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(54) RADIOACTIVE ISOTOPE SENSOR DEVICE

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The present invention relates to radioactive isotope devices and, in particular, to radioactive isotope sensor devices used to control and automate technological processes in various industries, transport and agriculture.

Known in the art are sensor devices in which the ionizing radiation is registered by a detector unit which converts it into electric pulses fed to an electronic-relay unit.

Such an isotope sensor device uses an analog electronic - relay unit and a direct signal converter designed around an integrating RC-network. The presence of this network prevents the sensor devices from having highly stable response and release thresholds and a high statistical reliability of operation in case of small ionizing radiation differences. Besides, this RC-network limits the range of the response and release threshold adjustment in the device and makes it impossible to raise the ratio between the speed of operation and the statistical reliability. And finally, when a broad range of performance characteristics is required the presence of this network leads to increased complexity of the design which narrows the field of applications of such radioactive isotope relay devices to control and automate technological processes.

According to the present invention there is provided a radioactive isotope sensor device in which a detector unit registers ionizing radiation and converts it into electric pulses which are applied to an electronic bistable unit, the latter comprising a discrete comparison device with two outputs and two inputs, a first of the inputs being connected to the detector unit which delivers a random series of electric pulses at a repetition frequency representative of the intensity of said ionizing radiation, a bistable device coupled with the outputs of the discrete comparison device and a threshold frequency setter yielding a regular series of electric pulses at a frequency which is settable to yield pulses at one or other of two threshold frequencies in response to signals received at its inputs which are each connected to a respective output of the bistable device, the output of the threshold frequency setter being connected to the second input of the discrete comparison device, whereby the sensor device will acquire either the "yes" - or the "no"-state depending upon the relation between the frequencies of the random and regular pulse series that are being compared.

The present invention may be used to provide a radioactive isotope sensor device responsive to the levels of liquid and bulk materials in containers of various shapes having a preset thickness and made of a specified material.

The present invention may also be used to proved a radioactive isotope sensor device responsive to the positions and displacements of objects, parts of mechanisms and means of transportation.

The invention may further be used to provide a radioactive isotope sensor device responsive to changes in the density of a fluid.

The threshold frequency setter may comprise two pulse generators, two logical AND-elements with two inputs and one output and a commn logical OR-element with two inputs and one output, the output of each generator being connected to one input of its logical AND-element, while the outputs of the logical AND-elements are connected, via the logical OR-element, to the second input of the comparison device and while each logical AND-element has its other input connected to the relay element so that the respective frequency threshold is ensured either from one or from the other generator depending upon the state of the relay element ("yes" or "no").

To increase the reliability of the device and to raise the stability of the hysteresis ratio it is feasible that the threshold frequency setter should contain a pulse generator with two frequency setting means connected to the second input of the discrete comparison device, as well as a switching element connected to the outputs of the relay element and coupled with the first and second frequency setting means so that the respective threshold frequency is produced depending upon the state of the relay element ("yes" or "no"). It will be understood that the use of switched threshold frequencies, in accordance with the invention, allows the conditions at which the relay element is respectively actuated and released to be selected arbitraily without affecting the reliability of the apparatus.

The discrete comparison device may comprise a reversible counter with the required memory capacity and two similar comparison elements to sense the sign of the difference between the numbers of applied pulses, one of said comparison elements having one of its inputs connected to the detector unit and the other input connected to the output of the threshold frequency setter, and its output connected to the inputs of the reversible counter, while in order to ensure unambiguous operation of the latter in case of memory overflow it has its outputs connected to the inputs of the other comparison element which, in its turn, has its outputs connected to the inputs of the relay element.

It is also preferable that each comparison element should comprise a trigger with separate inputs and two gates with two inputs and one output having their inputs connected in parallel to the respective inputs and outputs of the trigger.

The proposed radioactive isotope sensor device has a high speed of operation with a high statistical reliability in a wide range of ionizing radiation differences, a wide range of response threshold and release threshold adjustments and a high stability of the response and release thresholds within a wide range of ambient temperature and supply voltage variations.

