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(54) Control signal generating circuits

(57) An actuator, of quasi-continuous type, for regulating or control means contains a change-over switch (4) which can be switched over from one limiting position (a) to another (c) depending on the size of a control signal, and a smoothing circuit (16, 17) feedable in response to the switch position with different pulses having a mean value corresponding to the control signal. To prolong the life of the change-over switch and save expense, especially with regard to the smoothing, a rectifier circuit (5) feedable with AC voltage is provided, in which the connection of diodes (6-9) can be so changed by the change-over switch (4) that the rectifier circuit acts as a full wave rectifier or is short circuited depending on the two limiting positions (c, a) and in an intermediate position (b) of the change-over switch (4) the rectifier operates as half-wave. The rectifier is coupled to the smoothing circuit, e.g. by a photo diode (11) and transistor (12).

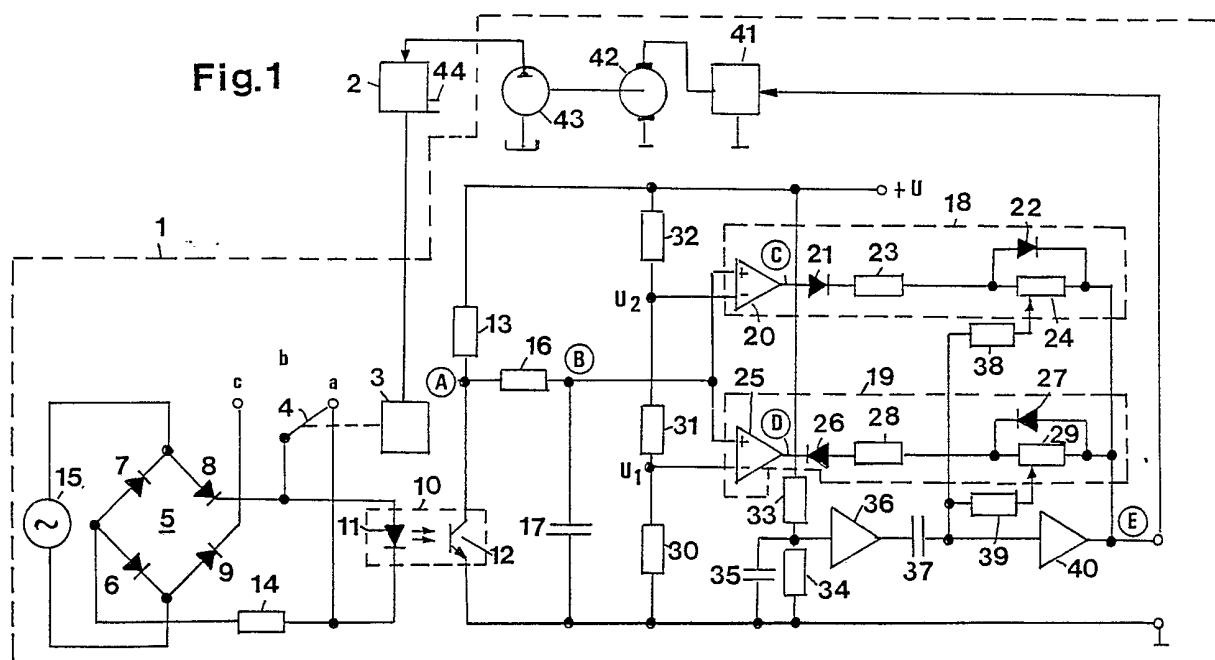


Fig.1

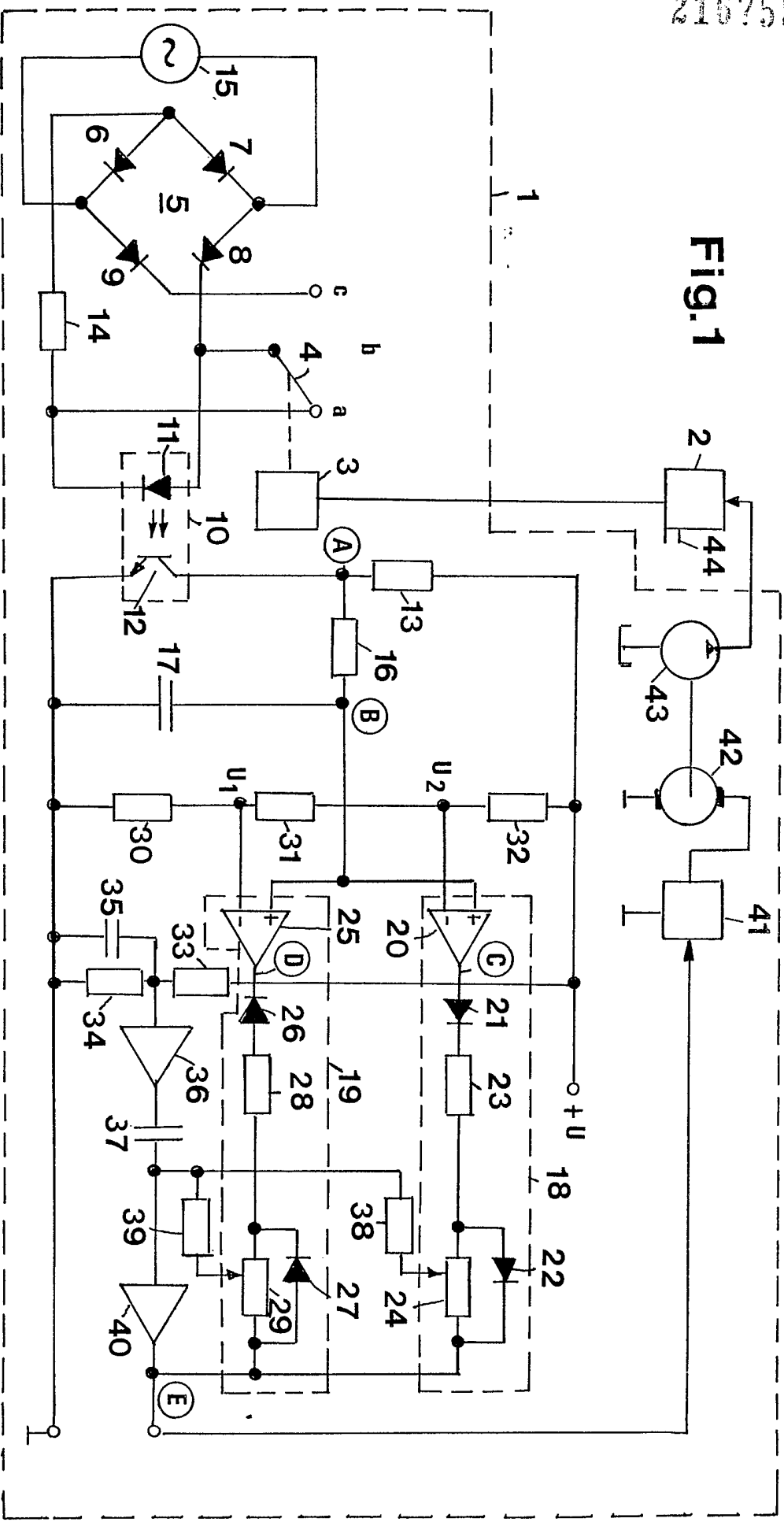
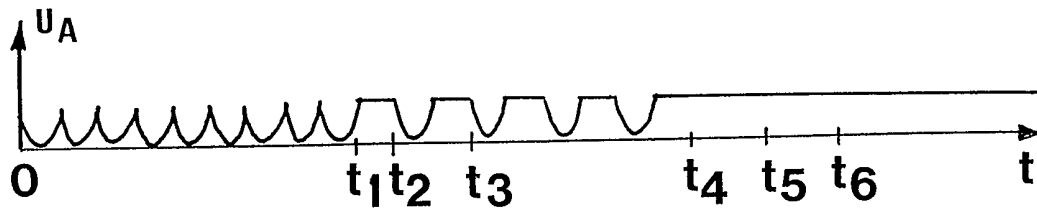
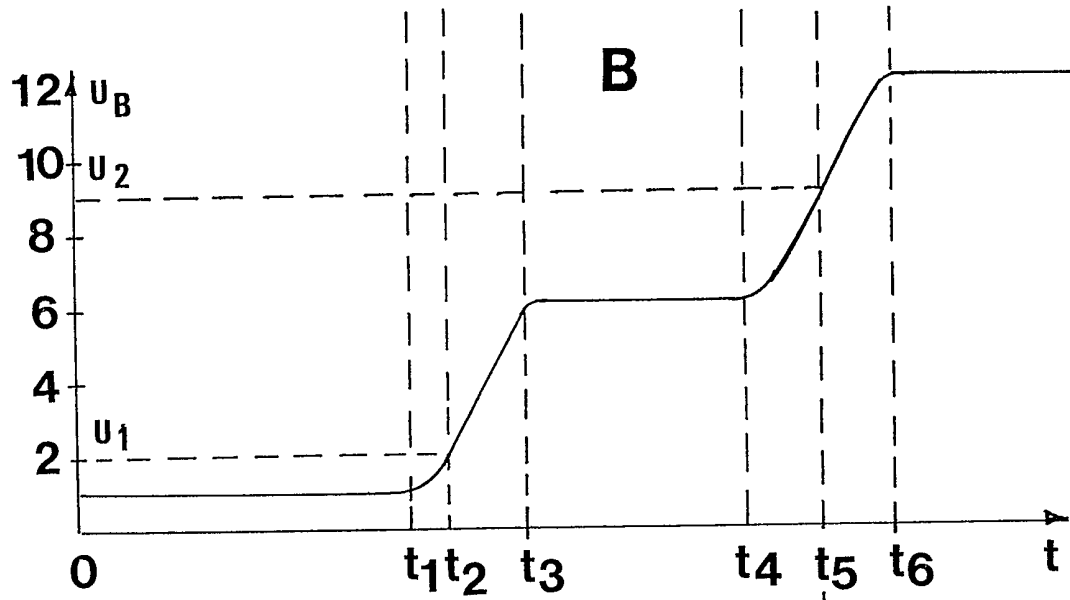


