Equation 5 is a fixed quantity. The circuitry of feedback means 50 does not have to calculate pressure P by dividing by a denominator of Equation 5. The denominator of Equation 5 can thus be included in a scale factor K1 and $P = K1 ((N2-N1) + (N4-N3)/2^N)$. The quantity (N2-N1) is counted by a first up/down counter in the counter circuit 308. The quantity (N4-N3) is counted by a second up/down counter in the counter circuit 308. The divider ratio N can be selected to be an integral number and hence the 2^N denominator of the $(N4-N3)/2^N$ term in the numerator of equation 5 represents merely a shift of the position of the binary equivalent of a decimal point. The outputs of the first and second up/down counter can thus be loaded directly into the shift register circuit 314 without the need for any division or other complex arithmetic calculations in the feedback means 50 of FIG. 5. A digital word is loaded into the shift register which has a higher order byte representing (N2-N1) and a lower order byte representing $(N4-N3)/2^N$.

In FIG. 7, a flow chart 360 illustrates an exemplary sequence of operation for a transmitter 10 comprising a feedback means 50 as shown in FIG. 5 and corresponding to the timing diagram of FIG. 6. At power-up or start 362, the coarse excitation mode is selected and the counters for N1, N2, N3, N4 are preset to zero at 364. Alternatively, the counters can be preset to a non-zero value stored in non-volatile memory 313. Depending on the logic level of Vs at 366, the generating means couples a larger packet of charge from either capacitance Ca or Cb to the measurement means. The count of either N1 or N2 is correspondingly increased by 1 for each charge packet as shown at 368, 370. Charges are repetitively coupled in this manner until the quantity (N1+N2) is equal to the preselected value M1 shown at 372. Once the preselected value M1 is reached, the fine excitation mode is selected at 374. In the fine excitation mode, smaller packet of charge are coupled from either capacitance Ca or Cb to the measurement means as shown at 376, 378, depending upon the logic level of Vs as shown

at 380. Charges are repetitively coupled in this manner until the number of fine charge packets (N3+N4) is equal to a second preselected number M2 as shown at 382. Counting of charge packets stops at this point in the sequence, however, additional smaller charge packets are coupled to the integrator to rebalance the integrator and prepare it for the next measurement cycle as shown at 384. The numbers (N2-N1) and (N4-N3) are then transferred from counters to the high and low bytes of the shift register respectively as shown at 386, and a new measurement cycle is begun as shown at 388.

Circuitry for the transmitter 10 preferably comprises an MOS integrated circuit to provide low power consumption. In the example illustrated in FIG. 6, the selected numbers M1=8 and M2=16 are illustrated. A further preferred embodiment uses selected number M1=1024 and M2=320 with a divider ratio of 64 to provide a desired 16 bits of resolution within 1500 oscillator cycles. With 10 microsecond oscillator cycles, a measurement cycle can be completed in 15 milliseconds. An important improvement is obtained over simple single or dual slope A/D converters which would require 64,000 cycles to obtain the 16 bit resolution of the sensed parameter.

Claims

1. A transmitter (10) for providing an output representative of a sensed parameter (P,12) comprising: generating means (11) for providing a generator signal comprising a plurality of charge packets having a magnitude of charge which is a function of the sensed parameter (P,12), the generating means (11) including reactance means (14,16) for forming the charge packets in response to electrical excitation; measurement means (60) coupled to the generating means (11) for measuring the generator signal as a function of the reactance means (14,16) and for providing a measurement signal as a function thereof; the generating means generating a number of first charge packets increasing the measurement of the generator signal in a first direction, and generating a number of second charge packets increasing the measurement of the generator signal in a second direction, opposite the first direction and feedback means (50) coupled to the measurement means (60) for providing a control signal to the generating means (11) as a function of the measurement signal to provide the first and second charge packets so the measurement of the generator signal tends toward a charge balanced state and the feedback means providing an output signal representative of the numbers of charge packets; the transmitter (10) characterized by:



- pled from capacitors 14 and 44 during a measurement interval;
- N2 is the number of larger charge packets coupled from capacitors 16 and 46 during a measurement interval;
- N3 is the number of smaller charge packets coupled from capacitors 14 and 44 during a measurement interval;
- N4 is the number of smaller charge packets coupled from capacitors 16 and 46 during a measurement interval;
- 2^N is the divider ratio of the higher to the lower excitation magnitudes; and
- K is a scaling factor.

