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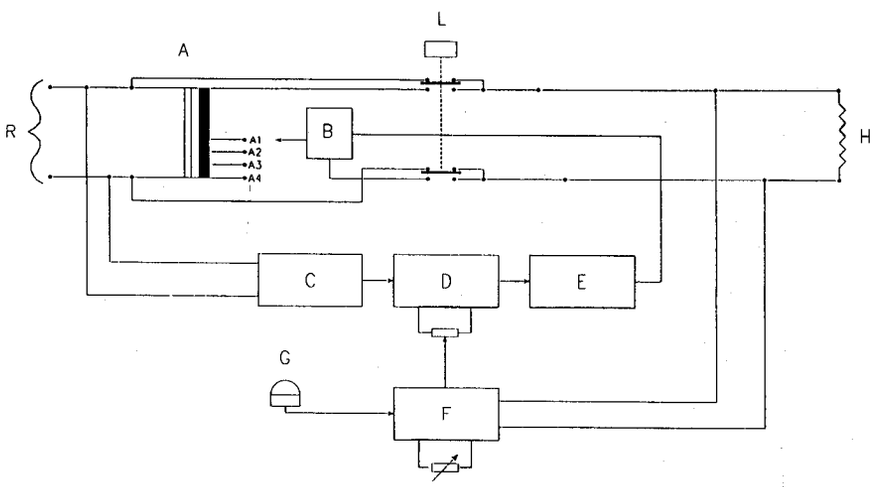
(54) Device for the regulation of electrical supply voltage to electric-discharge lamps

(57) Device for the regulation of electrical supply voltage to electric-discharge lamps, comprising:
a) an autotransformer, endowed with:
- an input section connected to the mains supply
- an output section,

b) a power circuit inserted between the transformer output and the electric-discharge lamps,
c) a control circuit regulating the power circuit. The former basically consists of:
i) a measurement circuit connected to the mains,
ii) a threshold circuit connected after the measurement circuit,
iii) a command circuit, connected after the threshold circuit, regulating the power circuit.

FIG. 1



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The present invention concerns a device for the regulation of electrical supply voltage to electric-discharge lamps.

In more detail, the present invention concerns a device capable of regulating the electrical supply voltage to electric-discharge lamps in order to obtain substantial reductions in power consumption.

It is well known that, in the case of electrical equipment operating at a defined voltage, a possible reduction of this voltage has, as an immediate consequence, a reduction in energy consumed, hence a drop in operating cost. This possibility, though theoretically valid, has never been applied in practice because the reductions referred to above are also accompanied by an unacceptable reduction in equipment efficiency. For example, in the case of incandescent lamps, a reduction in the voltage applied to the load produces a drop in luminosity which precludes this approach to energy saving.

However, there exists an electrical equipment in which this disadvantage is not so significant. In the case of electric-discharge lamps generally, i.e. in the cases of neon-type or fluorescent lamps, sodium-vapour lamps at low and high pressures and mercury-vapour lamps, it has been found that the luminous flux perceived by the human eye remains almost unaltered even when the electrical supply voltage applied to them is substantially reduced. Fig. 6 shows, in a general manner, the curves relating to the luminous flux emitted by an electric-discharge lamp (ALPHA) and by an incandescent lamp (BETA), as a function of the applied voltage. The diagram shown in fig. 6 is only a qualitative illustration of the variation of light output as a function of voltage, as it is an extrapolation of a number of diagrams referring to specific lamps.

By analysing the diagram it can be seen that, in the case of discharge lamps, it should be possible to reduce the applied voltage down to values only just above those which trigger the luminescent discharge, without suffering any substantial luminosity reduction. It is known that the reduction in voltage, from its mains value to the discharge trigger value is substantial, sometimes of the order of 40%. Thus, the possible reduction in the consumption of electrical energy, and hence the cost of such consumption, should be similarly substantial.

Bearing in mind the above situation, it would be very desirable to have at one's disposal a device which, when inserted between the mains and the load made up of electric-discharge lamps, would be capable of automatically regulating the voltage applied to the load during specified periods, for example at night, when the small drop in light output can be tolerated. The device would bring back the voltage to its mains value when the luminosity must be at its maximum.

The Applicant has now found a device which permits the application of the regulation referred to above without generating any radio-frequency disturbances in its environment and/or phase change towards the power supply line.

This device therefore constitutes the subject of the present invention defined as:

a device for the regulation of electrical supply voltage to electric-discharge lamps, comprising:

a) a single-winding transformer endowed with an input section connected to the mains supply and an output section made up of a number of taps,

b) a power circuit inserted between the transformer taps and the electric-discharge lamps,

c) a control circuit, powered directly from the mains, which regulates the power circuit. This control circuit basically consists of:

i) a measurement circuit connected to the mains at the transformer input,

ii) a threshold circuit, connected after the measurement circuit,

iii) a command circuit, connected after the threshold circuit, regulating the power circuit,

iv) as an option, a correction circuit connected to the mains furnishes a correction signal to the threshold circuit.

According to the present invention, the single-winding transformer is the element regulating the supply to the lamps. This is because, commanded by the power circuit which controls the switching of the load (lamps) between the taps, it effectively regulates the voltage to the user (lamps). In addition, the transformer maintains its output voltage constant when faced with mains voltage variations by altering its own working turns.

Any arrangement capable of operating the transformer function as described above can be employed in the device forming the subject of the present application, even if an autotransformer consisting of a winding on a core is preferred. The output of the autotransformer comprises a number of taps, each of which supplies a decreasing voltage. The number of taps and the intermediate voltage values depend on the type of lamps to be regulated.

The power circuit carries out the function of interface between the command/control circuits and the load, switching the load to the appropriate transformer tap. It consists basically of a number of contactors or electromechanical relays (equal in number to the quantity of transformer taps) which make it possible to switch the load to the desired voltage. Alternatively, the power circuit can be constructed employing static

(semiconductor-type) relays.

The control circuit consist basically of:

- a measurement circuit,
- a threshold circuit,
- a command circuit,
- optionally, a correction circuit.

The measurement circuit has the task of continuously measuring the mains voltage and to supply, to the threshold circuit, a voltage to be compared with the preset value. It comprises an A.D.C. (Analogue to Digital Converter), constructed using integrated circuits and discrete components. As this circuit is connected to the mains voltage, it supplies, in real time, the value of the mains voltage (in digital form) to the threshold circuit.

The threshold circuit compares the voltage obtained from the measurement circuit with the preset value and sends the appropriate signal to the command circuit. The threshold circuit consists essentially of a digital comparator.

The command circuit processes the signal supplied by the threshold circuit and sends, to the power circuit, the increase/reduce command for the desired variation in the user voltage. The command circuit consists essentially of a forward-back counter.

The correction circuit has the function of checking the possible variations in the voltage supplied to the lamps at the output of the device forming the subject of the present invention. Any possible voltage variation, usually undesired, produces a signal which is then used by the threshold circuit as a correction to the preset voltage value. The correction circuit basically consists of a transformer, a diode-type rectifier bridge with a filtering capacitor and of a transistor-type amplifier circuit, with the possibility of adjustment.

In a preferred embodiment of the device forming the subject of the present invention, the above-mentioned circuits may also include a by-pass circuit which permits the switching of the load directly across the mains in the cases of fault or maintenance. This circuit consists essentially of a manual or automatic disconnecting switch. In its latter form, it is ready to act automatically when a fault occurs in the device.

The device for the regulation of electrical supply voltage to electric discharge lamps, forming the subject of the present invention, can be more easily understood by referring to the drawings shown in the attached figures. These show an embodiment which is used purely as an example and does not limit the scope of the invention, and in which:

- figure 1 shows an overall block schematic of the device forming the subject of the invention,
- figure 2 shows the electrical schematic of the measurement circuit,
- figure 3 shows the electrical schematic of the threshold circuit,
- figure 4 shows the electrical schematic of the command circuit,
- figure 5 shows the electrical schematic of the correction circuit, and
- figure 6 shows, as mentioned previously, qualitative diagrams of the luminosity of an incandescent-type lighting system and of a system using luminescent elements, as a function of the applied voltage.

Referring to the figures, the device forming the subject of the present invention comprises:

- the autotransformer (A), connected to the mains (R), having at its output four taps (from A_1 to A_4) which in the case of the example being studied, permit the transition from the mains voltage (~ 220/230 V) to lower voltage ranges (such as ~ 200 V using A_3, A_4, ~ 180 V using A_2, A_4 and ~ 160 V using A_1, A_4),
- the power circuit (B) which, upon a suitable command from the control circuit, inserts itself between an autotransformer tap and the load (H),
- the measurement circuit (C),
- the threshold circuit (D),
- the command circuit (E).