The invention will be better understood from the following description of its embodiments given by way of example with reference to the accompanying drawings, in which:

Fig. 1 presents a block diagram of the radioactive isotope relay device according to the invention,

Fig. 2 presents a version of the proposed radioactive isotope relay device with two pulse generators;

Fig. 3 presents a schematic diagram of the device as shown in Fig. 2;

Fig. 4 presents a block diagram of another version of proposed radioactive isotope relay device with one pulse generator;

Fig. 5 presents a schematic diagram of the device as shown in Fig. 4.

The radioactive isotope sensor device according to the invention comprises a radioactive source 1 (Fig. 1) of ionizing radiation (in the version to be described it is gamma-radiation but it can as well be any other type of ionizing radiation) and a detector unit 2 registering this radiation and converting it into electric pulses to be fed to an electronic-relay unit 3.

The electronic-bistable unit 3 contains a discrete comparison device 4 having two outputs and two inputs one of which is connected to the detector unit 2 delivering a random series of electric pulses, and a bistable device 5, hereinafter termed a relay element, coupled with the outputs of the comparison device 4. The unit 3 contains also a threshold frequency setter 6 yielding selectively one or other of two regular series of electrical impulses. The two inputs of the setter 6 are connected to the outputs of the relay element 5 serving as the output of the sensor device itself (the output of the device is indicated by the direction of arrows A in the drawing). The output of the setter 6 is connected to the second input of the comparison device 4. Due to this arrangement the device will be either in the "yes" or in the "no" - state depending upon the ratio between the frequencies of the random and of the regular pulse series that are being compared.

In the first embodiment of the radioactive isotope relay device the threshold frequency setter 6 (Fig. 2) comprises two pulse generators 7, 8, two logic AND-elements 9, 10 with two inputs and one output, and a common logic OR-element 11 with two inputs and one output. The output of the generator 7 is connected to one input of the logic AND-element 9 while the output of the generator 8 is connected to one input of the logic AND-element 10. The outputs of the logic AND-elements 9, 10 are connected to the inputs of the logic OR-element 11 the output of which is connected to the second input of the comparison device 4. The other inputs of the logic AND-elements 9, 10 are connected to the respective output of the relay element 5 so that one of the generators 7 or 8 will yield a threshold frequency corresponding to the state of the relay element 5 ("yes" or "nor").

In the embodiment of the device that is being described the detector unit 2 (Fig. 3) contains an ionizing radiation detector 12 coupled with a pulse shaper-amplifier 13.

The discrete comparison device 4 comprises a reversible counter 14 with a required memory capacity determined by the number of its digits, and two similar comparison elements 15, 16 to sense the sign of the difference between the numbers of pulses applied to the two inputs of device 4. The comparison element 15 has one of its inputs connected to the shaper-amplifier 13, while its other input is connected to the logic OR-element 11 of the setter 6. The outputs of the comparison element 15 are coupled with the inputs of the reversible counter 14. To ensure unambiguous operation in cases when the capacity of the counter 14 is exceeded a comparison element 16 has its inputs connected to the outputs of the reversible counter 14 while the outputs of the element 16 are coupled with the inputs of the relay element 5 arranged as a trigger which is thus set to one or other of its stable conditions according as the number of pulses received from the detector exceeds or is less than the number of pulses received from the setter 6.

The comparison element 15 contains a trigger 17 with separate inputs and two gates each of which has two inputs and one output. The inputs of the gates are cross connected to the respective inputs and outputs of the trigger 17. One of the gates contains a diode 19 which passes the signal applied to it by way of a capacitor 18 which is connected to the input of the trigger 17 while an enabling signal is applied to it from the output of trigger 17 by way of a resistor 20; the second gate includes a diode 22 which is connected to the second input of the trigger 17 through a capacitor 21 and is enabled by a signal obtained from the first output of trigger 17 by way of a resistor 23.

The outputs of the comparison element 15 are coupled to the inputs of the reversible counter.