Fig. 2

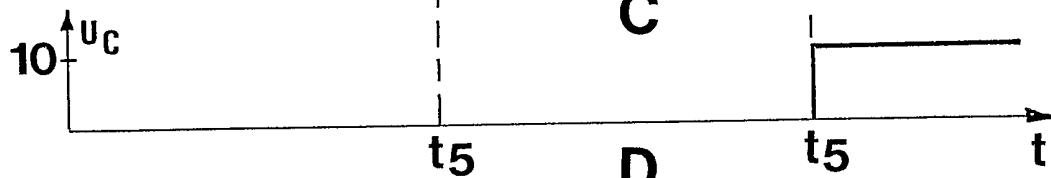
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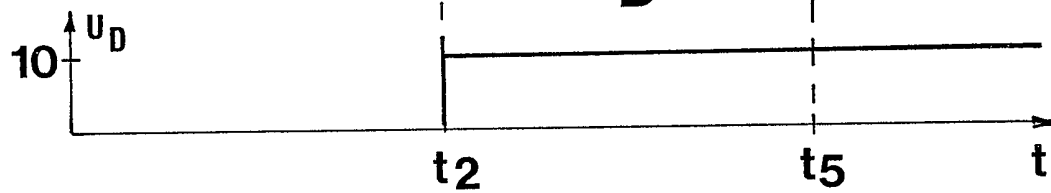
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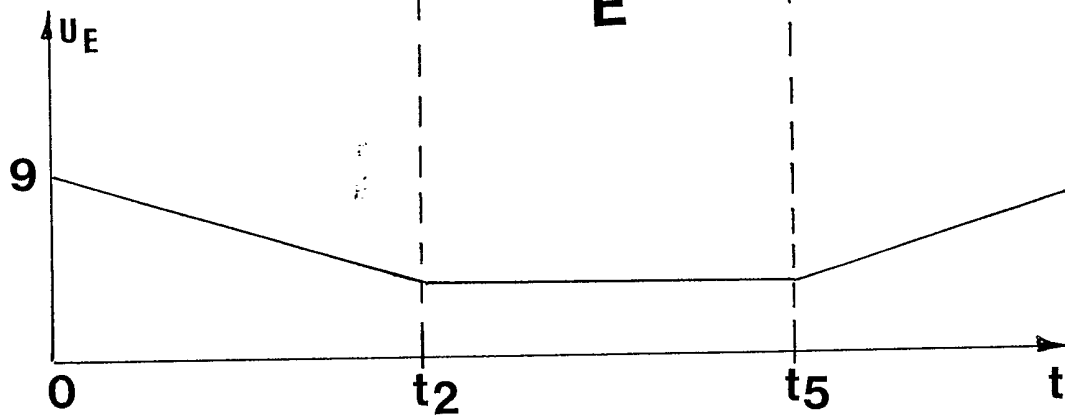
C