The device illustrated in this example also comprises a correction circuit (F) connected to a photocell (G) which, checking the ambient luminosity, acts upon the correction circuit so as to maintain the above-mentioned ambient luminosity constant as the natural luminosity changes.

Finally, the device also comprises a by-pass (L), which disconnects the device forming the subject of the present invention in the cases of fault or maintenance.

The measurement circuit C, connected to the mains R, comprises the following successive elements:

- transformer (C_1),
- diode-type rectifier bridge (C_2),
- operational amplifier (C_3)

- integral photo-coupler (C_4) and,
- ADC (C_5) with 12 output bits.

The threshold circuit D consists essentially of a threshold comparator (D_1), which receives the 12 signals from the ADC (C_5) and 12 preset signals (D_2). A correction signal (F_4) can also arrive at the comparator D_1 to correct the preset signals D_2.

The command circuit (E) comprises the following elements:

- an inverting amplifier (E_1), which receives, from the threshold comparator, the signal (D_3) "keep the voltage unchanged",
- an "END" circuit (E_2), which receives the signals (D_4) "increase the voltage" or (D_5) "decrease the voltage" and the denied signal (D_3 - denied)
- three timer circuits (E_3) of which two (E_3') check the presence of signals D_4 and D_5 for a time longer than the preset minimum. The third one (E_3'') inhibits the functioning of the the command circuit during the period of lamp lighting-up, for example five minutes,
- a decimal forward-back counter, (E_6) set to be limited to five outputs,
- a pulse generating circuit (E_4) (SCHMITT-TRIGGER) which converts the continuous signal from the timers (E_3') into a command pulse signal to the counter
- an "OR" circuit (E_5) at the output of timer (E_3'') which permits counter reset even from its number "5" output,
- a non-inverting amplifier circuit (E_7) having the task of amplifying the current at the output of the counter (E_6),
- a guidance circuit (E_8) of the signal (E_9) to the power circuit, made up of a series (equal in number to the transformer taps) of discrete elements (resistance plus transistor plus protection diode).

The correction circuit F comprises the following elements:

- a transformer (F_1) connected directly to the mains ahead of the load H,
- a diode-type rectifier bridge with a filtering capacitor (F_2),
- a transistor-type amplifier circuit with the possibility of adjustment (F_3), consisting of resistors (F_3'), a calibration potentiometer (F_3''), and a transistor (F_3'''), which emits a signal (F_4) for the correction of the threshold circuit.

On the basis of the text above and the drawings in the attached figures, the functioning of the device for the regulation of electrical supply voltage to electric discharge lamps forming the subject of the present invention is made absolutely clear.

When, during defined time periods (for example at night) it is possible to reduce the luminous intensity of the lamps without incurring user discomfort, or under the command of a photocell which detects the level of the ambient illumination and correlates it with the time zone, the device automatically switches the load to a preset voltage which is normally 30-40% below the nominal value, but still sufficient to assure the luminosity desired during the respective time zone.

A 30% reduction in the supply voltage corresponds to a 30% reduction in the power consumed and, if it is borne in mind that the present device could function during a third of the full day, it can be seen that, over 24 hours, the average saving derided from it is about 20% of the overall consumption of electrical energy during the full day.

As an example, let us consider the set of lamps for the illumination of a multi-storey car park. For an average-size car park, accomodating 800-1000 vehicles, it can be assumed that the lamps installed consume a total of at least 50 kW. In this type of use, the lamps are lit 24 hours a day which, in terms of electrical power consumed, corresponds to 1200 kWh. It can be deduced that, by limiting to only 30% the voltage drop applied by means of the present device for 16 hours a day, the energy saving is 240 kWh.

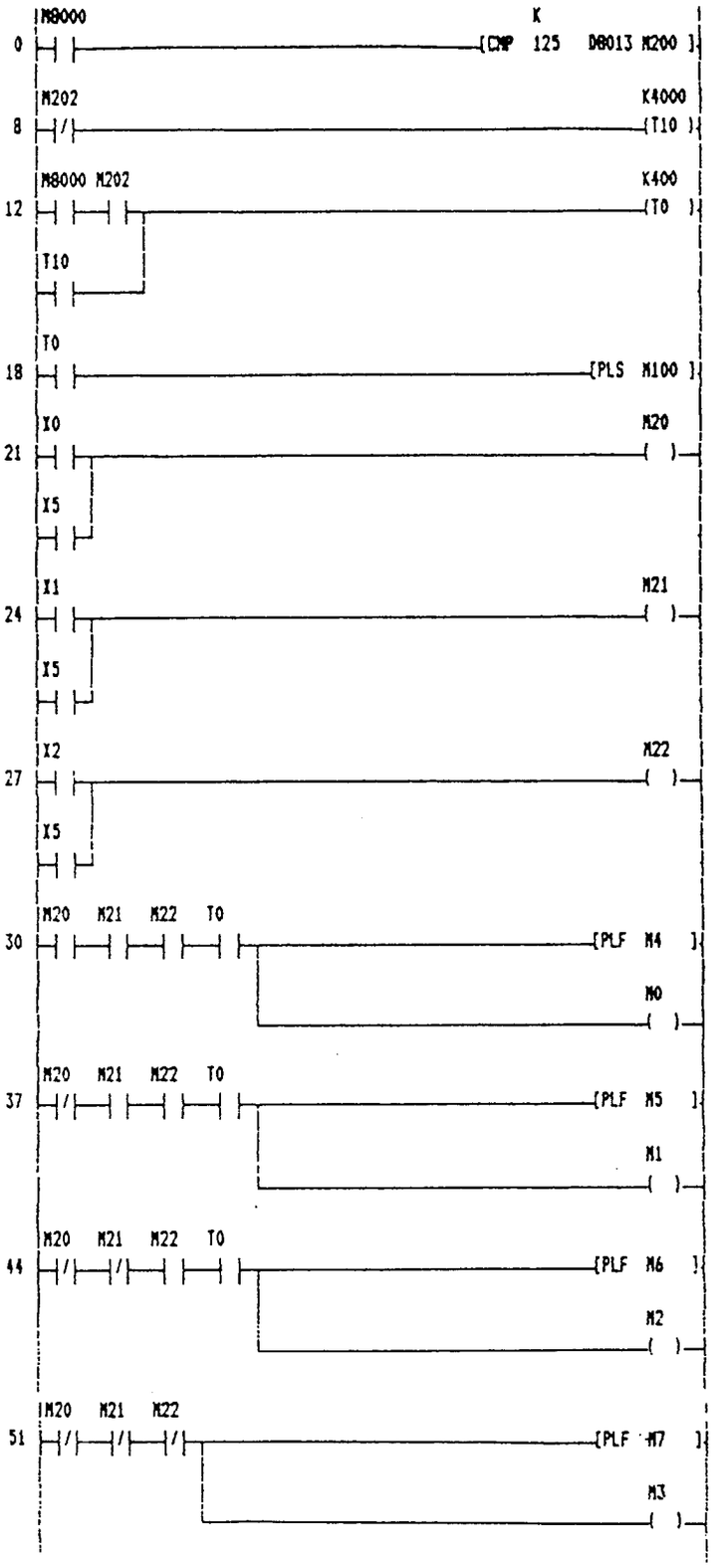
According to an alternative design, the device for the regulation of electrical supply voltage to electric discharge lamps forming the subject of the present invention can be constructed employing a PLC (Programmable Logic Computer) with the corresponding software).