The comparison element 16 contains a trigger 24 with separate inputs and two gates, each of which has two inputs and one output. The inputs of the gates are cross-connected to the respective inputs and outputs of the trigger 24. One of the gates includes a diode 26 which is coupled to the first input of trigger 24 by way of a capacitor 25 and is enabled by a signal applied to it from the second output of trigger 24 by way of a resistor 27; the other gate includes a diode 29 which is coupled to the second input of trigger 24 and is enabled by a signal applied to it from the first output of trigger 24 by way of a resistor 30. The outputs of diodes 26, 29 are coupled to the inputs of the relay element 5.

The pulse generators 7, 8 comprise pulse shaping circuits 31, 32 respectively and frequency setting means using capacitors 33, 34 and variable resistors 35, 36.

The logic AND-elements 9, 10 comprise transistors 37, 38 respectively, the collector circuits thereof containing resistors 39, 40, while the bases of the transistors are connected, via resistors 41, 42 and 43, 44 to the pulse shaping circuits 31, 32 and to the outputs of the relay element 5, respectively. The bases of the transistors 37, 38 are fed with a bias voltage U_1, which arrives via resistors 45, 46. The collectors of the transistors 37, 38 are coupled, via capacitors 47, 48, with the inputs of the logic OR-element 11.

The logic OR-element 11 contains diodes 49, 50, each having one of its leads connected to capacitors 47, 48, respectively, while their common lead is connected to the input of the trigger 17. The common lead of the diodes 49, 50 is connected, via a resistor 51, to the body (shown in the drawing out of true position) of the electronic-relay unit 3.

The second embodiment version of the proposed radioactive isotope relay device is very similar to the first embodiment version described above.

The pricipal difference consists in that the threshold frequency setter 6 (Fig. 4) comprises only one pulse generator 56 with two frequency setting means 53, 54, the generator being coupled with the second input of the comparison device 4. Besides, the setter 6 comprises also a switching element 55 connected to the outputs of the relay element 5 and coupled with the frequency setting means 53, 54 so that the required frequency threshold is obtained depending on the state of the relay element 5 ("yes" or "no").

The pulse generator 52 (Fig. 5) comprises a pulse shaping circuit 56 the output of which is connected to the trigger 17 and which has its input connected to the first 53 and to the second 54 frequency setting means. The means 53, 54 use variable resistors 57, 58 (Fig. 5), respectively, and a common capacitor 59.

The functions of the switching element 55 are performed by transistors 60, 61 whose collectors are connected to the variable resistors 57, 58, respectively, and whose bases are connected to the outputs of the relay element 5. The collector circuits of the transistors 60, 61 contain resistors 62, 63 the common point of which is coupled with the capacitor 59. The bases of the transistors 60, 61 are fed with a bias voltage U_2 which arrives via resistors 64, 65.

The functions of the switching element 55 can be performed by thyristors, switching diodes or electromagnetic relays.

The operation of the first embodiment version of the proposed radioactive isotope relay device can be described as follows.

The energy of gamma-ray quanta emitted by the source 1 (Fig. 3) is received by the ionizing radiation detector 12 and converted into electric pulses to be formed and amplified in the pulse shaper-amplifier 13 from the output of which they are fed to one of the inputs of the trigger 17 of the comparison element 15. Unlike the random series of electric pulses produced by the detector unit 2, the second input of the trigger 17 is fed with a regular series of electric pulses delivered from the threshold frequency setter 6.

The response threshold, that is, the value of the mean pulse rate from detector 2 which must be exceeded in order that relay 5 shall be actuated, is set by the frequency of the regular pulse series produced by the pulse generator 8 while the release threshold, that is, the value below which the mean pulse rate of the detector pulses must fall in order to cause relay 5 to be released, is set by the pulse generator 7. The response and release thresholds are adjusted in the pulse generators 7, 8 with the help of the variable resistors 35, 36 respectively.

