United States Patent [19]

Narita et al.

[11] **3,928,810**

[45] **Dec. 23, 1975**

[54] **ELECTRONIC ANALOG HOLD CIRCUIT**

[75] Inventors: **Mikio Narita**, Yokohama; **Kiyoto Ohashi**, Tokyo; **Jun Yamamoto**, Yokohama, all of Japan

[73] Assignee: **Fischer & Porter Co.**, Warminster, Pa.

[22] Filed: **Jan. 17, 1974**

[21] Appl. No.: **434,001**

[30] **Foreign Application Priority Data**

Jan. 25, 1973 Japan 48-9941

[52] **U.S. Cl.** **328/127;** 307/229; 328/168; 328/172

[51] **Int. Cl.**........ **G06g 7/18;** H03b 3/02; H03k 1/14

[58] **Field of Search** 328/127, 128, 168, 151, 328/172; 307/229, 230; 318/611, 618

[56] **References Cited**

UNITED STATES PATENTS

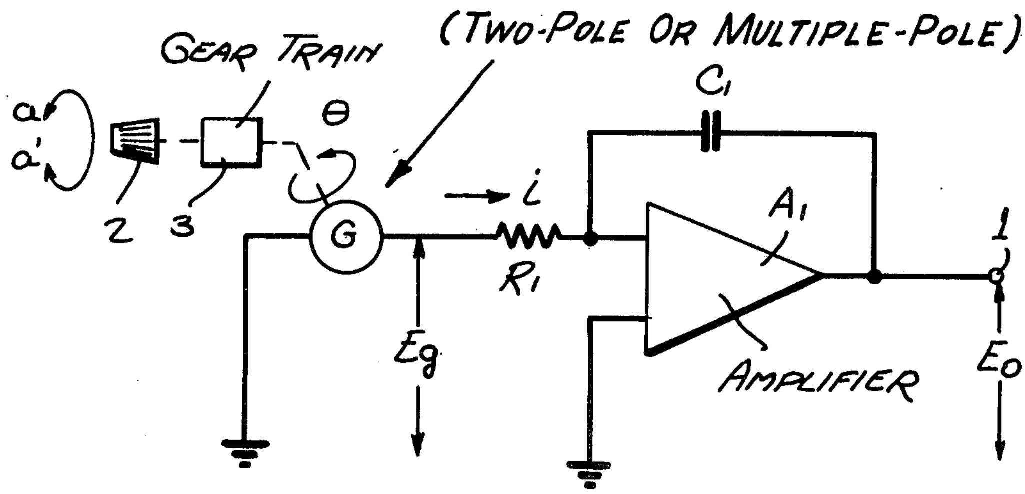
3,072,856	1/1963	Close	328/127 X
3,093,784	6/1963	Mintzer	318/618 X
3,511,979	5/1970	Rabe et al.	328/127 X
3,781,628	12/1973	Rauschelbach	318/611 X
3,783,393	1/1974	Kakiura	328/128 X

Primary Examiner—John Zazworsky

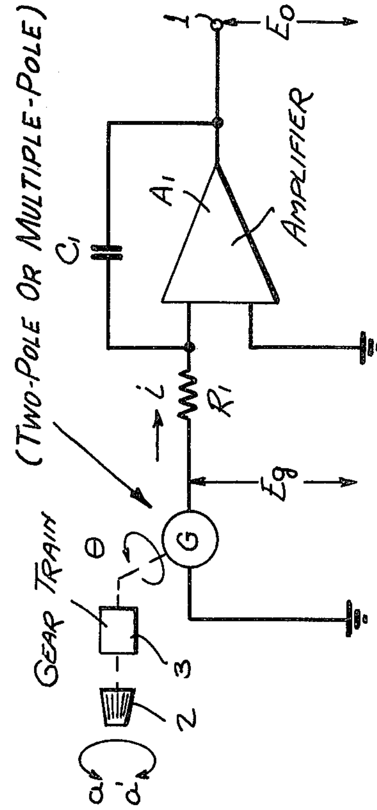
[57] **ABSTRACT**

An electronic hold circuit in which a capacitor is connected between the output of an operational amplifier and an input thereof. A manually-operated device is provided to alter the output of the output of the hold circuit, the device being constituted by a D-C generator connected between a resistor leading to an input of the amplifier and a point of reference potential, the output of the generator being varied by means of a manually-rotatable element whereby by rotating the element, the capacitor is charged with current resulting from the output voltage of the generator, thereby changing the output of the analog hold circuit.