In a preferred embodiment the preselected numbers M1 and M2 and the divider ratio N are selected fixed numbers, and hence the denominator of Equation 5 is a fixed quantity. The circuitry of feedback means 50 does not have to calculate pressure P by dividing by a denominator of Equation 5. The denominator of Equation 5 can thus be included in a scale factor K1 and $P = K1 ((N2-N1) + (N4-N3)/2^N)$. The quantity (N2-N1) is counted by a first up/down counter in the counter circuit 308. The quantity (N4-N3) is counted by a second up/down counter in the counter circuit 308. The divider ratio N can be selected to be an integral number and hence the 2^N denominator of the (N4-N3)/ 2^N term in the numerator of equation 5 represents merely a shift of the position of the binary equivalent of a decimal point. The outputs of the first and second up/down counter can thus be loaded directly into the shift register circuit 314 without the need for any division or other complex arithmetic calculations in the feedback means 50 of FIG. 5. A digital word is loaded into the shift register which has a higher order byte representing (N2-N1) and a lower order byte representing (N4-N3)/ 2^N .

In FIG. 7, a flow chart 360 illustrates an exemplary sequence of operation for a transmitter 10 comprising a feedback means 50 as shown in FIG. 5 and corresponding to the timing diagram of FIG. 6. At power-up or start 362, the coarse excitation mode is selected and the counters for N1, N2, N3, N4 are preset to zero at 364. Alternatively, the counters can be preset to a non-zero value stored in non-volatile memory 313. Depending on the logic level of Vs at 366, the generating means couples a larger packet of charge from either capacitance Ca or Cb to the measurement means. The count of either N1 or N2 is correspondingly increased by 1 for each charge packet as shown at 368, 370. Charges are repetitively coupled in this manner until the quantity (N1+N2) is equal to the preselected value M1 shown at 372. Once the preselected value M1 is reached, the fine excitation mode is selected at 374. In the fine excitation mode, smaller packet of charge are coupled from either capacitance Ca or Cb to the measurement means as shown at 376, 378, depending upon the logic level of Vs as shown

at 380. Charges are repetitively coupled in this manner until the number of fine charge packets (N3+N4) is equal to a second preselected number M2 as shown at 382. Counting of charge packets stops at this point in the sequence, however, additional smaller charge packets are coupled to the integrator to rebalance the integrator and prepare it for the next measurement cycle as shown at 384. The numbers (N2-N1) and (N4-N3) are then transferred from counters to the high and low bytes of the shift register respectively as shown at 386, and a new measurement cycle is begun as shown at 388.

Circuitry for the transmitter 10 preferably comprises an MOS integrated circuit to provide low power consumption. In the example illustrated in FIG. 6, the selected numbers M1=8 and M2=16 are illustrated. A further preferred embodiment uses selected number M1=1024 and M2=320 with a divider ratio of 64 to provide a desired 16 bits of resolution within 1500 oscillator cycles. With 10 microsecond oscillator cycles, a measurement cycle can be completed in 15 milliseconds. An important improvement is obtained over simple single or dual slope A/D converters which would require 64,000 cycles to obtain the 16 bit resolution of the sensed parameter.

Claims

1. A transmitter (10) for providing an output representative of a sensed parameter (P,12) comprising: generating means (11) for providing a generator signal comprising a plurality of charge packets having a magnitude of charge which is a function of the sensed parameter (P,12), the generating means (11) including reactance means (14,16) for forming the charge packets in response to electrical excitation; measurement means (60) coupled to the generating means (11) for measuring the generator signal as a function of the reactance means (14,16) and for providing a measurement signal as a function thereof; the generating means generating a number of first charge packets increasing the measurement of the generator signal in a first direction, and generating a number of second charge packets increasing the measurement of the generator signal in a second direction, opposite the first direction and feedback means (50) coupled to the measurement means (60) for providing a control signal to the generating means (11) as a function of the measurement signal to provide the first and second charge packets so the measurement of the generator signal tends toward a charge balanced state and the feedback means providing an output signal representative of the numbers of charge packets; the transmitter (10) characterized by:



the generating means (11) including means (20) for varying a level of the electrical excitation to the reactance means (14,16) as a function of the control signal to alter magnitudes of the charge packets; and

the feedback means (50) including adjustment means (51) coupled to the generating means (11) for providing the control signal to vary the level of the electrical excitation to the reactance means (14,16) the adjustment means controlling the means for varying to adjust the electrical excitation to a first level so the reactance means provides charge packets having a magnitude as a function of the first level, the adjustment means controlling the means for varying to vary the electrical excitation from the first level to a second level so the reactance means provides the charge packets having a magnitude as a function of the second level, wherein the adjustment means controls variation in the electrical excitation so the measurement of the generator signal first converges on the charge balanced state more coarsely when the electrical excitation is at the first level and next converges on the charge balanced state more finely when the electrical excitation is at the second level, the output signal being representative of the numbers of charge packets provided to the measurement means.