The stability of the electronic-relay unit 3 is determined in terms of stability of the response and release threshold frequencies which depend upon supply voltage fluctuations (the supply voltage source is not shown in the drawing) and ambient temperature variations. Regular pulse series from the outputs of the generators 7, 8 are applied respectively to the bases of the transistors 37, 38 in the logic AND-elements 9, 10 via the resistors 41, 42.

When the relay element 5 is in the "no"-state the base of the transistor 37 will receive a negative voltage arriving from an output of the relay element 5 via the resistor 43 and the base of transistor 38 will receive a voltage approaching zero arriving from the other output of the relay element 5 via the resistor 44, so that this transistor is turned on and the second input of the trigger 17 will be fed with a regular pulse series which arrives from the pulse generator 8 via the logic OR-element 11.

When the relay element 5 passes to the "yes"-state the voltages applied to the bases of the transistors 37, 38 from the outputs of the relay 5 via the resistors 43, 44 will be interchanged. In this case the second input of the trigger 17 will be fed with a regular pulse series arriving from the generator 7 via the logic OR-element 11.

One of the functions of the discrete comparison device 4 is to compare the random pulse series from the detector with a regular pulse series and to control the relay element 5 driving it either to the "yes"-state or to the "no"-state depending upon the ratio between the compared frequencies. The second function of the comparison device 4 is to average the random pulse series, the degree of averaging being determined by the memory capacity of the reversible counter 14, i.e. by the number of its digits.

The comparison device 4 is arranged to operate so that a pulse can appear at the output of one of its channels only after the pulses that were registered earlier in the opposite channel have all been erased.

Three characteristic situations can occur in the course of operation of the radioactive isotope relay device.

In the first characteristic situation, when the average frequency of the random pulse series is less than the frequency of the regular pulse series, pulses of the difference frequency (negative difference between numbers of pulses) are applied to the count-down input of the reversible counter 14 via the capacitor 21 and the diode 22 of the comparison element 15. In a case when the memory capacity of the reversible counter 14 is exceeded by data arriving at this count-down input a pulse from the respective output is fed, via the capacitor 28 and the diode 29 of the comparison element 16, to the input of the relay element 5. This pulse will either confirm the "no"-state of the relay element 5 or will drive the latter to this state. This action will occur provided that the comparison element 16 has not previously received pulses from the count-up input of counter 14, in which case the trigger 24 of comparison element 16 will have been set by the received pulses to a condition in which diode 29 is cut off. The appearance of a pulse at either output of the reversible counter 14 causes the simultaneous erasure of previously registered data. If the trigger 24 of the comparison element 16 was previously set as described, the pulse from the output of the reversible counter 14 will reset the trigger 24 of the comparison element 16 to the opposite state. Simultaneously, the gate containing the capacitor 28, the diode 29 and the resistor 30 will be opened and in case of the capacity of the reversible counter 14 being again exceeded, a pulse from the output of the latter will pass through this gate to the input of the relay element 5 driving it to the "no"-state.

In the second characteristic situation, when the average frequency of the random pulse series exceeds the frequency of the regular series, pulses of the difference frequency (positive difference between the number of pulses) are applied to the count-up input of the reversible counter 14 via the capacitor 18 and the diode 19 of the comparison element 15. An overflow pulse appearing at the count-up output of the reversible counter 14 when the capacity of the counter is exceeded will cause the erasureing of data previously registered in it before. Simultaneously, this pulse is fed, via the capacitor 25 and the diode 26, to the input of the relay element 5 confirming its "yes"-state or driving it to this state if the trigger 24 has not been previously reset by pulses arriving from the count-down output of the comparison device 4. In case such pulses have arrived from the count-down output the pulse from the count-up output of the reversible counter 14 will set the trigger 24 to the opposite state. Simultaneously, the gate containing the capacitor 25, the diode 26 and the resistor 27 will be opened and pass a pulse to relay 5 when another overflow pulse is received from the reversible counter 14.