6 Claims, 6 Drawing Figures



FIRST EMBODIMENT



First Embodiment

Fig. 3.

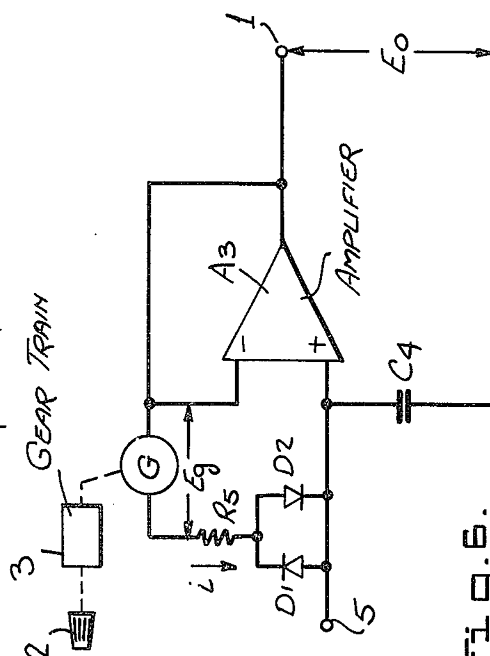
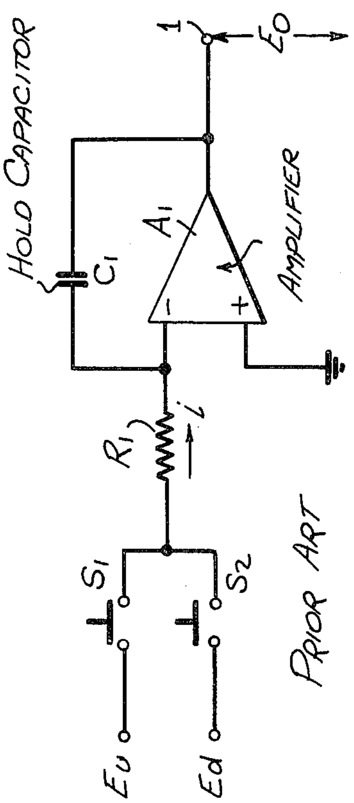
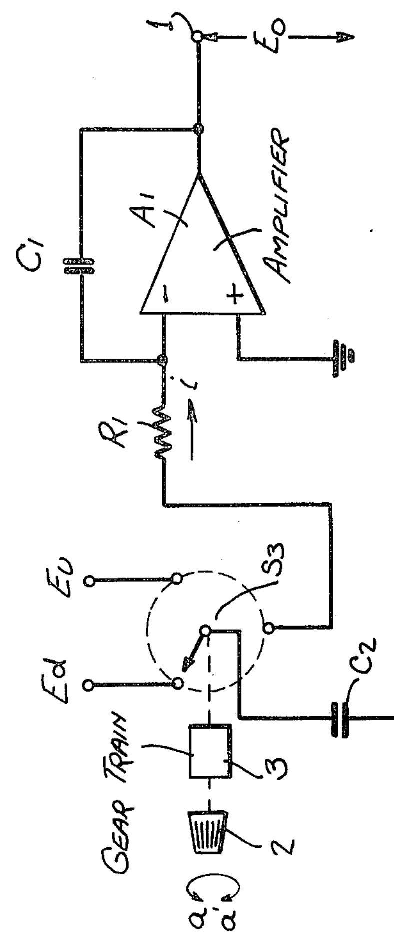


Fig. 6.



Prior Art

Fig. 1.