D



E



SPECIFICATION

Control signal generating circuits

5 The present invention relates to a control signal generating circuit.

A known actuator, of quasi-continuous type, for regulation or control comprises a change-over switch, which can be switched over from one
10 limiting position to another depending on the value of a control input, and a smoothing circuit fed as a result of the switching operation with a series of pulses, the mean value of which corresponds to the value of the control input. Thus, the known actuator
15 is quasi-continuous in that even though a switching operation is taking place a continuous output is obtained from the smoothing circuit.

The known actuator contains a bimetallic switch which, depending on the difference or departure
20 between the existing and desired temperature values, will switch on the one or other of two different DC voltages for a longer or shorter time to a smoothing circuit containing an ohmic resistor in series with a condenser or a choke. A substantially
25 smoothed actuating or control signal will then be derived at the output of the smoothing circuit. However, this construction calls for frequent operation of the change-over switch between the two voltages, even if the temporal mean value of the DC
30 voltages applied to the smoothing circuit corresponds to the set desired value. This reduces the life of the change-over switch. Further, a high expenditure on smoothing components is required in the DC circuit (high capacitance and inductance) to obtain
35 an actuating signal that is as continuous as possible. Similarly, to form the two DC voltages one requires either expensive batteries and the like or rectifiers with smoothing means, possibly voltage transformers, for example voltage dividers, to achieve the
40 difference DC voltages.

The invention is based on the problem of providing a control signal generating circuit of quasi-continuous type including switching means, in which a longer life for the switching means can be
45 obtained at less expense.

The present invention provides a control signal generating circuit for regulating or control means, comprising switching means which can be switched
50 between a plurality of switched states by a control input, and a smoothing circuit fed, in use, as a result of operation of the switching means with a series of pulses the mean value of which corresponds to the value of the control input, wherein a rectifier circuit feedable with AC voltage is provided, in which
55 connections associated with the rectifier circuit can be so changed by the switching means that the rectifier circuit acts as a half-wave or full-wave rectifier, and the rectified output is connected to or disconnected from the smoothing circuit according
60 to the switch state of the switching means.

Preferably, the switching means is a mechanical switch switchable between first and second end positions by way of an intermediate position.

The above problem can be solved in accordance
65 with the invention in that a rectifier circuit feedable

with AC voltage is provided, in which the connection of diodes can be so changed by the change-over switch that the rectifier circuit acts as a one-way or two-way rectifier depending on the two limiting
70 positions and an intermediate position of the change-over switch and its DC circuit is coupled to or separated from the smoothing circuit.

In this construction, less frequent operation of the change-over switch is required because in the
75 intermediate position of the change-over switch one can produce a mean actuating signal which is at least close to the desired value, so that the change-over switch will mostly assume its intermediate position. Further, batteries or expenditure for smoothing can be dispensed with on the input side of the
80 change-over switch. At the same time, the expense in the smoothing circuit on the output side of the changeover switch can be kept low because the harmonic content of substantially sinusoidal half
85 waves is less than that of square waves. The change-over switch can be a simple two pole change over switch and nevertheless be capable of transmitting three different actuating signals.