Accordingly, the following constitutes a further subject of the present invention: a device for the regulation of electrical supply voltage to electric discharge lamps, comprising:

A) a single-winding transformer endowed with an input section connected to the mains supply and an output section consisting of a number of taps,

B) a power circuit inserted between the transformer taps and the electric-discharge lamps,

C) a PLC having a capacity in the range between 10 and 1000 Mbytes, inserted between the mains at the transformer input, the mains at the input to the lamps and the power circuit, operating with the following programme: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M202
K4000
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T10
M8000 M202
K400
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T0
T10
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X0
M20
21
X5
X1
M21
24
X5
X2
M22
27
X5
M20 M21 M22 T0
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PLF M4
M0
M20 M21 M22 T0
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M20 M21 M22
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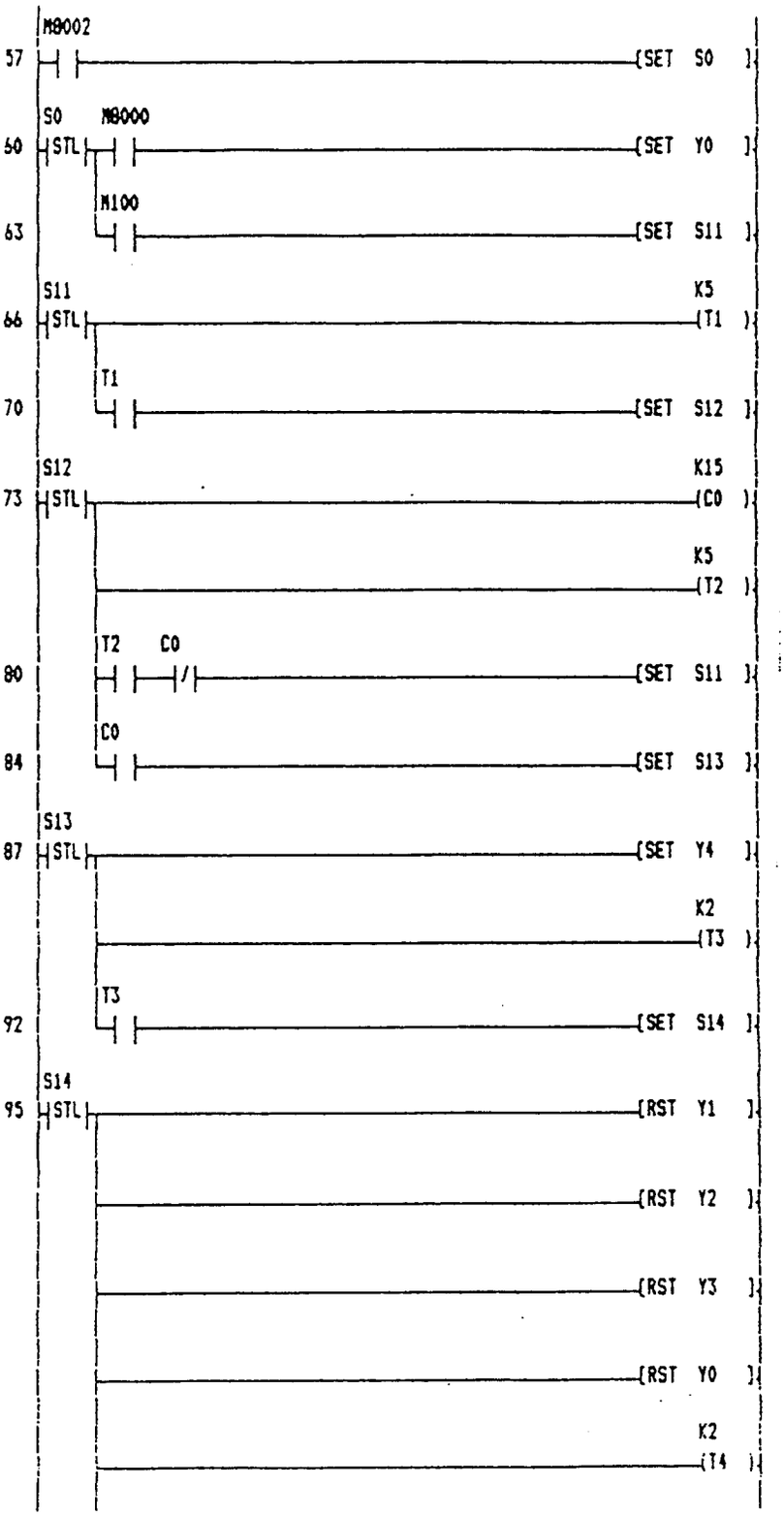
PLF M7
M3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SET Y0
M100
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S11
STL
K5
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SET S12
S12
STL
K15
73
C0
K5
T2
T2
C0
80
SET S11
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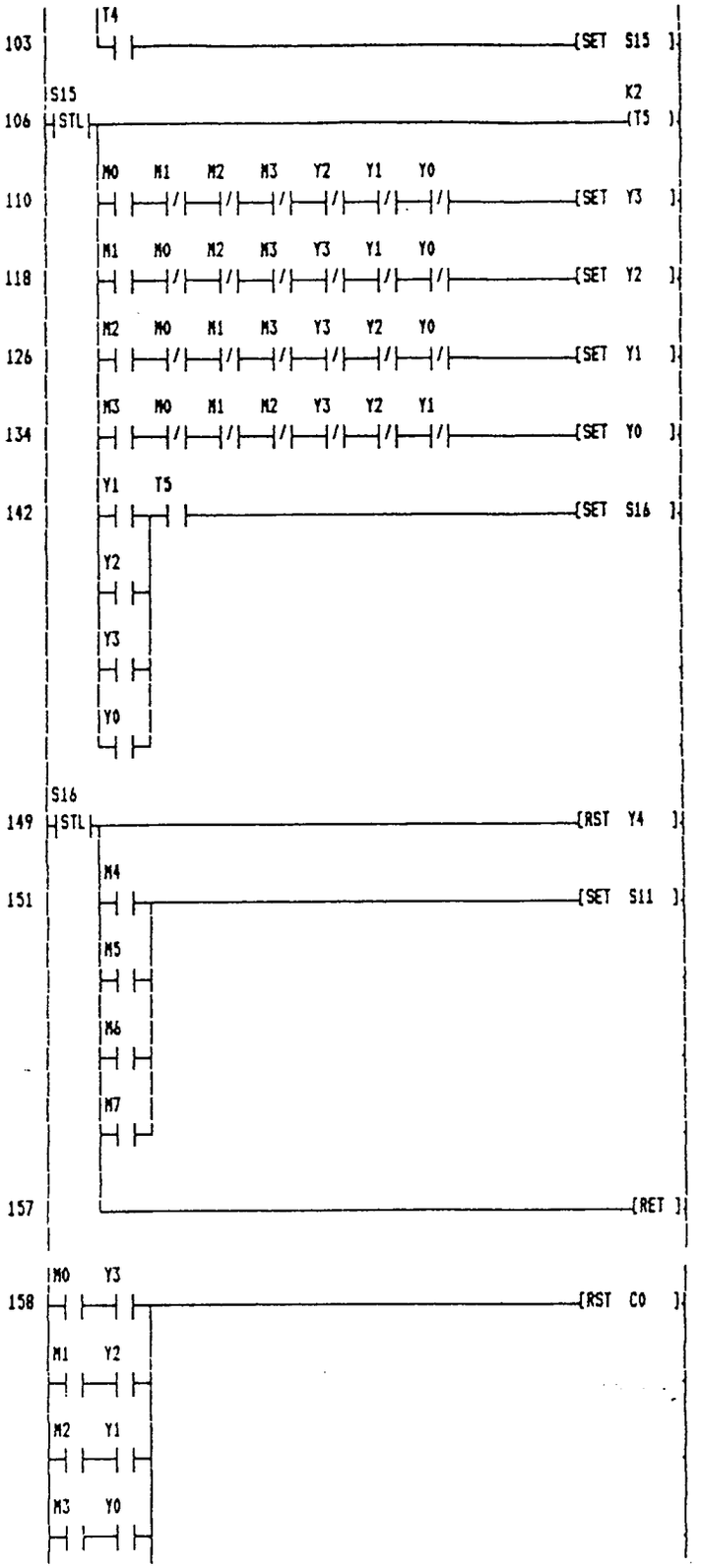
K2
T4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S15
STL
K2
T5
110
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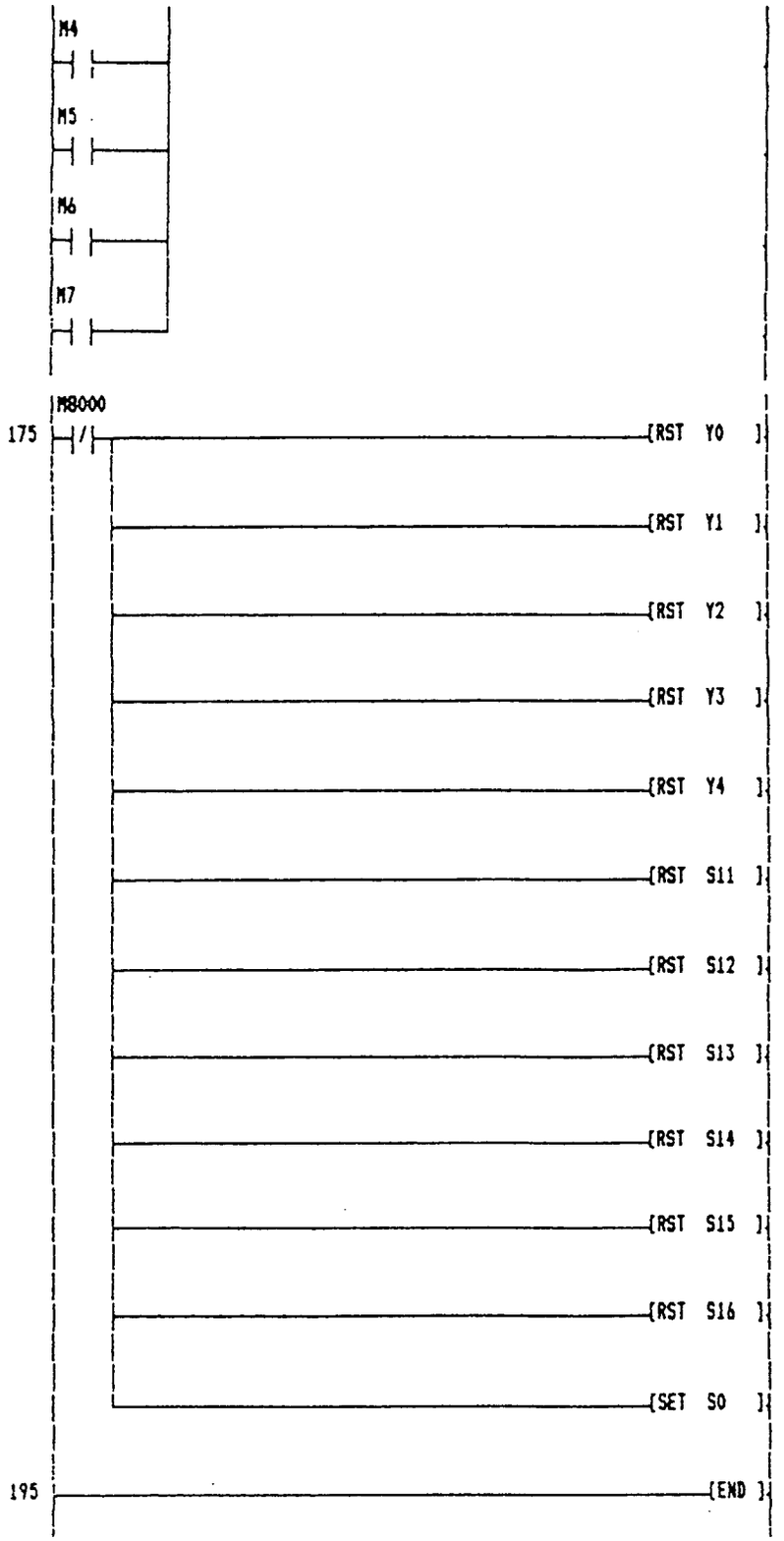
SET Y3
118
M1 M0 M2 M3 Y3 Y1 Y0
SET Y2
126
M2 M0 M1 M3 Y3 Y2 Y0
SET Y1
134
M3 M0 M1 M2 Y3 Y2 Y1
SET Y0
142
Y1 T5
SET S16
Y2
Y3
Y0
149
S16
STL
RST Y4
151
M4
SET S11
M5
M6
M7
157
RET
158
M0 Y3
RST C0
M1 Y2
M2 Y1
M3 Y0