2. A transmitter (10) as recited in Claim 1 wherein the means (20) for varying couples a first level of excitation to the reactance means (14,16) during a first time interval and couples a second level of excitation, different from the first level, to the reactance means (14,16) during a second time interval, different from the first time interval.
3. A transmitter (10) as recited in Claim 2 wherein the excitation is cyclical.
4. A transmitter (10) as recited in Claim 3 wherein the first time interval comprises a selected number of cycles of the excitation.
5. A transmitter (10) as recited in Claim 4 wherein the second level of excitation has a smaller magnitude than the first level of excitation.
6. A transmitter (10) as recited in Claim 5 wherein the second level of excitation is coupled to the reactance means (14,16) for balancing the charge coupled during the first time interval.
7. A transmitter (10) as recited in Claim 6 wherein the reactance means (14,16) comprises a capacitive sensor (14,16).

8. A transmitter (10) as recited in Claim 7 wherein the sensed parameter (P,12) is a pressure (P) coupled to the capacitive sensor (14,16).

9. A transmitter (10) recited in Claim 8 wherein the means (20) for varying comprises divider means (22,24) coupled to the capacitive sensor (14,16) for providing the first and second levels of excitation.

10. A transmitter (10) as recited in Claim 9 wherein the means (20) for varying further comprises switching means (26,28) coupled to the divider (22,24) for selectively coupling the first and second levels of excitation to the capacitive sensor (14,16).

11. A transmitter (10) as recited in Claim 10 wherein the generating means (11) further comprise correction means (34,44,46) coupled to the reactance means (14,16) for correcting for stray reactance.

12. A transmitter (10) as recited in Claim 11 wherein the feedback means (50) comprises counter means (114,116,118,308) coupled to a feedback signal for counting a number of charge packets coupled to the measurement means (60) during a time interval.

13. A transmitter (10) as recited in Claim 9 wherein the output is a function of the number of charge packets coupled from the generating means (11) to the measurement means (60) during the first and second time intervals.

14. A transmitter (10) as recited in Claim 13 wherein the output P is calculated substantially by the feedback means (50)

$$P = K \frac{(N2) - (N1) - (N3/N)}{(N2) + (N1) + (N3/N)}$$

where K is a proportionality constant, N is a divider ratio of the divider means (22,24), N1 and N2 are numbers of charge packets coupled to the measurement means (60) during the first time interval and N3 is a number of charge packets coupled to the measurement means (60) during the second time interval.

15. A transmitter (10) as recited in Claim 13 wherein the output P is calculated by feedback means (50) substantially as

$$P = K \frac{(N2 - N1) + (N4 - N3)2^N}{(N1 + N2) + (N4 + N3)2^N}$$

where K is a proportionality constant, 2^N is a divider ratio of the divider means (22,24), N1 and N2 are numbers of charge packets coupled to the measurement means (60) during a first time in-



terval and N3 and N4 are numbers of charge packets coupled to the measurement means (60) during the second time interval.

16. A transmitter (10) as recited in Claim 15 wherein the quantity $(N1+N2) + (N4+N3/2^N)$ is controlled to a selected fixed value by the feedback means (50) such that the output is computed by counting.

17. A transmitter (10) as recited in claim 9 wherein the output is a 4-20 milliampere current.

18. A transmitter (10) as recited in Claim 17 wherein the transmitter (10) is energized by the output current.

19. A transmitter (10) as recited in Claim 1 wherein the transmitter (10) is energized by a two-wire loop and provides a digital output to the loop.