Preferably, the smoothing circuit is applied by way
90 of a drop resistor to a constant DC voltage and in parallel with a light receiver of an opto-coupler that is in the form of a phototransistor, the light generator of which lies in the DC circuit and which is de-energised in the one limiting position of the
95 change-over switch. In this limiting position a constant DC voltage will then already be applied to the smoothing circuit, namely the highest applied to the smoothing circuit, so that in this case there is no smoothing by the smoothing circuit. The expense in
100 the smoothing circuit can be reduced accordingly.

Preferably, the change-over switch short-circuits the light generator in the one limiting position and connects the rectifier circuit as a two-way bridge
105 rectifier in the other limiting position, the change-over switch in this other limiting position interconnecting the cathode of two diodes that form the plus pole of the two-way bridge rectifier. The output voltage of the smoothing circuit will be the largest or smallest at the two limiting positions of the change-over switch and has an intermediate value in the
110 intermediate position of the change-over switch in which the rectifier circuit is connected as a one-way rectifier.

The output of the smoothing circuit may be
115 connected to two trigger stages which have different threshold values and, on exceeding their threshold value, produce oppositely poled DC voltages as charging voltages for an integration condenser. In this way, it is possible to transform the on average
120 constant output voltages of the smoothing circuit into substantially linearly rising or falling control voltages depending on their size, so that the actuator receives an I behaviour (integral behaviour) which permits a continuous approach right up to the
125 desired value.

Further, one can ensure that each trigger stage comprises a comparator, one input of which lies at a reference potential determining its threshold value and the other input of which is connected to the
130 output of the smoothing circuit, and on the output

side two diodes connected in series in the same sense and a voltage divider parallel to the second of these diodes, that the tapping of the voltage divider is connected to the one connection of the integration
5 condenser by way of a charging resistor, the other connection of the integration condenser being at a reference potential, and that the one connection of the integration condenser is connected by way of an amplifier with an amplification of about 1 to that end
10 of the series circuits of these diodes that is remote from the comparators.

The (second) diodes of the trigger stages on the output side will here, in so far that a current passes through them, form constant voltage sources of
15 opposite polarity which, in conjunction with the amplifier having an amplification of 1, ensure charging or discharging of the integration condenser with a constant current, so that the voltage at the condenser and hence the output voltage at the
20 amplifier rises or falls linearly as is desired.

The reference potential of the integration condenser preferably lies between the reference potentials of the comparators. In this way, one obtains rapid approach of the quantity to be regulated to the
25 desired value when switching the regulating or control means on.

If the reference potential of the integration condenser is tapped at a voltage divider resistor which is bridged by a condenser, one obtains a gentle start or
30 continuous increase in the actuating signal even when the equipment is switched on.

A control system including a control signal generating circuit according to the invention will now be described by way of example only with reference to
35 the accompanying drawings, in which:

Figure 1 is a circuit diagram of the control system having an actuator and a regulating or control path according to the invention, and

Figure 2 shows the waveforms of different voltages at particular points in the *Figure 1* circuit.
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Referring to *Figure 1*, a control system 1 serves to regulate the pressure in a container 2 or tube system forming the regulated portion of the system and includes a regulator 3 with a pressure sensor which
45 forms a comparator and at which one can set the desired pressure value in a manner not shown. The other components of the control system 1 define an actuator of the system.

The output signal of the regulator 3 that forms the regulating means or regulating difference controls a change-over switch 4 as is indicated by the broken line between the regulator 3 and change-over switch 4. The change-over switch 4 therefore assumes, depending on the magnitude of the signal controlling it, a first limiting or end position at a fixed contact *a*, an intermediate position in a zone *b* and a second limiting or end position at a fixed contact *c*. The transition from the limiting or end position at contact *a* to the limiting or end position at contact *c* takes
60 place continuously, that is without a trigger action and without the change-over switch 4 staying in the intermediate position in zone *b*.

The change-over switch is at the output of a rectifier circuit 5 of four diodes 6, 7, 8, and 9.

65 An opto-coupler 10 contains a luminous diode as

light generator 11 and a phototransistor as light receiver 12. The light generator 11 is in series with a current limiting resistor 14 in the DC circuit of the rectifier circuit 5, it is possible instead to connect the
70 resistor 14 in the AC circuit of the rectifier circuit 5. The rectifier circuit 5 is energised by an AC voltage source 15 formed by the normal AC mains.