In this case too, the alternative device for the regulation of electrical supply voltage to electric-discharge lamps forming the subject of the present invention can be understood more easily by referring to the drawing in figure 7 attached, illustrating an example of its construction which is explanatory and does not limit the scope of the invention.

Referring to the drawing in figure 7, the device of the present invention comprises:

- the single-winding transformer (T) which, as in the preceding device, consists of an autotransformer connected to the mains supply. At the output, it is furnished with four taps (from T_1 to T_4) which, in the example being studied, permit the transition from the mains voltage (~ 220/230 V) to lower voltage ranges (such as ~ 200 V using T_3, T_4, ~ 180 V using T_2, T_4 and ~ 160 V using T_1, T_4),
- the power circuit (K) which, upon a suitable command, inserts itself between an autotransformer tap and the load (H). This circuit is substantially the same as in the preceding device,
- the PLC (J) which, using its operating programme, actuates the power circuit and selects the transformer tap, and hence the desired voltage.

Even if this is not shown in the figure, the alternative device for the regulation of electrical supply voltage to electric-discharge lamps forming the subject of the present invention may also comprise a by-pass circuit, which permits the switching of the load directly across the mains in the cases of fault or maintenance.

Claims

1. Device for the regulation of electrical supply voltage to electric-discharge lamps, which comprises:
a) a single-winding transformer endowed with an input section connected to the mains supply and an output section consisting of a number of (voltage) taps,
b) a power circuit inserted between the transformer taps and the electric-discharge lamps,
c) a control circuit, supplied directly from the mains, which regulates the power circuit. This control circuit basically consists of:
(i) a measurement circuit connected to the mains at the transformer input,
(ii) a threshold circuit, connected after the measurement circuit,
(iii) a command circuit, connected after the threshold circuit, which regulates the power circuit,
(iv) as an option, a correction circuit connected to the mains at the lamp input, which furnishes a correction signal to the threshold circuit.

2. Device in accordance with claim 1, in which the single-winding transformer forms the unit regulating the power supply to the lamps.

3. Device in accordance with claim 2, in which the single-winding transformer is an autotransformer consisting of a winding on a core.

4. Device in accordance with any one of the preceding claims, in which the power circuit carries out the function of interface between the command/control circuits and the load.

5. Device in accordance with claim 4, in which the power circuit consists essentially of a number of contactors or electromechanical relays or of static relays emplying semiconductos.

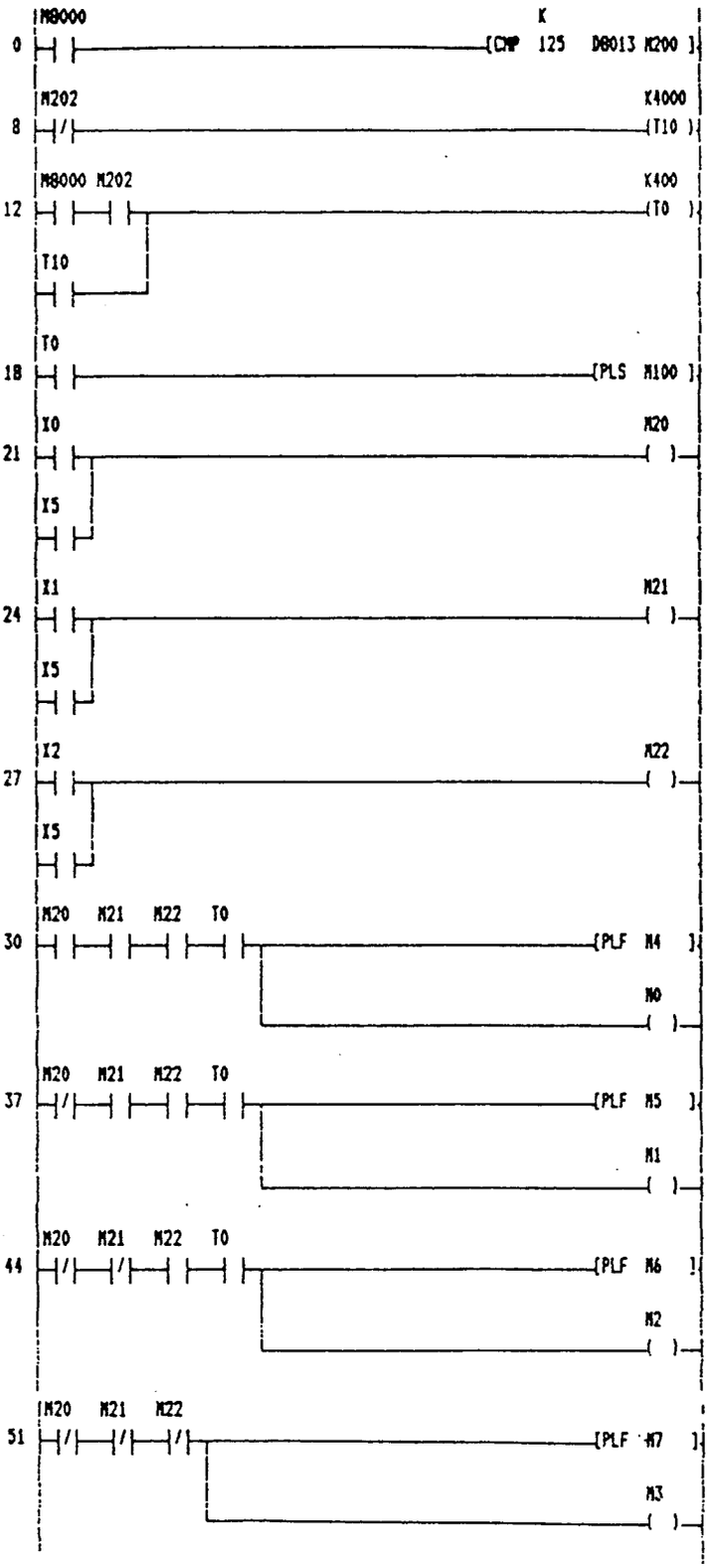
6. Device in accordance with claim 1, in which the measurement circuit comprises an A.D.C. (Analogue to Digital Converter).