Prior Art

Fig. 2.

Fig. 5.

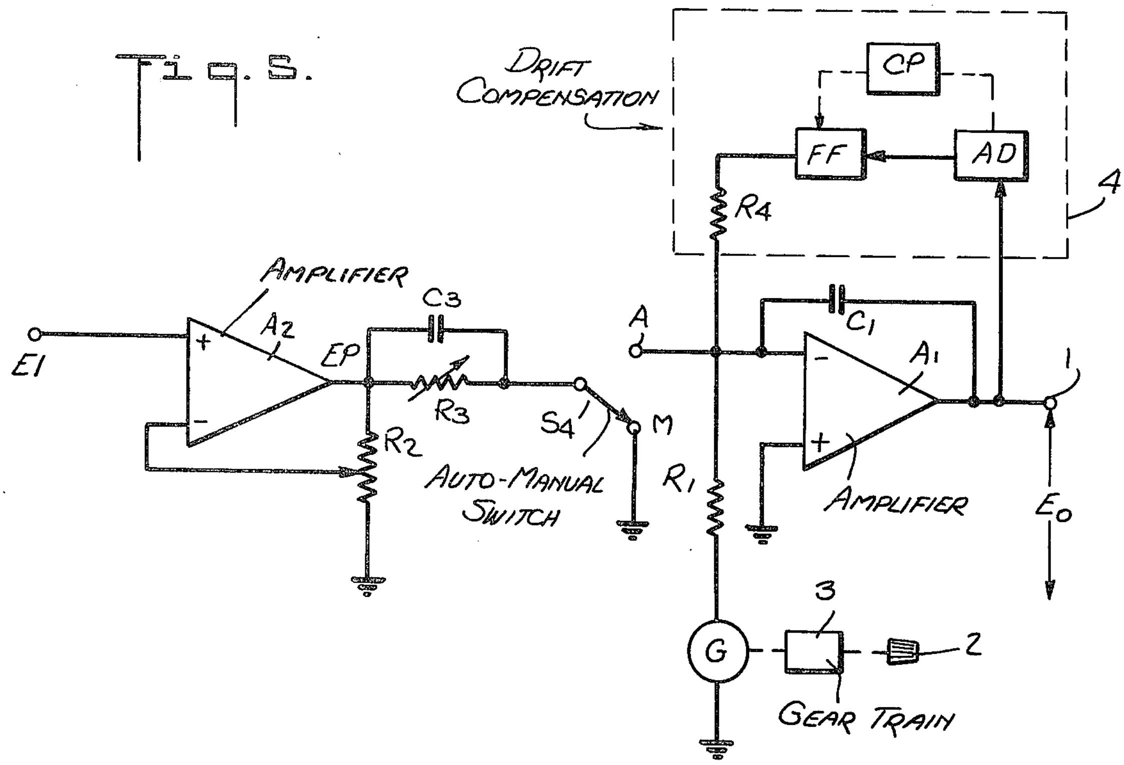
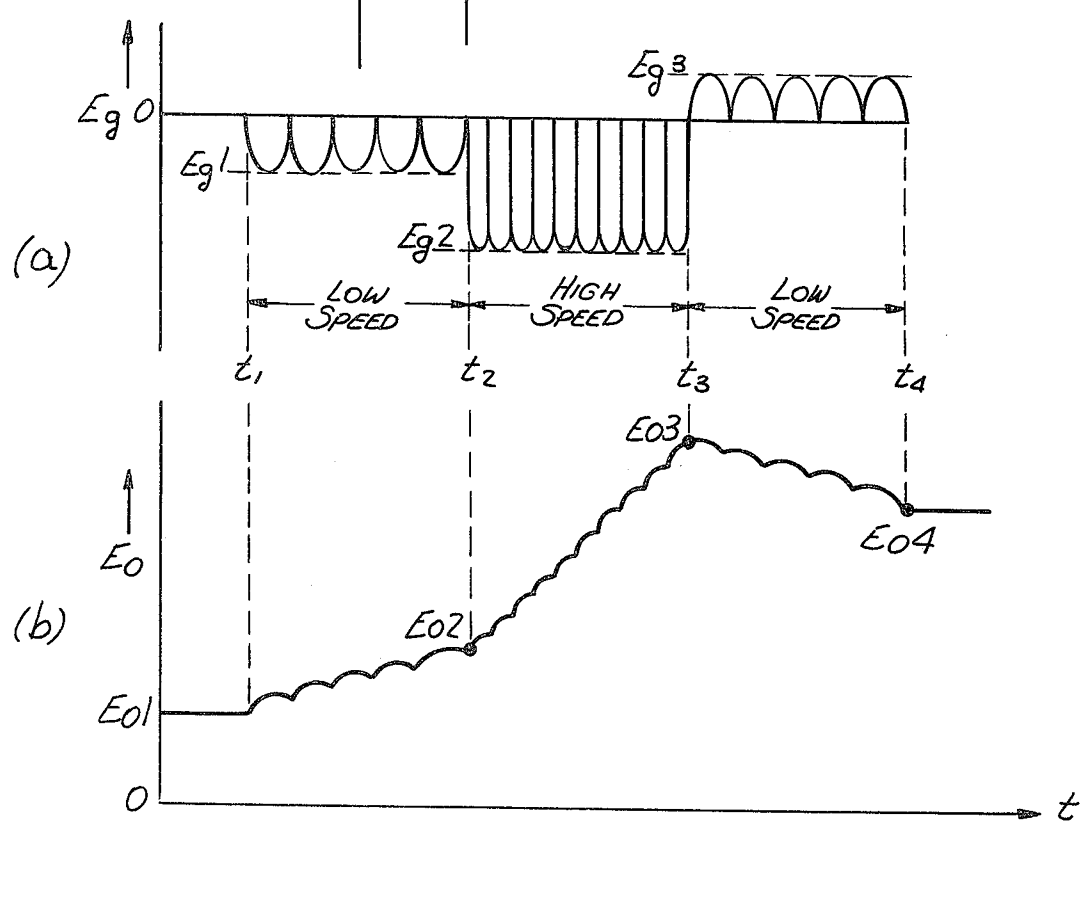