20. A method of providing an output signal which is a function of a sensed parameter, the method comprising:

during each of a plurality of measurement cycles:

using reactance means having a first excitation level applied thereto to form first charge packets of first polarity having a charge magnitude which is a function of the sensed parameter and the first excitation level;

using reactance means to form second charge packets of second opposite polarity having a charge magnitude which is a function of the first excitation level and the sensed parameter;

transferring a number of the first charge packets to a charge accumulator so charge in the charge accumulator exceeds a charge balance state in a first direction, and transferring a number of second charge packets to the charge accumulator until the charge in the charge accumulator passes the charge balance state in a second direction;

the method characterised by:

changing the excitation level applied to the reactance means to a second different excitation level;

using the reactance means to form third charge packets of the first polarity having a charge magnitude which is a function of the sensed parameter and the second excitation level;

using reactance means to form fourth charge packets of the second polarity having a charge magnitude which is a function of the second excitation level and the sensed parameter; and

transferring a number of the third charge

packets to the charge accumulator so the charge in the charge accumulator passes the charge balance state in the first direction, and transferring a number of fourth charge packets to the charge accumulator until the charge in the charge accumulator passes the charge balance state in the second direction, opposite the first direction;

counting the numbers of first, second, third and fourth charge packets which are transferred to the charge accumulator during a plurality of measurement cycles; and

providing the output signal based on the counted numbers.

Patentansprüche

1. Ein Sender (10) zum Erzeugen eines Ausgangssignals eines erfaßten Parameters (P,12), der folgendes aufweist: eine Erzeugungsvorrichtung (11) zum Erzeugen eines Generatorsignals, das eine Vielzahl von Ladungspaketen mit einer Größe der Ladung aufweist, die eine Funktion des erfaßten Parameters (P,12) ist, wobei die Erzeugungsvorrichtung (11) eine Reaktanzvorrichtung (14,16) zum Ausbilden der Ladungspakete ansprechend auf elektrische Erregung umfaßt; eine Meßvorrichtung (60), die mit der Erzeugungsvorrichtung (11) gekoppelt ist, zum Messen des Generatorsignals als eine Funktion der Reaktanzvorrichtung (14,16) und zur Erzeugung eines Meßsignals als eine Funktion davon; wobei die Erzeugungsvorrichtung eine Vielzahl von ersten Ladungspaketen erzeugt, die die Messung des Generatorsignals in eine erste Richtung erhöhen, und eine Vielzahl von zweiten Ladungspaketen erzeugt, die die Messung des Generatorsignals in eine zweite Richtung erhöhen, entgegengesetzt der ersten Richtung, und mit einer Rückkopplungsvorrichtung (50), die mit der Meßvorrichtung (60) zum Zuführen eines Steuersignals zur Erzeugungsvorrichtung (11) als eine Funktion des Meßsignals gekoppelt ist, um die ersten und zweiten Ladungspakete zu erzeugen, so daß die Messung des Generatorsignals zu einem ausgeglichenen Ladungszustand neigt und wobei die Rückkopplungsvorrichtung ein Ausgangssignal erzeugt, das die Anzahl an Ladungspaketen wiedergibt; wobei der Sender (10) dadurch gekennzeichnet ist, daß: die Erzeugungsvorrichtung (11) eine Vorrichtung (20) umfaßt, um ein Niveau der elektrischen Erregung zu der Reaktanzvorrichtung (14,16) als eine Funktion des Steuersignals abzuändern, um die Größen der Ladungspakete zu ändern; und die Rückkopplungsvorrichtung (50) eine Einstellvorrichtung (51) umfaßt, die mit der Erzeugungsvorrichtung (11) gekoppelt ist, zur Erzeugung des