7. Device in accordance with claim 1, in which the threshold circuit consists essentially of a digital comparator.

8. Device in accordance with claim 1, in which the command circuit consists essentially of a Forward-back counter.

9. Device in accordance with claim 1, in which the correction circuit consists essentially of a transformer of a diode-type rectifier bridge with a filtering capacitor bridge with transistor-type amplifier circuit with the possibility of adjustment.

10. Device for the regulation of electrical supply voltage to electric-discharge lamps, which comprises:
A) a single-winding transformer endowed with an input section connected to the mains supply and an output section consisting of a number of (voltage) taps,
B) a power circuit inserted between the transformer taps and the electric-discharge lamps,
C) a PLC having a capacity in the range between 10 and 1000 Mbytes, inserted betweem the mains at the transformer input, the mains power circuit, operating with the following programme: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0
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M202
K4000
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T10
M8000 M202
K400
12
T0
T10
T0
18
PLS M100
X0
M20
21
X5
X1
M21
24
X5
X2
M22
27
X5
M20 M21 M22 T0
30
PLF M4
M0
M20 M21 M22 T0
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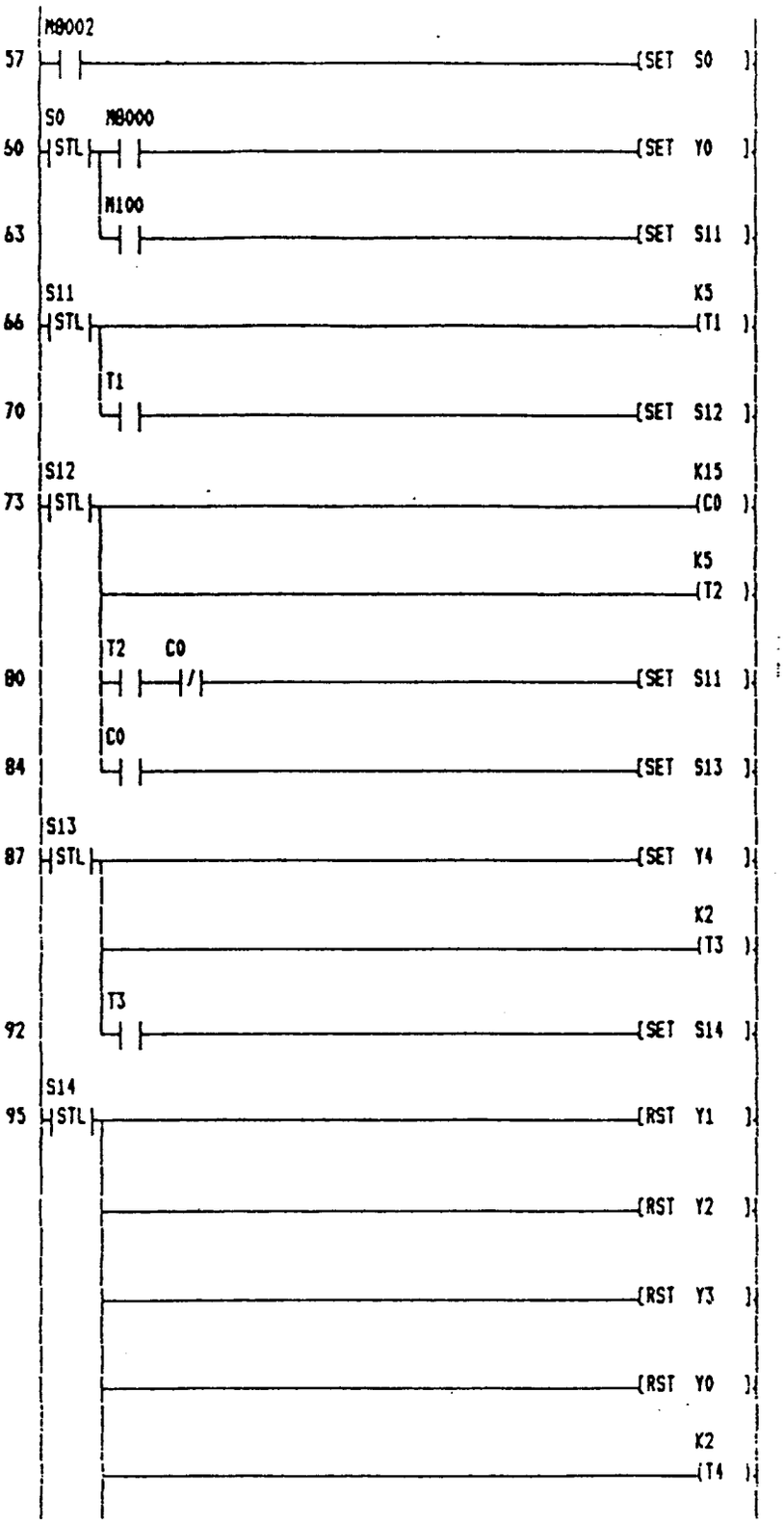
PLF M6
M2
M20 M21 M22
51
PLF M7
M3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SET S0
S0
STL
M8000
50
SET Y0
M100
63
SET S11
S11
STL
K5
66
T1
T1
70
SET S12
S12
STL
K15
73
C0
K5
T2
T2
C0
80
SET S11
C0
84
SET S13
S13
STL
87
SET Y4
K2
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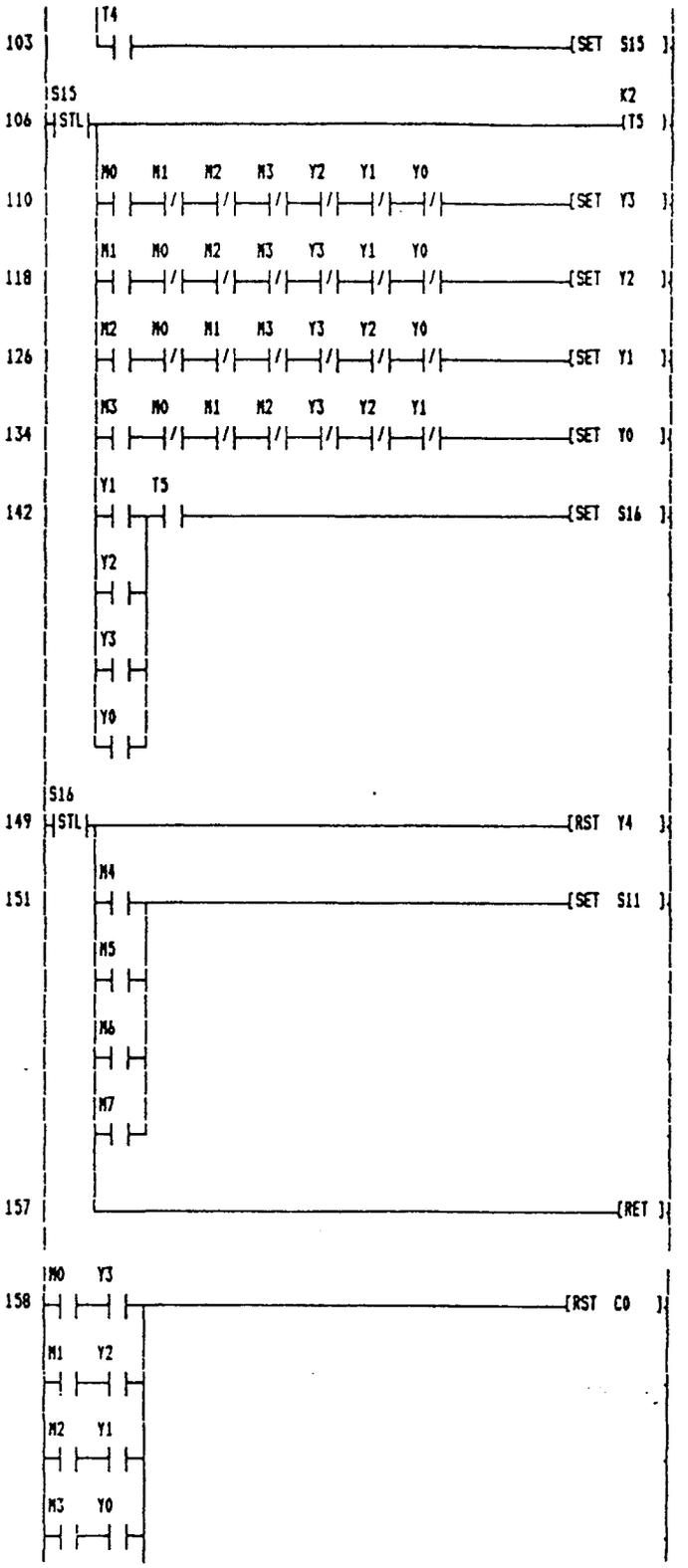
RST Y2
RST Y3
RST Y0
K2
T4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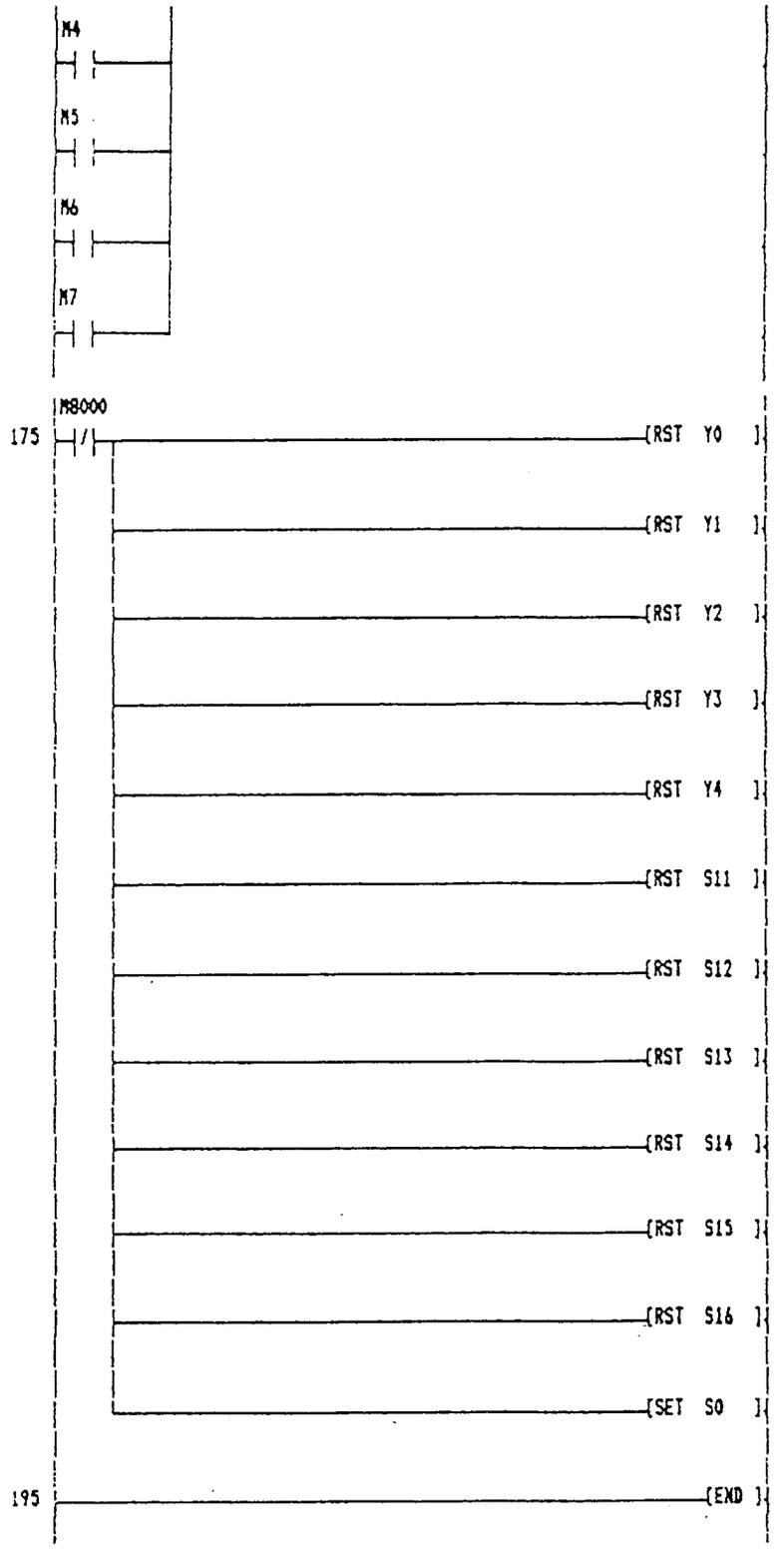
SET S15
S15
K2
106
STL
T5
M0 M1 M2 M3 Y2 Y1 Y0
110
SET Y3
M1 M0 M2 M3 Y3 Y1 Y0
118
SET Y2
M2 M0 M1 M3 Y3 Y2 Y0
126
SET Y1
M3 M0 M1 M2 Y3 Y2 Y1
134
SET Y0
Y1 T5
142
SET S16
Y2
Y3
Y0
S16
149
STL
RST Y4
M4
151
SET S11
M5
M6
M7
157
RET
M0 Y3
158
RST C0
M1 Y2
M2 Y1
M3 Y0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M5
M6
M7
M8000
175
195
[RST Y0]
[RST Y1]
[RST Y2]
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[RST S11]
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[RST S16]
[SET S0]
[END]