In case of the third characteristic situation, when the average frequency of the random pulse series is equal to the frequency of the regular pulse series with the hysteresis ratio (the ratio of the release threshold frequency to the response threshold frequency) being 1, the comparison device 4 will register the difference frequencies caused by fluctuations of the instant frequency of the statistic pulse series about its average value. In this case there is an equal probability of the pulses appearing at the output of either channel of the comparison device 4 and it depends upon the memory capacity of the reversible counter 14 and upon the values of the frequencies that are being compared.

In case the hysteresis ratio is less than 1, and the average frequency of the random pulse series is equal to the response threshold frequency the probability of false operation of the relay element is considerably decreased, since for the relay element to change to its opposite condition it is necessary that the mean value of the pulse rate shall be lower than the release threshold.

In this case the probaility of false operation depends upon the capacity of the reversible counter 14, the value of the frequencies being compared and the hystersis ratio.

The operation of the second embodiment version of the proposed radioactive isotope relay device is similar to that of the first embodiment version.

The difference consists in that the relay element 5 (Fig. 4) controls the switching element 55 which, in its turn, depending upon the state ("yes" or "no") of the relay element 5, will connect either the first setting means 53 or the second frequency setting means 54 to the pulse shaping circuit 56. The first frequency setting means 53 ensures that the pulse generator 52 produces a regular pulse series at its output with the response threshold frequency. The second frequency setting means 54 ensures that the generator 52 produces at its output a regular pulse series with the release threshold frequency.

When the relay element 5 (Fig. 5) is in the "no"-state one of its outputs produces a voltage approaching zero which is applied to the base of the transistor 61, while the other output produces a negative voltage which is applied to the base of the transistor 60 driving the latter to conduction and saturation. The transistor 61 is cut off by the positive bias voltage applied to its base from terminal U_2. The output of the generator 52 produces a regular pulse series with the response threshold frequency.

When the relay element 5 is in the "yes"-state one of its outputs produces a negative voltage which is applied to the base of the transistor 61 while the base of the transistor 60 is fed with a voltage approaching zero. The generator 52 then produces at its output a regular pulse series with the release threshold frequency.

The second embodiment of the proposed radioactive isotope relay device differs from the first version in that it has a higher stability of the hysteresis ratio which is quite important in case the device is used to react to small differences in the ionizing radiation intensity.

The proposed radioactive isotope relay device has a number of advantages if compared against its known counter-parts using analog electronic-relay units. Thus, it allows:

to detect a relative radiation difference of 10 per cent of the limit value to be detected whereas the respective figure for the known devices will be 100 per cent; it permits the speed of operation to be raised by a factor of 10; it permits the instability of the response and release threshold frequencies to be reduced to 5 per cent (instead of 40-50 per cent) and 0.05 per cent (instead of 10-15 per cent) respectively within the total range of threshold adjustments irrespective of supply voltage fluctuations, and to increase the gamma-ray radiation sensitivity to be raised to 0.04 mR/h.

The proposed radioactive isotope sensor device can be used to develop radioactive isotope devices for various purposes, e.g. liquid dispensers, servo level indicators for fluids, level controllers for bulk materials, liquid density regulators, item counters for conveyors, meter counters, tachometers, etc.

WHAT WE CLAIM IS:—

1. A radioactive isotope sensor device in which a detector unit registers ionizing radiation and converts it into electric pulses which are applied to an electronic bistable unit, the latter comprising a discrete comparison device with two outputs and two inputs, a first of the inputs being connected to the detector unit which delivers a random series of electric pulses at a repetition frequency representative of the intensity of said ionizing radiation, a bistable device coupled with the outputs of the discrete comparison device and a threshold frequency setter yielding a regular series of electric pulses at a frequency which is settable to yield pulses at one or other of two threshold frequencies in response to signals received at its inputs, which are each connected, to a respective output of the bistable device, the output of the threshold frequency setter being connected to the second input of the discrete comparison device, whereby the sensor device will acquire either the "yes"- or the "no"-state depending upon the relation between the frequencies of the random and regular pulse series that are being compared.