- Steuersignals, um das Niveau der elektrischen Erregung zu der Reaktanzvorrichtung (14,16) abzuändern, wobei die Einstellvorrichtung die Abänderungsvorrichtung steuert, um die elektrische Erregung auf ein erstes Niveau einzustellen, so daß die Reaktanzvorrichtung Ladungspakete erzeugt, die eine Größe als eine Funktion des ersten Niveaus aufweisen, wobei die Einstellvorrichtung die Abänderungsvorrichtung steuert, um die elektrische Erregung vom ersten Niveau auf ein zweites Niveau abzuändern, so daß die Reaktanzvorrichtung bewirkt, daß die Ladungspakete eine Größe als eine Funktion des zweiten Niveaus aufweisen, wobei die Einstellvorrichtung die Abänderung bei der elektrischen Erregung steuert, so daß sich die Messung des Generatorsignals dem ausgeglichenen Ladungszustand zuerst gröber annähert, wenn sich die elektrische Erregung auf dem ersten Niveau befindet, und sich dann dem ausgeglichenen Ladungszustand genauer annähert, wenn sich die elektrische Erregung auf dem zweiten Niveau befindet, wobei das Ausgangssignal die Anzahl der Ladungspakete wiedergibt, die der Meßvorrichtung zugeführt werden.
2. Sender (10) nach Anspruch 1, dadurch gekennzeichnet, daß die Abänderungsvorrichtung (20) während eines ersten Zeitintervalls ein erstes Erregungsniveau mit der Reaktanzvorrichtung (14,16) koppelt und während eines zweiten Zeitintervalls; das sich vom ersten Zeitintervall unterscheidet, ein zweites Erregungsniveau, das sich vom ersten Niveau unterscheidet, mit der Reaktanzvorrichtung (14,16) koppelt.
 3. Sender (10) nach Anspruch 2, dadurch gekennzeichnet, daß die Erregung zyklisch ist.
 4. Sender (10) nach Anspruch 3, dadurch gekennzeichnet, daß das erste Zeitintervall eine ausgewählte Anzahl an Erregungszyklen aufweist.
 5. Sender (10) nach Anspruch 4, dadurch gekennzeichnet, daß das zweite Erregungsniveau niedriger ist als das erste Erregungsniveau.
 6. Sender (10) nach Anspruch 5, dadurch gekennzeichnet, daß das zweite Erregungsniveau mit der Reaktanzvorrichtung (14,16) gekoppelt ist, um die während des ersten Zeitintervalls gekoppelte Ladung auszugleichen.
 7. Sender (10) nach Anspruch 6, dadurch gekennzeichnet, daß die Reaktanzvorrichtung (14,16) einen kapazitiven Sensor (14,16) aufweist.
 8. Sender (10) nach Anspruch 7, dadurch gekennzeichnet, daß der erfaßte Parameter (P,12) ein Druck (P) ist, der mit dem kapazitiven Sensor (14,16) gekoppelt ist.
 9. Sender (10) nach Anspruch 8, dadurch gekennzeichnet, daß die Abänderungsvorrichtung (20) eine Teilverrichtung (22,24) aufweist, die mit dem kapazitiven Sensor (14,16) gekoppelt ist, um das erste und zweite Erregungsniveau zu erzeugen.
 10. Sender (10) nach Anspruch 9, dadurch gekennzeichnet, daß die Abänderungsvorrichtung (20) weiterhin eine Schaltungsvorrichtung (26,28) aufweist, die mit dem Teiler (22,24) gekoppelt ist, um wahlweise das erste und zweite Erregungsniveau mit dem kapazitiven Sensor (14,16) zu koppeln.
 11. Sender (10) nach Anspruch 10, dadurch gekennzeichnet, daß die Erzeugungsvorrichtung (11) weiterhin eine Korrekturvorrichtung (34,44,46) aufweist, die mit der Reaktanzvorrichtung (14,16) gekoppelt ist, um Streu-Reaktanz zu korrigieren.
 12. Sender (10) nach Anspruch 11, dadurch gekennzeichnet, daß die Rückkopplungsvorrichtung (50) eine Zählvorrichtung (114,116,118,308) aufweist, die mit einem Rückkopplungssignal gekoppelt ist, um eine Anzahl an Ladungspaketen zu zählen, die während eines Zeitintervalls der Meßvorrichtung (60) zugeleitet werden.
 13. Sender (10) nach Anspruch 9, dadurch gekennzeichnet, daß das Ausgangssignal eine Funktion der Anzahl an Ladungspaketen ist, die während des ersten und zweiten Zeitintervalls von der Erzeugungsvorrichtung (11) der Meßvorrichtung (60) zugeleitet werden.
 14. Sender (10) nach Anspruch 13, dadurch gekennzeichnet, daß das Ausgangssignal P im wesentlichen durch die Rückkopplungsvorrichtung (50) berechnet wird

$$P = K \frac{(N2) - (N1) - (N3/N)}{(N2) + (N1) + (N3/N)}$$
 wobei K eine Proportionalitätskonstante, N ein Teilungsquotient der Teilverrichtung (22,24), N1 und N2 Anzahlen an Ladungspaketen, die während des ersten Zeitintervalls der Meßvorrichtung (60) zugeleitet werden, und N3 eine Anzahl an Ladungspaketen ist, die während des zweiten Zeitintervalls der Meßvorrichtung (60) zugeleitet werden.
 15. Sender (10) nach Anspruch 13, dadurch gekennzeichnet, daß das Ausgangssignal P durch die

Rückkopplungsvorrichtung (50) im wesentlichen als

$$P = K \frac{(N2 - N1) + (N4 - N3)/2^N}{(N1 + N2) + (N4 + N3)/2^N}$$

berechnet wird, wobei K eine Proportionalitätskonstante, 2^N ein Teilungsquotient der Teilervorrichtung (22,24), N1 und N2 Anzahlen an Ladungspaketen, die während eines ersten Zeitintervalls in die Meßvorrichtung (60) eingekoppelt werden, und N3 und N4 Anzahlen an Ladungspaketen sind, die während des zweiten Zeitintervalls in die Meßvorrichtung (60) eingekoppelt werden.