FIG. 1

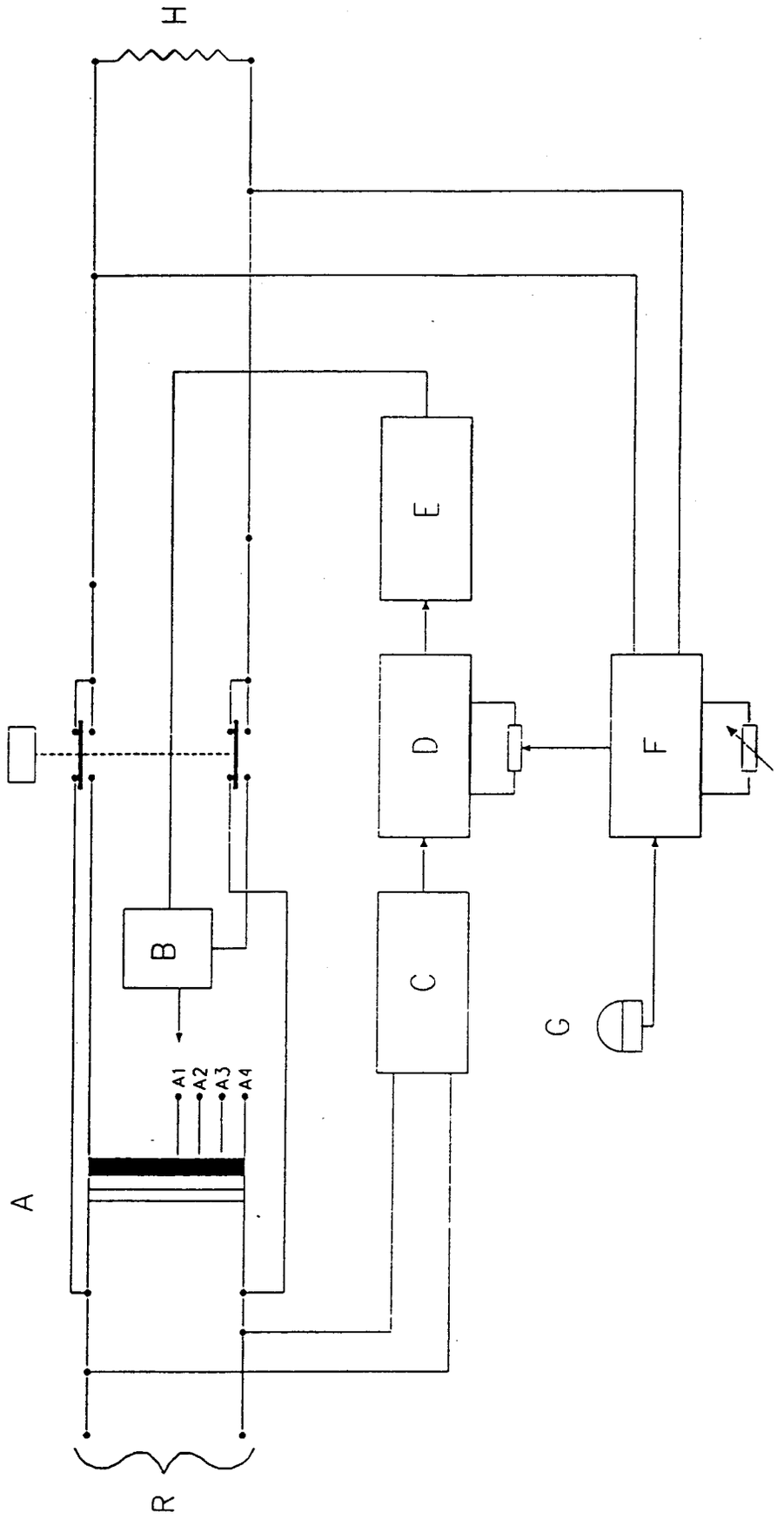


FIG. 2

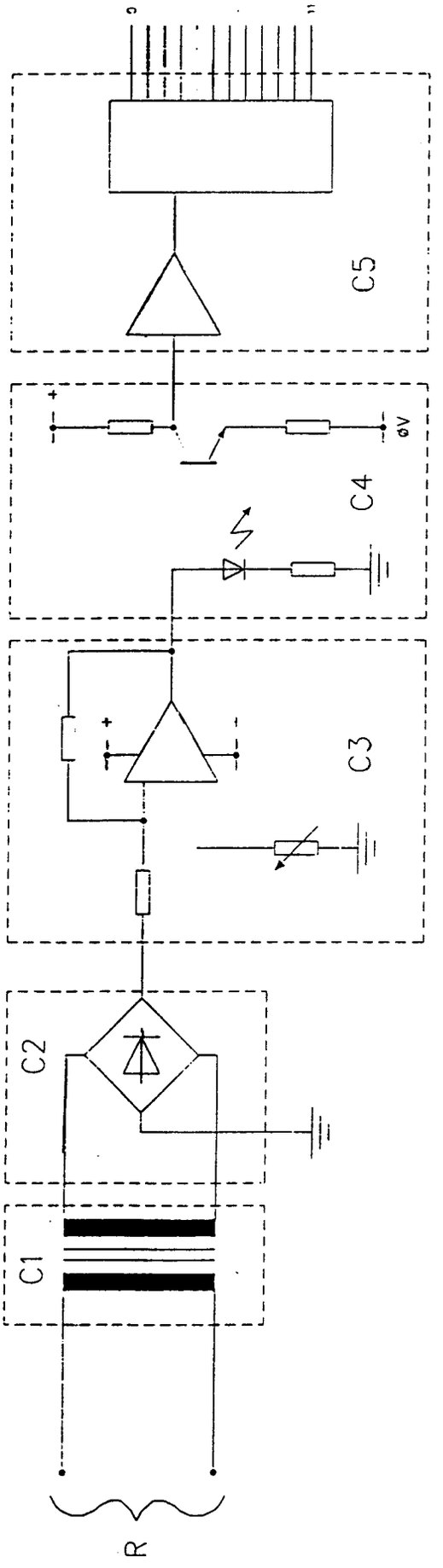
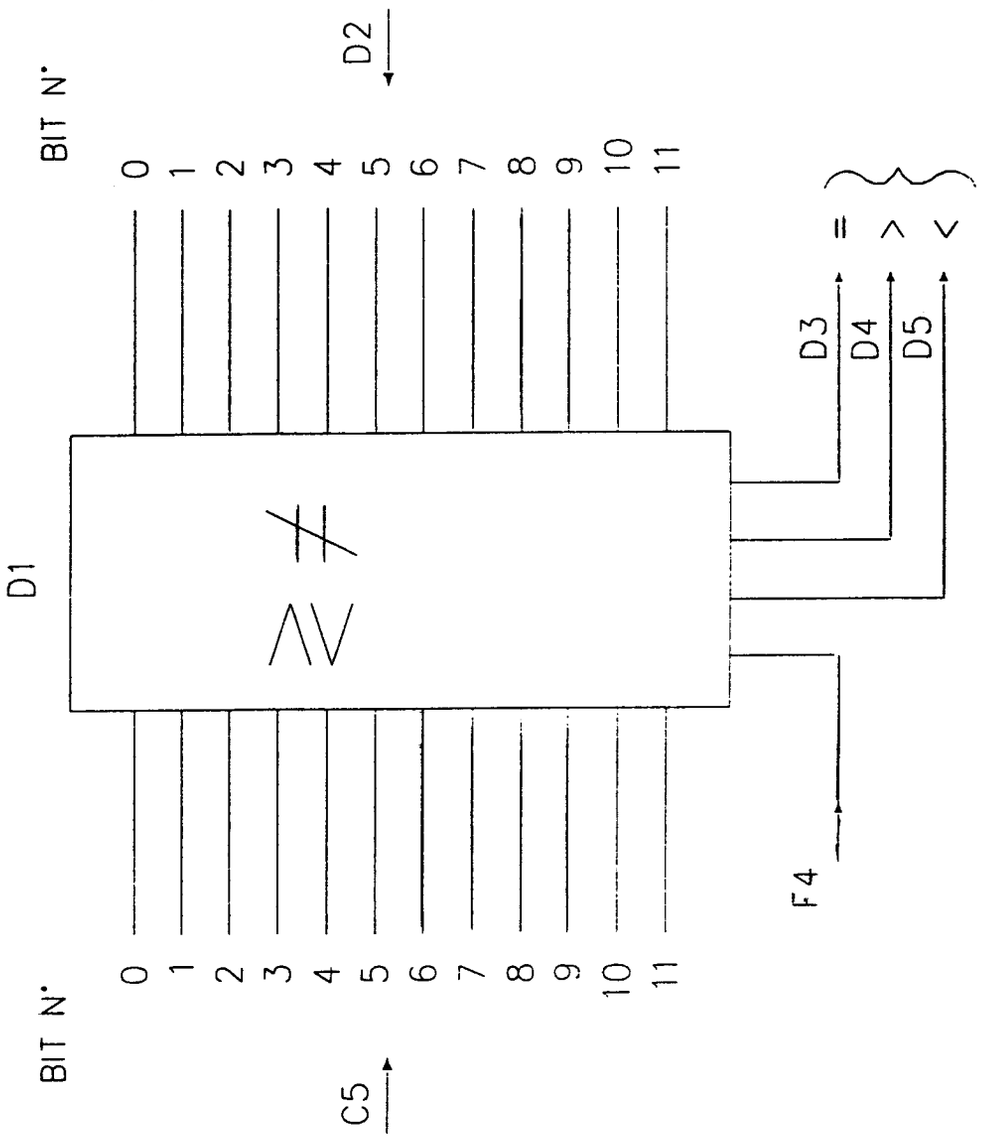