In the limiting or end position at contact *a*, the change-over switch 4 short-circuits the light generator 11. In the intermediate position in zone *b*, the diodes 6 and 8 form a half-wave rectifier, and in the limiting or end position of the change-over switch at contact *c*, the diodes 6 to 9 define a full-wave rectifier, the change-over switch 4 connecting the
80 cathodes of diodes 8 and 9 that form the positive terminal of the full-wave rectifier.

The light receiver 12 is connected in parallel with a smoothing circuit consisting of a resistor 16 and a condenser 17. The smoothing circuit is energised by
85 way of a voltage-dropping resistor 13 from a constant operating voltage *U* of about 12 volt.

The voltage U_B at the output of the smoothing circuit or smoothing condenser 17 is fed to two trigger stages 18 and 19. The trigger stage 18
90 contains a comparator 20 and, in the output circuit of the comparator 20, two diodes 21 and 22 connected in the same sense, a current limiting resistor 23 between the diodes 21 and 22, and a voltage divider 24 parallel to the second diode 22 on the output side.
95 The trigger stage 19 also contains a comparator 25 and, in the output circuit of the comparator 25, two diodes 26 and 27 connected in series in the same sense, a current limiting resistor 28 between the diodes 26 and 27, and a voltage divider 29 parallel to the second diode 27 on the output side.
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The diodes 21, 22 of trigger stage 18 are, however, poled oppositely to the diodes 26, 27 of trigger stage 19.

The non-inverting inputs (+) of the comparators 20, 25 are connected to the output *B* of the smoothing circuit and the inverting inputs (−) of the comparators 20, 25 are each connected to a different tapping of a voltage divider which consists of resistors 30, 31 and 32 and is likewise applied to the
110 DC operating voltage *U*.

The tapping of a further voltage divider consisting of resistors 33 and 34 applied to the DC operating voltage as well as of a condenser 35 connected in parallel with the resistor 34 on the common potential or earth side is connected to one end of an integration condenser 37 by way of an amplifier 36 with an amplification of about 1:1 (about unity). The other connection of the integration condenser 37 is connected by way of equal charging resistors 38 and
115 39 to the tapplings of the voltage dividers 24 and 29 which each have an adjustable and a fixed resistor in series and, by way of an amplifier 40 with high input resistance and an amplification of about 1:1 (about unity), to the outputs of trigger stages 18 and 19.

125 The output *E* of amplifier 40 is connected to a frequency control input of an inverter 41. The latter feeds a motor 42 driving a pump 43 which fills the container 2 with pressure fluid and is driven at a speed corresponding to the output frequency of the inverter 41. The pressure fluid is withdrawn at an
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outlet 44 of the container 2.

The operation of the regulating means is as follows. At a high pressure in the container 2, the change-over switch 4 assumes the limiting or end position at the contact *c*. In this position, half-wave rectified current of substantially sinusoidal half waves flows through the luminous diode 11 and the phototransistor 12 of the opto-coupler 10. The voltage U_A at point A in Figure 1 therefore has somewhat the shape shown in Figure 2A in the form of full-wave rectified inverse substantially sinusoidal half waves. Accordingly, the voltage U_B at the output B of the smoothing circuit has its lowest value as shown in Figure 2B. This value is lower than the reference potential U_1 at the inverting input (-) of comparator 25 and lower than the reference potential U_2 at the inverting input (-) of comparator 20. The output voltages U_C and U_D at the outputs C and D of comparators 20 and 25 are therefore (practically) zero. The amplifier 40 therefore drives a current through the diodes 26 and 27 whilst the diodes 21 and 22 are blocked. By reason of the constant pass voltage drop at diode 27, the voltage at the voltage divider resistor 29 is also constant. Further, since the voltage drop at amplifier 40 is practically zero on account of the amplification of 1:1, the voltage at resistor 39 is also substantially equal to the constant voltage that is tapped at the voltage divider 29 between the output E and resistor 39, that is the voltage at resistor 39 is also substantially constant. Since the input current of amplifier 40 is negligibly small, a constant current likewise flows through the integration condenser 37 and linearly discharges the integration condenser 37. This is shown by the shape in Figure 2E of the output voltage u_E at output E between the instants 0 and t_2 . The output voltage E therefore linearly reduces the frequency of the inverse rectifier 41, the speed of motor 42 and of the pump and thus a corresponding reduction of the pressure in the container 2. At the time t_1 , the pressure has decreased to such an extent that the change-over switch 4 has moved out of the limiting position at the contact *c* and moves to an intermediate position in the zone b. In this intermediate position, only a half-wave rectified ("half missing") current flows through the luminous diode 11 and the phototransistor 12 because the AC source 15 can drive a current only by way of the diodes 8 and 6. Accordingly, the voltage U_A at point A or at the phototransistor 12 has somewhat the shape shown in Figure 2A between the times t_1 and t_3 . In the zone between t_1 and t_3 , the mean value of voltage U_A is thus higher than in the zone between 0 and t_1 , so that the condenser 17 will start to charge to a higher voltage U_B at the time t_1 , as is shown in Figure 2B.