16. Sender (10) nach Anspruch 15, dadurch gekennzeichnet, daß die Menge $(N1+N2) + (N4+N3)/2^N$ bis zu einem gewählten festen Wert durch die Rückkopplungsvorrichtung (50) gesteuert wird, so daß das Ausgangssignal durch Zählen berechnet wird.

17. Sender (10) nach Anspruch 9, dadurch gekennzeichnet, daß das Ausgangssignal ein 4-20 Milliamperestrom ist.

18. Sender (10) nach Anspruch 17, dadurch gekennzeichnet, daß der Sender (10) durch den Ausgangsstrom erregt wird.

19. Sender (10) nach Anspruch 1, dadurch gekennzeichnet, daß der Sender (10) durch eine Zweidraht-Schleife erregt wird und der Schleife ein digitales Ausgangssignal zuführt.

20. Ein Verfahren zur Erzeugung eines Ausgangssignals, das eine Funktion eines erfaßten Parameters ist, wobei das Verfahren folgendes aufweist: während jedes einer Vielzahl von Meßzyklen: Verwendung einer Reaktanzvorrichtung mit einem ersten darauf aufgetragenen Erregungsniveau, zur Ausbildung erster Ladungspakete mit erster Polarität, die eine Ladungsgröße aufweisen, die eine Funktion des erfaßten Parameters und des ersten Erregungsniveaus ist; Verwendung einer Reaktanzvorrichtung zur Ausbildung zweiter Ladungspakete mit zweiter entgegengesetzter Polarität, die eine Ladungsgröße aufweisen, die eine Funktion des ersten Erregungsniveaus und des erfaßten Parameters ist; Übertragung einer Anzahl von ersten Ladungspaketen auf einen Ladungsakkumulator, so daß die Ladung im Ladungsakkumulator einen ausgeglichenen Ladungszustand in einer ersten Richtung übersteigt, und Übertragung einer Anzahl von zweiten Ladungspaketen auf einen Ladungsakkumulator, bis die Ladung im Ladungsakkumulator den ausgeglichenen Ladungszustand in einer zweiten Richtung übersteigt;



wobei das Verfahren gekennzeichnet ist durch: den Wechsel des auf die Reaktanzvorrichtung aufgetragenen Erregungsniveaus zu einem zweiten anderen Erregungsniveau; die Verwendung der Reaktanzvorrichtung zur Ausbildung dritter Ladungspakete mit der ersten Polarität, die eine Ladungsgröße aufweisen, die eine Funktion des erfaßten Parameters und des zweiten Erregungsniveaus ist; die Verwendung der Reaktanzvorrichtung zur Ausbildung vierter Ladungspakete mit der zweiten Polarität, die eine Ladungsgröße aufweisen, die eine Funktion des zweiten Erregungsniveaus und des erfaßten Parameters ist; und die Übertragung einer Anzahl von dritten Ladungspaketen auf den Ladungsakkumulator, so daß die Ladung im Ladungsakkumulator den ausgeglichenen Ladungszustand in der ersten Richtung übersteigt, und Übertragung einer Anzahl von vierten Ladungspaketen auf den Ladungsakkumulator bis die Ladung im Ladungsakkumulator den ausgeglichenen Ladungszustand in der zweiten Richtung übersteigt, entgegengesetzt zu der ersten Richtung; das Zählen der Anzahl an ersten, zweiten, dritten und vierten Ladungspaketen, die während einer Vielzahl von Meßzyklen auf den Ladungsakkumulator übertragen werden; und das Erzeugen des Ausgangssignals, das auf der gezählten Anzahl basiert.