FIG. 3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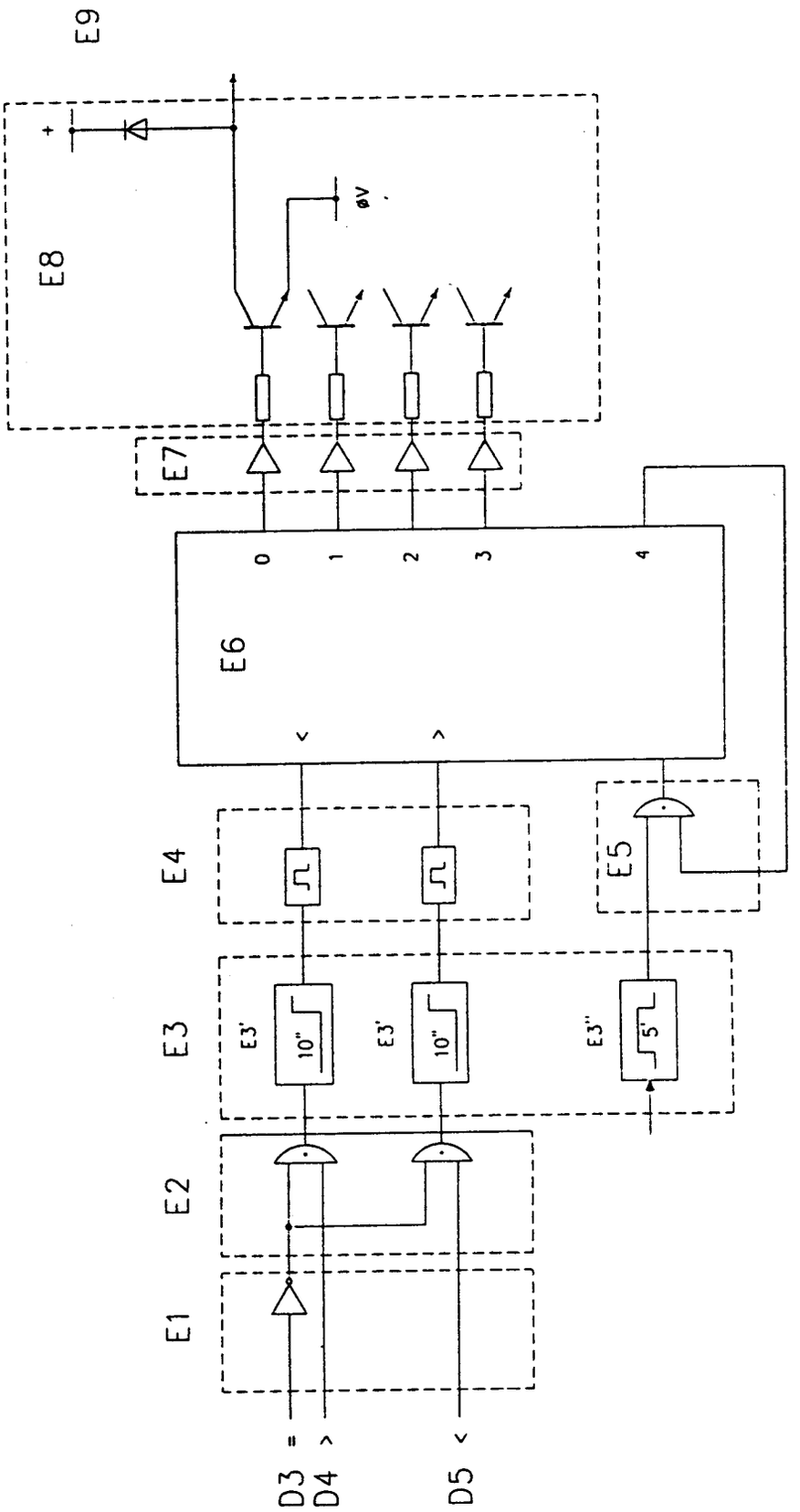
C5