DRIFT COMPENSATION
CP
FF
AD
R4
4
AMPLIFIER
C3
A2
EP
C1
A
A1
1
EI
R3
S4'
M
R2
AUTO-MANUAL SWITCH
R1
AMPLIFIER
Eo
3
G
2
GEAR TRAIN

Fig. 4.


Eg 0
Eg 3
Eg 1
Eg 2
(a)
LOW SPEED
HIGH SPEED
LOW SPEED
t1
t2
t3
t4
E03
Eo
E04
(b)
E02
E01
0
t

ELECTRONIC ANALOG HOLD CIRCUIT

BACKGROUND OF THE INVENTION

This invention relates generally to electronic analog hold circuits, and more particularly to an improved circuit of this type having manually operated means for altering the output thereof.

The use of a potentiometer as a manually operated means for adjusting the set point or output of an electronic controller or of a manual station in a process control system is well known. However, in remote set point operation, a complicated and relatively expensive servomechanism is required in order to follow the output of the potentiometer in accordance with a remote set point so as to effect a balanceless, bumpless transfer from remote to local.

In order to overcome this drawback, it is now the practice to use an electronic analog hold circuit in the setpoint section or in the manual section of the system. In one such arrangement, a push-button type of manually operated means is included in the analog hold circuit to vary the output thereof. In another such arrangement, a knob-operated, rotatable multi-contact switch is employed to effect a change in output.

The problem with push-button rather than potentiometer control is that it is very difficult to effect a small change in output. Moreover, an operator accustomed to manipulate a potentiometer which delivers an output proportional to the rotation angle finds it less expedient to operate a push-button control. In the case of a rotary, multi-contact switch as against a conventional potentiometer control, the former entails greater manufacturing costs.