At the time t_2 , the voltage U_B will exceed the voltage U_1 tapped at resistor 30, so that the output voltage U_D of comparator 25 will now jump to a higher positive value, as is shown by Figure 2D. On the other hand, the voltage U_B does not yet reach the value of voltage U_2 which, in its entirety, is dropped across the resistors 30 and 31, so that the output voltage U_C of comparator 20 remains at zero (Figure 2C).

In the intermediate position of the change-over

switch 4, all diodes 21, 22, 26 and 27 are blocked. The integration condenser 37 can therefore neither charge nor discharge and therefore retains the voltage it reached at the time t_2 . As long as the change-over switch 4 remains between the limiting positions *a* and *c*, the output voltage U_E (Figure 2E) therefore remains constant even though the voltage U_B at the smoothing condenser 27 continues to rise up to the time t_3 (and at the same time also the voltage U_A somewhat but this is neglected in the Figure 2A illustration) to a new mean value corresponding to the new mean value of voltage U_A . Accordingly, the pressure in container 2 also remains constant if there is no external influence thereon.

Assume that at the time t_4 the pressure in container 2 has dropped to an extent that the change-over switch 4 reaches the limiting position at contact *a*. In this position, the light emitting diode 11 is short-circuited by the change-over switch 4 so that the diode 11 and the phototransistor 12 are de-energised. The voltage U_A at the point A now ceases to pulsate. The smoothing condenser 17 is thus charged to a higher voltage U_B until the instant t_6 (the voltage U_A simultaneously rises somewhat further but this has been neglected in Figure 2A for the sake of simplicity).

At the time t_5 , the voltage U_B at the smoothing condenser 17 also exceeds the voltage U_2 , so that the output voltage U_C of the comparator 20 also jumps to a positive higher value (Figure 2C). The diodes 21 and 22 which are now conductive permit linear charging of the integration condenser 37 and hence an increase in the pressure in the container 2 again.

The voltage tapped at the voltage divider formed by the resistors 32 and 34 determines the starting value of the integration. This voltage is between U_1 and U_2 , so that the integration condenser 37 more rapidly reaches the desired value when the regulating means are switched on. To achieve a gentle start, the resistor 34 is bridged by the condenser 35.

The charging and discharging speed of the integration condenser 37 can be determined by means of the adjustable voltage dividers 24 and 29.

The resistances of resistors 23 and 28 are selected to be equal, as are the resistors 24 and 29.

The change-over switch 4 can be a three position switch with a further fixed contact at a position in the middle between the contacts *a* and *c*. This middle contact would, however, remain free or unconnected. Further, the regulator 3 and change-over switch 4 can be in the form of a structural unit, for example a "pressostat".

Between the output E of amplifier 40 and its input as well as earth, there can in each case be a resistor for discharging the integration condenser 37 after switching the regulating means 1 off, so that the amplifier 40 will not be loaded by an excessively high voltage on switching on. "Resistors" here mean "ohmic" resistors.