2. A radioactive isotope sensor device as claimed in claim 1 in which the threshold frequency setter comprises two pulse generators, two logic AND-elements each having one output and two inputs one of which is connected to its pulse generator; a logic OR-element with two inputs connected respectively to the outputs of the logic AND-elements and one output connected to the second input of the discrete comparison device, the second inputs of said logic AND-elements being connected to the bistable device so that either one or the other generator will produce the respective threshold frequency depending upon the state of the relay element ("yes" or "no").

3. A radioactive isotope sensor device as claimed in Claim 1 in which the threshold frequency setter comprises one pulse generator connected to the second input of the discrete comparison device and provided with two frequency setting means; a switching element connected to the outputs of the relay element coupled with the first and second frequecy setting means so that the respective frequency threshold is obtained depending upon the state of bistable device ("yes" or "no").

4. A radioactive isotope sensor device as claimed in any of Claims 1 to 3 in which the discrete comparison device comprises a reversible counter having a required memory capacity; two identical comparison elements each arranged to sense the sign of the difference between the numbers of pulses applied to its two inputs, one of said elements having one of its inputs connected to the detector unit and the other input connected to the threshold frequency setter, while the outputs of this comparison element are connected to the inputs of the reversible counter which has its overflow outputs connected to the inputs of the other comparison element so as to ensure its unambiguous operation in case the capacity of the reversible counter is exceeded, the outputs of the second comparison element being connected to the inputs of the relay element.

5. A radioactive isotope relay device as claimed in Claim 4 in which each comparison element comprises a trigger with separate inputs and two gates, each having two inputs and one output, while the inputs are cross-connected to the respective inputs and outputs of the trigger.

6. A radioactive isotope relay device substantially as hereinbefore described, with reference to and as shown in the accompanying drawings.

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1372789 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