SUMMARY OF THE INVENTION

In view of the foregoing, it is the main object of this invention to provide an improved, low-cost analog hold circuit having manually operated means to alter the output thereof.

More particularly, it is an object of this invention to provide a circuit of the above-type in which the manually operated means is of the rotary type and affords the same operational feeling as a potentiometer or a multi-contact rotary switch.

Briefly stated, these objects are accomplished in an analog hold circuit comprising an operational amplifier and a hold capacitor connected between the output and one input thereof, a manually operated device being provided to alter the output of the circuit. The device is constituted by a D-C generator connected between a resistor leading to an input of the amplifier and a point of reference potential, the output of the D-C generator being varied by a rotatable knob or thumb wheel mechanically coupled to the generator. Inasmuch as the generator output is proportional to the derivative of the rotation angle of the knob or wheel, the output of the analog hold circuit is proportional to said rotation angle.

OUTLINE OF THE DRAWINGS

For a better understanding of the invention as well as other objects and further features thereof, reference is made to the following detailed description to be read in conjunction with the accompanying drawings, wherein:

FIG. **1** is a schematic diagram of an electronic analog hold circuit provided with one known form of manual-operating means to vary the output of the circuit;

FIG. **2** is a schematic diagram of another known form of manual-operating means;

FIG. **3** is a schematic diagram of a first preferred embodiment of an electronic analog hold circuit provided with a manually-operated device in accordance with the invention;

FIG. **4** is a diagram graphically illustrating the operating principle of the embodiment of the invention shown in FIG. **3**;

FIG. **5** is a schematic diagram of a second preferred embodiment of the invention; and

FIG. **6** is a schematic diagram of a third preferred embodiment of the invention.

DESCRIPTION OF THE INVENTION

Prior Art: Before describing the structure and operation of a manually operated device in accordance with the invention, we shall first consider two prior art forms of electronic analog hold circuits provided with manually operated means to alter the circuit output.

In the prior art arrangement shown in FIG. **1**, a hold capacitor C_1 is connected between the output terminal and the inverting input terminal (−) of an amplifier A_1. The non-inverting input terminal (+) of the amplifier is connected to a potential source having a predetermined level. A push-button S_1 is connected between a voltage source E_u and one end of an input resistor R_1 whose other end is connected to the inverting input (−) of the amplifier, the voltage level of source E_u being lower than said predetermined level. A second push-button E_d is connected between a voltage source E_d and the inverting input terminal (−) through resistor R_1, the level of source E_d being higher than said predetermined level.

By pushing button S_1 or S_2, the lower voltage E_u or the higher voltage may be selectively applied to the input resistor R_1. With this arrangement, when push-button S_2 is held in, a predetermined current (i) is caused to flow into hold capacitor C_1 through resistor R_1, as indicated by the arrow, and the output E_o then developed at the output terminal **1** of the amplifier decreases at a uniform rate. But when push-button S_2 is held in, the current (i) is caused to flow in the reverse direction with respect to the arrow direction, as a consequence of which the output E_o increases at a uniform rate. Thus the voltage change in the output is proportional to the operating time of push-button S_1 or S_2.

With this push-button type of manual operation, the output E_o is changed at a uniform rate. In order to cause the output E_o to attain a desired voltage value, one must manipulate push-button S_1 and S_2 until this value is attained. The operational feeling involved is quite different from that of a rotatable potentiometer whose output is proportional to the angle of rotation. Hence an operator accustomed to the feel of a potentiometer finds it difficult to accommodate himself to a push-button action. Moreover, it is difficult to manipulate push-buttons to make a slight change of the output E_o when such a change is necessary.

In order to provide a control arrangement whose feel is similar to that of a potentiometer and thereby obviate the disadvantage of a push-button operation, it is known to make use of an endlessly rotatable multi-contact switch S_3 as shown in FIG. **2**. This switch, in the form shown, has a set of three fixed contacts, the first being connected to a voltage source E_u whose level is lower than the predetermined potential level, the second being connected to a voltage source E_d whose level is higher than said predetermined level and the third being connected to input resistor R_1 leading to the inverting input terminal (−) of the amplifier. The movable contact of switch S_3 which selectively engages the fixed contacts, is connected to one end of a capacitor C_2 whose other end is connected to the predetermined potential level. The value of capacitance C_2 is small relative to that of hold capacitor C_1.