Referred to an adjustment of the desired value (or the leading parameter), the regulating means 1 can be regarded as control means. The regulating means 1 will function as control means even on "open"

operation, that is for example upon adjustment of the change-over switch 4 in response to a physical parameter other than the pressure in container 2 and not detected (measured) by the regulator 3, for example upon adjustment of the change-over switch by hand or according to a predetermined programme.

CLAIMS

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1. A control signal generating circuit for regulating or control means, comprising switching means which can be switched between a plurality of switched states by a control input, and a smoothing circuit fed, in use, as a result of operation of the switching means with a series of pulses the mean value of which corresponds to the value of the control input, wherein a rectifier circuit feedable with AC voltage is provided, in which connections associated with the rectifier circuit can be so changed by the switching means that the rectifier circuit acts as a half-wave or full-wave rectifier, and the rectified output is connected to or disconnected from the smoothing circuit according to the switched state of the switching means.

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2. A circuit as claimed in claim 1, wherein the switching means is a mechanical switch switchable between first and second end positions by way of an intermediate position.

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3. A circuit as claimed in claim 1 or 2, wherein the smoothing circuit is connected by way of a dropping resistor to a source of substantially constant DC voltage.

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4. A circuit as claimed in any of claims 1 to 3, wherein the smoothing circuit is connected in parallel with a light-receiver of an opto-coupler, and the light generator of the opto-coupler is connected in the DC circuit of the rectifier circuit but is arranged to be de-energised for one state of the switching means.

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5. A circuit as claimed in claim 4, wherein the light receiver is a photo-transistor.

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6. A circuit as claimed in claim 4 or 5 when dependent on claim 2, wherein the switching means is arranged to short-circuit the light generator in the said one state which corresponds to one of the end positions of the switch.

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7. A circuit as claimed in claim 6, wherein the switching means is arranged to connect the rectifier circuit as a full-wave bridge rectifier circuit in the other end position.

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8. A circuit as claimed in claim 7, wherein, in the said other end position, the switching means interconnects like electrodes of two diodes arranged to define one DC terminal of the full-wave rectifier circuit.

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9. A circuit as claimed in claim 8, wherein the like electrodes are cathodes and the one DC terminal is the positive terminal.

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10. A circuit as claimed in any preceding claim, wherein the output of the smoothing circuit is connected to the inputs of a plurality of trigger circuits, each with a different threshold value.

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11. A circuit as claimed in claim 1, wherein the outputs of the trigger circuits are connected to an

integrator circuit.

12. A circuit as claimed in claim 11, wherein the number of trigger circuits is two, the one trigger circuit producing an oppositely-poled DC output voltage to the other when its threshold value is exceeded.

13. A circuit as claimed in claim 12, wherein the said oppositely-poled DC output voltages are employed, in use, as charging voltages for an integration condenser of the integrator circuit.

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14. A circuit as claimed in any of claims 10 to 13, wherein each trigger circuit comprises a comparator circuit having one input arranged to lie at a reference potential to determine the threshold value of the particular circuit, and the other input of which comparator circuit is connected to the output of the smoothing circuit.

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15. A circuit as claimed in claims 13 and 14, wherein each comparator circuit has its output connected to a respective pair of diodes connected in series in the same sense, a respective voltage divider is connected in parallel with the second of the diodes of each pair, the tapping of each voltage divider is connected to one end of the integration condenser by way of a respective charging resistor, the other end of the integration condenser is arranged to be at a reference potential, and the said one end of the integration condenser is connected by way of an amplifier circuit with gain of about unity to the ends remote from the comparator circuits of the series-connected diode pairs.

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16. A circuit as claimed in claim 15, wherein the reference potential for the integration condenser is derived from a resistive voltage divider having a parallel-connected condenser.

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17. An actuator comprising an actuating device in combination with a circuit as claimed in any preceding claim connected to control the operation of the actuating device.

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18. A control signal generating circuit for regulating or control means substantially as herein described with reference to, and as illustrated by, the accompanying drawings.

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19. A pressure regulation system including a circuit as claimed in claim 18 and being substantially as herein described with reference to, and as illustrated by, the accompanying drawings.

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