FIG. 4



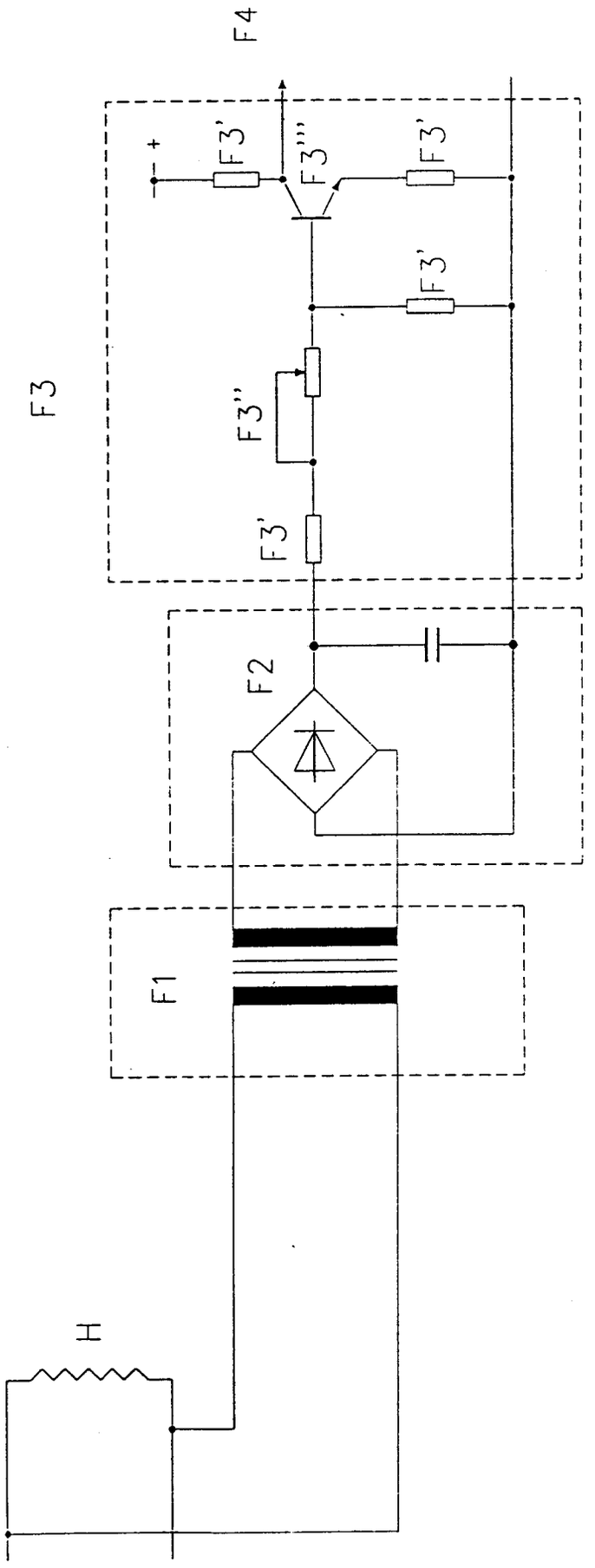


FIG. 5

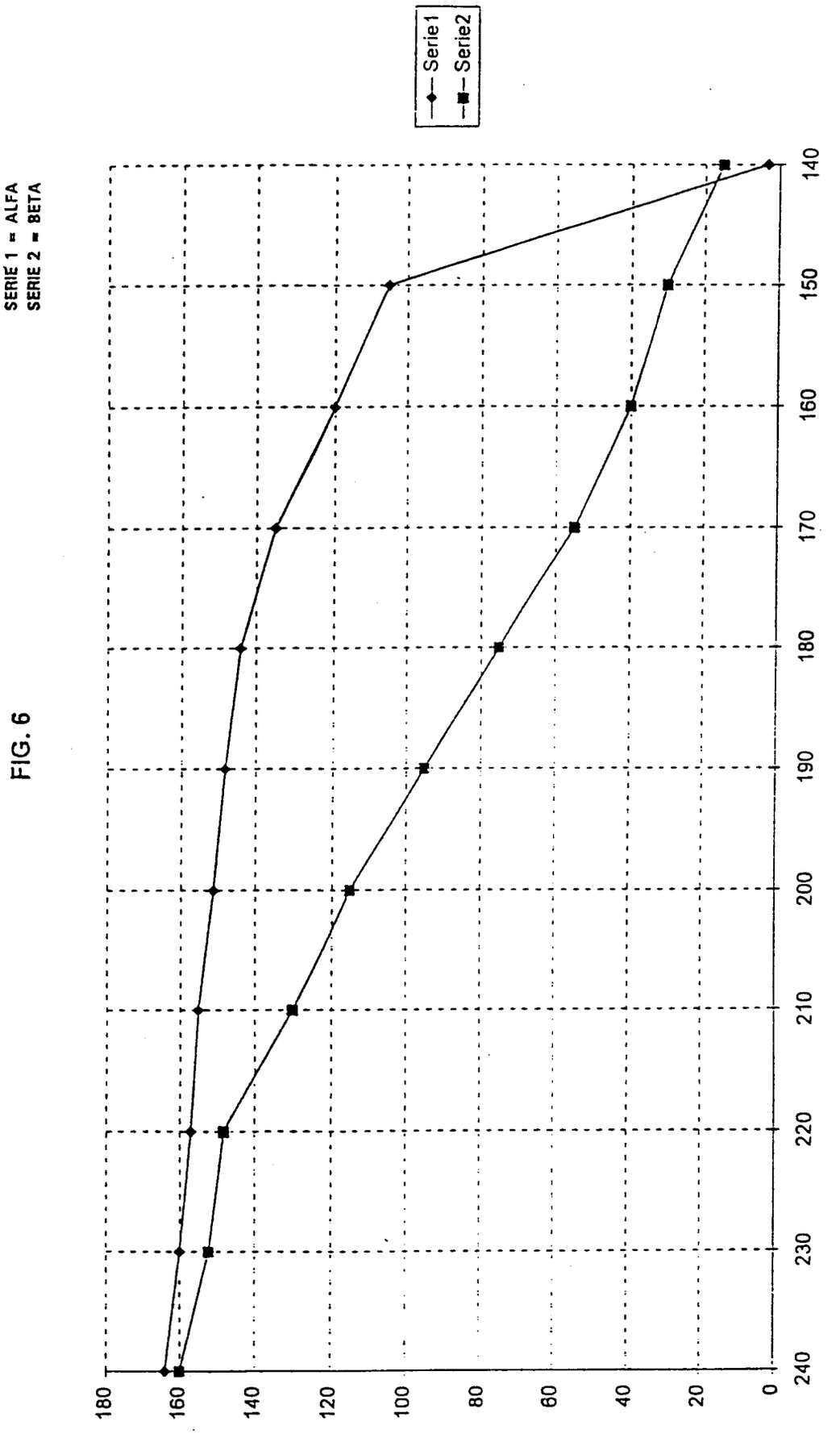

Serie1
Serie2
SERIE 1 = ALFA
SERIE 2 = BETA
180
160
140
120
100
80
60
40
20
0
140
150
160
170
180
190
200
210
220
230
240

FIG. 6

FIG. 7