Revendications

1. Emetteur (10) pour la fourniture d'une sortie représentative d'un paramètre détecté (P, 12) comprenant: un moyen générateur (11) pour fournir un signal de générateur comprenant une pluralité de paquets de charge ayant une valeur de charge qui est fonction du paramètre détecté (P, 12), le moyen générateur (11) comprenant un moyen à réactance (14, 16) pour former les paquets de charge en réaction à une excitation électrique; un moyen de mesure (60) relié au moyen générateur (11) pour mesurer le signal de générateur en fonction du moyen à réactance (14, 16) et pour fournir un signal de mesure en fonction de celui-ci; le moyen générateur générant un certain nombre de premiers paquets de charge augmentant la mesure du signal de générateur dans une première direction, et générant un certain nombre de deuxièmes paquets de charge augmentant la mesure du signal de générateur dans une deuxième direction, opposée à la première direction, et un moyen de rétroaction (50) couplé au moyen de mesure (60) pour fournir un signal de commande au moyen générateur (11) en fonction du signal de mesure afin de four-



nir les premiers et les deuxièmes paquets de charge de telle manière que la mesure du signal de générateur tende vers un état d'équilibre de charge et le moyen de rétroaction fournissant un signal de sortie représentatif des nombres de paquets de charge, l'émetteur (10) étant caractérisé en ce que :

le moyen générateur (11) comprend un moyen (20) pour faire varier un niveau de l'excitation électrique du moyen à réactance (14, 16) en fonction du signal de commande pour faire varier la valeur des paquets de charge, et

le moyen de rétroaction (50) comprenant un moyen d'ajustement (51) relié au moyen générateur (11) afin de fournir le signal de commande destiné à faire varier le niveau de l'excitation électrique du moyen à réactance (14, 16), le moyen d'ajustement contrôlant le moyen de variation afin d'ajuster l'excitation électrique à un premier niveau, de sorte que le moyen à réactance fournisse des paquets de charge ayant une valeur qui est fonction du premier niveau, le moyen d'ajustement contrôlant le moyen de variation afin de faire varier l'excitation électrique du premier niveau vers un deuxième niveau, de sorte que le moyen à réactance fournit les paquets de charge ayant une valeur qui soit fonction du deuxième niveau, dans lequel le moyen de variation commande la variation de l'excitation électrique, de telle sorte que la mesure du signal de générateur converge d'abord plus grossièrement vers l'état d'équilibre de charge lorsque l'excitation électrique est au premier niveau et converge ensuite plus finement vers l'état d'équilibre de charge lorsque l'excitation électrique est au deuxième niveau, le signal de sortie étant représentatif des nombres de paquets de charge fournis au moyen de mesure.

2. Emetteur (10) selon la revendication 1, dans lequel le moyen de variation (20) applique un premier niveau d'excitation au moyen à réactance (14, 16) pendant un premier intervalle de temps et applique un deuxième niveau d'excitation, différent du premier niveau, au moyen à réactance (14, 16) pendant un deuxième intervalle de temps, différent du premier intervalle de temps.
3. Emetteur (10) selon la revendication 2, dans lequel l'excitation est cyclique.
4. Emetteur (10) selon la revendication 3, dans lequel le premier intervalle de temps comprend un nombre sélectionné de cycles d'excitation.
5. Emetteur (10) selon la revendication 4, dans lequel le deuxième niveau d'excitation a une valeur plus faible que le premier niveau d'excitation.

6. Emetteur (10) selon la revendication 5, dans lequel le deuxième niveau d'excitation est appliqué au moyen à réactance (14, 16) afin d'équilibrer la charge appliquée pendant le premier intervalle de temps.
7. Emetteur (10) selon la revendication 6, dans lequel le moyen à réactance (14, 16) comprend un capteur capacitif (14, 16).
8. Emetteur (10) selon la revendication 7, dans lequel le paramètre détecté (P, 12) est une pression (P) appliquée au capteur capacitif (14, 16).
9. Emetteur (10) selon la revendication 8, dans lequel le moyen de variation (20) comprend un moyen de division (22, 24) appliqué au capteur capacitif (14, 16) afin de fournir les premier et deuxième niveaux d'excitation.
10. Emetteur (10) selon la revendication 9, dans lequel le moyen de variation (20) comprend, en outre, un moyen de commutation (26, 28) relié au diviseur (22, 24) pour appliquer de manière sélective les premier et deuxième niveaux d'excitation au capteur capacitif (14, 16).
11. Emetteur (10) selon la revendication 10, dans lequel le moyen générateur (11) comprend, en outre, un moyen de correction (34, 44, 46) couplé au moyen à réactance (14, 16) afin de corriger la réactance parasite.
12. Emetteur (10) selon la revendication 11, dans lequel le moyen de rétroaction (50) comprend un moyen de comptage (114, 116, 118, 308) couplé à un signal de rétroaction afin de compter un nombre de paquets de charge appliqués au moyen de mesure (60) pendant un intervalle de temps.
13. Emetteur (10) selon la revendication 9, dans lequel la sortie est fonction du nombre de paquets de charge appliqués par le moyen générateur (11) au moyen de mesure (60) pendant les premier et deuxième intervalles de temps.
14. Emetteur (10) selon la revendication 13, dans lequel la sortie (P) est calculée en substance par le moyen de rétroaction (50)