The movable contact of switch S_3 is mechanically linked by a transmission **3** which may be in the form of a multiplying gear train, to a rotatable knob **2**.

Thus when knob **2** is turned manually in the counterclockwise direction (a), the movable contact of switch S_3 is rotated in the same direction. As a consequence, in the course of each full rotation, the movable contact is connected to input resistor R_1 only after it has been connected to the higher voltage source E_d. Since capacitor C_2 coupled to the movable contact is charged with the higher voltage E_d, in every counterclockwise rotation of switch S_3, this higher voltage is applied to input resistor R_1.

Thus, a very small current (i) flows into hold capacitor C_1 intermittently through input resistor R_1, in the direction shown by the arrow, as the movable contact of switch S_3 repeatedly rotates in the counterclockwise direction, and hold capacitor C_1 is thereby charged in a stepwise manner. The output E_o of the analog hold circuit is thereby caused to decrease in a stepwise manner.

But when knob **2** is rotated in a clockwise direction (a), the movable contact of switch S_3 then proceeds to rotate repeatedly in the same direction, as a result of which the lower voltage E_u is repeatedly applied to input resistor R_1, causing the output E_o to increase in a stepwise manner. Thus the change in the output of the analog hold circuit is proportional to the number of rotations of switch S_3 as determined by the rotation angle of knob **2.** In this way, the operator can change output E_o with a feeling comparable to that experienced when using a potentiometer for manual control.

In order, however, to obtain the same resolution as that of a conventional potentiometer, every stepwise change in output E_o must be set extremely small. Hence the movable contact of switch S_3 must be rotated several hundred times in order to run through the full span (0–100%) of the output E_o. To accomplish this purpose, transmission **3** must be structured so that one can traverse the full span of the output merely by rotating control knob **2** a few times. It is for this reason that multiple-contact switches have been developed where instead of a single set of three fixed contacts as shown in FIG. **2,** the switch has several sets of such contacts which are sequentially engaged by the movable contact in the course of each rotation. But such specially constructed switches are relatively expensive and add substantially to the cost of the electronic hold circuit.

First Embodiment: Referring now to FIG. **3,** there is shown a first preferred embodiment of this invention which includes a D-C generator G in place of the rotational switch S_3 and the capacitor C_2 shown in FIG. **2.** The output of generator G is varied by means of a knob **2** through a suitable transmission **3,** Generator G is electrically connected so as to supply an output voltage Eg between the one end of the input resistor R_1 and the predetermined voltage level common to the non-inverting input terminal (+) of amplifier A_1.

When in this arrangement, knob **2** is rotated counterclockwise, the D-C generator G is rotated $\theta°$ in the same direction through transmission **3.** In accordance with the rotation of the generator, an electromotive force proportional to the variation rate of said θ, i.e., $d\theta/dt$ (rad/sec) is generated. The output voltage E_g of generator G may be expressed by the following equation:

$$E_g = K \cdot \frac{d\theta}{dt} \quad (1)$$

where: K is constant.

Accordingly, when the current (i) flows through the input resistor R_1 in the direction shown by an arrow in FIG. **3,** the following equation can be derived:

$$i = \frac{K}{R_1} \frac{d\theta}{dt} \quad (2)$$

On the other hand, as the output E_o of the analog hold circuit corresponds to the time integral of the current (i), the following equation can be derived:

$$E_o = -\frac{1}{C_1} \int \left(\frac{K}{R_1} \frac{d\theta}{dt} \right) dt = -\frac{AK}{C_1 R_1} \theta \quad (3)$$

where: A is constant.