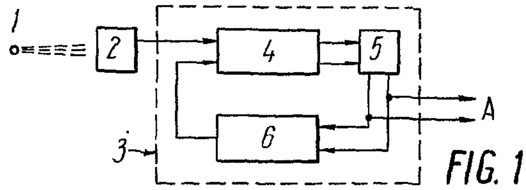

FIG. 1

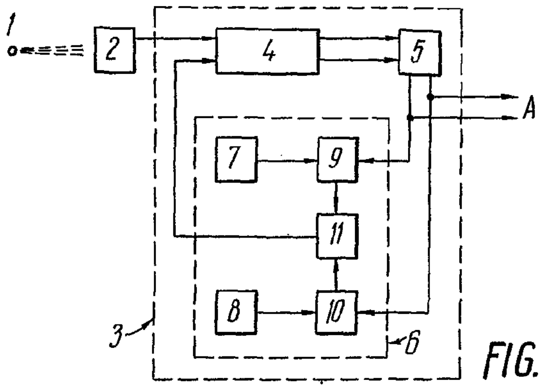

FIG. 2

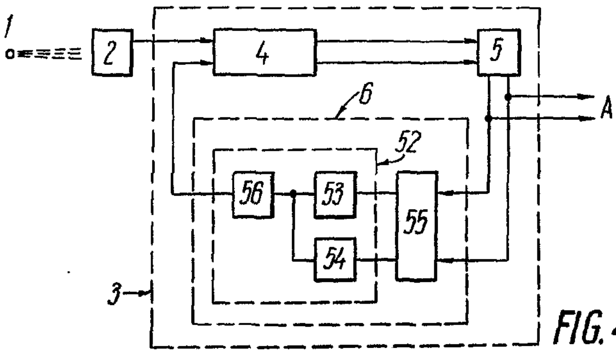

FIG. 4

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Sheet 2

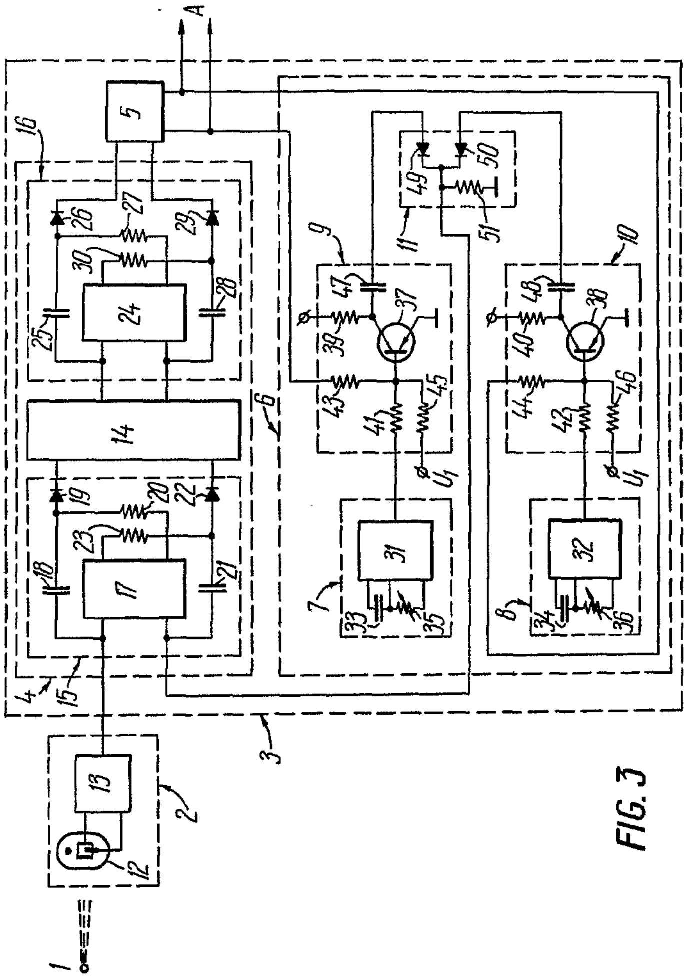

FIG. 3

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Sheet 3

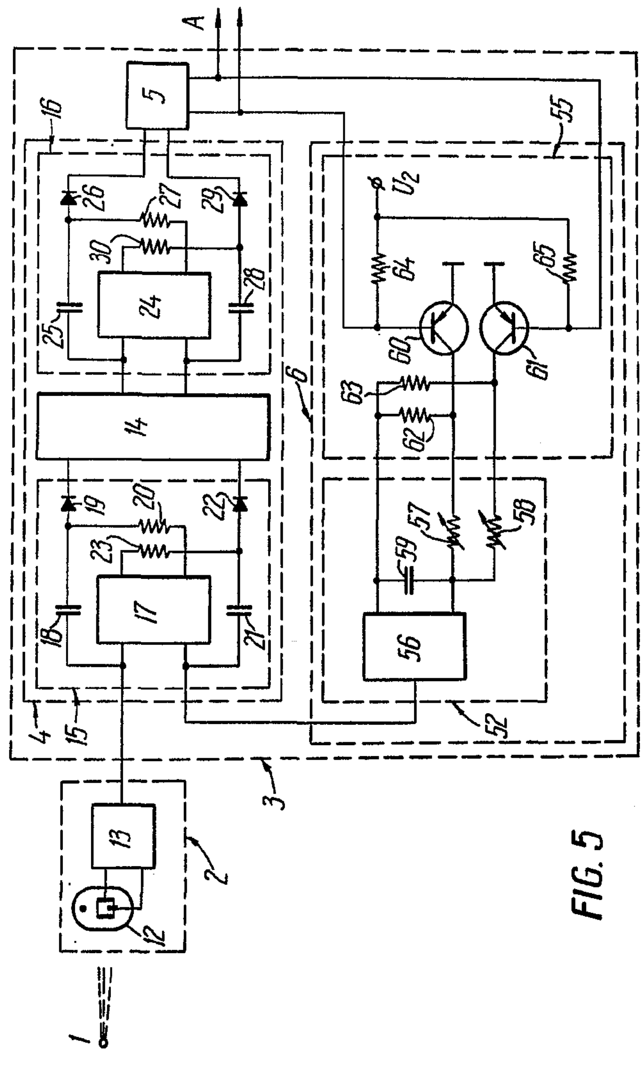

FIG. 5