$$P = K \frac{(N2) - (N1) - (N3/N)}{(N2) + (N1) + (N3/N)}$$

où K est une constante de proportionnalité, N est un rapport de division du moyen de division (22, 24), N1 et N2 sont des nombres de paquets de charge appliqués au moyen de mesure (60) pendant le premier intervalle de temps et N3 est un nombre de paquets de charge appliqués au



moyen de mesure (60) pendant le deuxième intervalle de temps.

15. Emetteur (10) selon la revendication 13, dans lequel la sortie (P) est calculée en substance par le moyen de rétroaction (50) de la façon suivante

$$P = K \frac{(N2 - N1) + (N4 - N3)/2^N}{(N2 + N1) + (N4 + N3)/2^N}$$

où K est une constante de proportionnalité, 2^N est un rapport de division du moyen de division (22, 24), N1 et N2 sont des nombres de paquets de charge appliqués au moyen de mesure (60) pendant un premier intervalle de temps et N3 et N4 sont des nombres de paquets de charge appliqués au moyen de mesure (60) pendant le deuxième intervalle de temps.

16. Emetteur (10) selon la revendication 15, dans lequel la quantité $(N1+N2) + (N4+N3)/2^N$ est régie à une valeur sélectionnée par le moyen de rétroaction (50), de telle sorte que la sortie soit calculée par comptage.

17. Emetteur (10) selon la revendication 9, dans lequel la sortie est un courant de 4-20 milliampères.

18. Emetteur (10) selon la revendication 17, dans lequel l'émetteur (10) est excité par le courant de sortie.

19. Emetteur (10) selon la revendication 1, dans lequel l'émetteur (10) est excité par une boucle à deux fils et fournit une sortie numérique à la boucle.

20. Procédé pour fournir un signal de sortie qui soit fonction du paramètre détecté, le procédé comprenant :

pendant chaque cycle d'une pluralité de cycles de mesure :

l'emploi d'un moyen à réactance auquel un premier niveau d'excitation est appliqué afin de former des premiers paquets de charge d'une première polarité ayant une valeur de charge qui est fonction du paramètre détecté et du premier niveau d'excitation;

l'emploi d'un moyen à réactance afin de former des deuxièmes paquets de charge d'une deuxième polarité opposée ayant une valeur de charge qui est fonction du premier niveau d'excitation et du paramètre détecté;

le transfert d'un certain nombre des premiers paquets de charge vers un accumulateur de charges, de telle sorte que la charge dans l'accumulateur de charges dépasse un état d'équilibre de charge dans une première direction, et le transfert d'un certain nombre de deuxièmes pa-

quets de charge vers un accumulateur de charges jusqu'à ce que la charge dans l'accumulateur de charges dépasse un état d'équilibre de charge dans une deuxième direction;

le procédé étant caractérisé par :

le changement du niveau d'excitation appliqué au moyen à réactance vers un deuxième niveau d'excitation différent;

l'emploi d'un moyen à réactance pour former des troisièmes paquets de charge de la première polarité ayant une valeur de charge qui est une fonction du paramètre détecté et du deuxième niveau d'excitation;

l'emploi du moyen à réactance pour former des quatrièmes paquets de charge de deuxième polarité ayant une valeur de charge qui est une fonction du deuxième niveau d'excitation et du paramètre détecté, et

le transfert d'un certain nombre de troisièmes paquets de charge vers l'accumulateur de charges, de telle sorte que la charge dans l'accumulateur de charges dépasse l'état d'équilibre de charge dans la première direction, et le transfert d'un certain nombre de quatrièmes paquets de charge dans l'accumulateur de charges jusqu'à ce que la charge dans l'accumulateur de charges dépasse l'état d'équilibre de charge dans la deuxième direction, opposée à la première direction;

le comptage des nombres de premiers, deuxièmes, troisièmes et quatrièmes paquets de charge transférés vers l'accumulateur de charges pendant une pluralité de cycles de mesure; et la fourniture du signal de sortie sur la base des nombres comptés.