As a result, the output E_o of amplifier A_1 decreases in proportion to the rotation angle θ. That is, the output E_o of the analog hold circuit is altered in proportion to the rotation angle of the generator, i.e., to the rotation angle of the knob **2.**

When knob **2** is rotated clockwise, an output voltage of reverse polarity to that produced by a counterclockwise rotation is generated by the generator G. As a consequence, the output E_o of the analog hold circuit increases rather than decreases in the manner previously described.

FIG. **4** is a diagram illustrating the relationship between E_g, the generator output, and E_o, the circuit output. In this figure, the waveform (a) shows the output voltage E_g of the DC generator G while the waveform (b) shows the output E_o of the analog hold circuit.

When generator G is slowly rotated clockwise from time t_1 to t_2, a negative pulsating D-C voltage E_g**1** of small amplitude is generated and the output E_o concurrently increases from level E_{01} to E_{02}, under the influence of these pulsations. Thereafter, when the D-C generator is rotated clockwise at a faster rate in the interval from time t_2 to t_3, a negative pulsating output E_g**2** of larger amplitude is generated and the output E_o of the analog hold circuit increases from level E_{02} to E_{03} with a larger gradient.

However, when the D-C generator G is rotated counterclockwise in the subsequent interval from time t_3 to t_4, a positive pulsating output E_g**3** of small amplitude is generated, and the output E_o of the analog hold circuit then decreases slowly from level E_{03} to E_{04}, under the influence of these pulsations. When rotation of the D-C generator G is thereafter arrested, the output voltage Eg and also the current (i) becomes zero. As a consequence, the analog hold circuit holds the voltage value E_{04}.

The reasons the pulsations of the waveform shown in FIG. **4** are very large is that in this example, a simple two pole D-C generator is used. However, these pulsations in output voltage E_o can be minimized and a more desirable D-C output can be obtained, when a conventional multiple pole generator is used in the place of a two pole D-C generator. In this instance, the output E_o can be increased or decreased more smoothly.

Second Embodiment: FIG. **5** shows a second preferred embodiment of the invention in which the analog hold circuit shown in FIG. **3** is applied to a manual station in an electronic controller. As shown in this figure, when Auto-Manual change-over switch S_4 is transferred to its "Manual" position M, the circuit including operational amplifier A_1 acts as a hold amplifier and generates a manual output E_o in the manner explained in connection with FIGS. **3** and **4.**

When the Auto-Manual change-over switch S_4 is transferred to its "Auto" position A, the proportional operational amplifier composed of an amplifier A_2 and a potentiometer R_2, to which a deviation input E_i is applied, generates a proportional output E_p as a function of input E_i. This output is then applied to the inverting input terminal of the amplifier A_1 through a parallel circuit of a capacitor C_3 and a variable resistor R_3. In this case, the circuit composed of the amplifier A_1 and capacitor C_1 acts as a proportional-integral operational amplifier. Its proportional gain is determined by the ratio between capacitor C_1 and capacitor C_3, and its integral time is determined by capacitor C_3 and variable resistor R_3.

The section **4** of the arrangement encircled by dotted lines which is connected between the output terminal and the inverting input terminal of the amplifier A_1 is a drift compensating circuit. This circuit acts to compensate the drift of the output E_o because of decay of the hold memory through the leakage resistance of the capacitor C_1 and the limited input impedance of the amplifier A_1.

The drift compensating circuit contains a converter AD for converting the output E_o to a signal whose frequency corresponds to the output E_o, a clock pulse generator CP, a counter FF to count the frequency of the signal for a predetermined period and a resistor **4** for generating a compensation signal in accordance with the output state (1 or 0) of the counter FF at the end of counting, so that the compensation signal may be supplied to the inverting input terminal of the amplifier A_1.

By the use of this drift compensating circuit, the output drift of the analog hold circuit can be made less than 0.1 percent of full scale. From the technical point of view, it will be appreciated that this electronic analog hold circuitry may be used in place of the conventional potentiometer.

Third Embodiment: FIG. **6** shows a third preferred embodiment of this invention, in which the manually operated means in accordance with the invention is applied to an ordinary sample hold circuit. The sample hold circuit is composed of an amplifier A_3 and a capacitor C_4 connected between the non-inverting input terminal and the reference potential level. Between the output terminal and the inverting terminal of the amplifier A_3, one may provide a circuit so that the output E_o is fed back directly or through a divider (not shown).

With this construction, the output of generator G which is connected between the inverting input terminal and the non-inverting input terminal of the amplifier A_3 through resistor R_5 and the parallel circuit of diodes D_1 and D_2, is applied across these input terminals. The current (i) from generator G flows into the capacitor C_4 through the current-regulating resistor R_5 and the diode D_1 or D_2 depending on its direction. Also, the current from the low impedance output terminal **1** flows to generator G.

A terminal **5** connected to the non-inverting input terminal of the amplifier A_3 acts to receive input signals to charge the capacitor C_4, other than the manual operating signal produced by generator G. The diodes D_1 and D_2 act as a switch for separating the circuit including the generator G from both input terminals of the amplifier A_3, and serves to secure an input offset voltage of the amplifier A_3, which is necessary for the amplifier's normal function.

The D-C generator included in this invention is the ordinary type adapted to generate positive or negative D-C voltage in accordance with the direction of rotation. Accordingly, many commercially available, low-cost D-C generators can be used for this purpose without making any changes therein. Furthermore, since the generator in this invention is not rotated continuously, a highly durable generator is not required.

An ordinary D-C generator has a commutator and brushes. However, a brushless D-C generator containing Hall effect elements and transistorized switching circuits is also applicable to this invention. Moreover, an A-C generator may be used in place of a D-C generator if a rectifying means and means for detecting the rotating direction are added thereto to produce the necessary D-C output.

As noted previously, the operating principle of the circuit in accordance with this invention differs markedly from that of the conventional circuit. That is, in the analog hold circuit of this invention, the alteration of the output E_o, i.e., the alteration of the memory of the capacitor C_1 is brought about by the voltage of the generator G. On the other hand, in the conventional analog hold circuit having push buttons as shown in FIG. **1** or an endlessly rotatable switch as shown in FIG. **2,** the alteration of the output E_o is caused by the voltage supplied by external voltage sources E_d, E_{u1}

The present circuit may, therefore, be composed of inexpensive components as distinguished from conventional circuits containing a specially-structured rotatable switch as shown in FIG. **2.** And, in accordance with this invention, the output E_o of the circuit can be changed with the same operational feeling as that of the conventional potentiometer.

While there have been shown preferred embodiments of this invention, it will be appreciated that many changes may be made therein without, however, departing from the essential spirit of the invention as disclosed herein.

We claim:

1. An electronic analog hold circuit comprising:

a. an operational amplifier having a hold capacitor connected thereto and

b. a manually operated device to alter the output of the hold circuit, said device including a D-C generator connected between a point of reference potential and an input to said amplifier, said generator being rotated in either direction by means of a manually operated knob or thumb wheel which is mechanically coupled to the generator shaft to cause it to make several turns for each turn of the knob or wheel, whereby the voltage produced by said generator has a polarity that depends on the direction of rotation and gives rise to a current which charges said capacitor to change the output of said analog hold circuit.

2. An electronic analog hold circuit as set forth in claim **1** wherein said knob or thumb wheel is mechanically coupled to said generator through a gear train whereby a single turn of said knob or wheel results in several turns of said generator.

3. An analog hold circuit as set forth in claim **1** wherein said operational amplifier has an inverting and a noninverting input and said hold capacitor and said generator are both connected to said inverting input, said non-inverting input being connected to said point of reference potential.

4. An analog hold circuit as set forth in claim **1** wherein said generator is a multiple pole generator producing a relatively smooth output whose polarity depends on the direction of rotation.

5. An analog hold circuit as set forth in claim **1**, wherein said hold capacitor is connected between the output of said amplifier and an input thereof, said generator being connected to said input through an input resistor.

6. An analog hold circuit as set forth in claim **5** further including a drift compensation circuit connected between the output and said input of the amplifier.

* * * * *