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(12) (19) (CA) **Demande-Application**

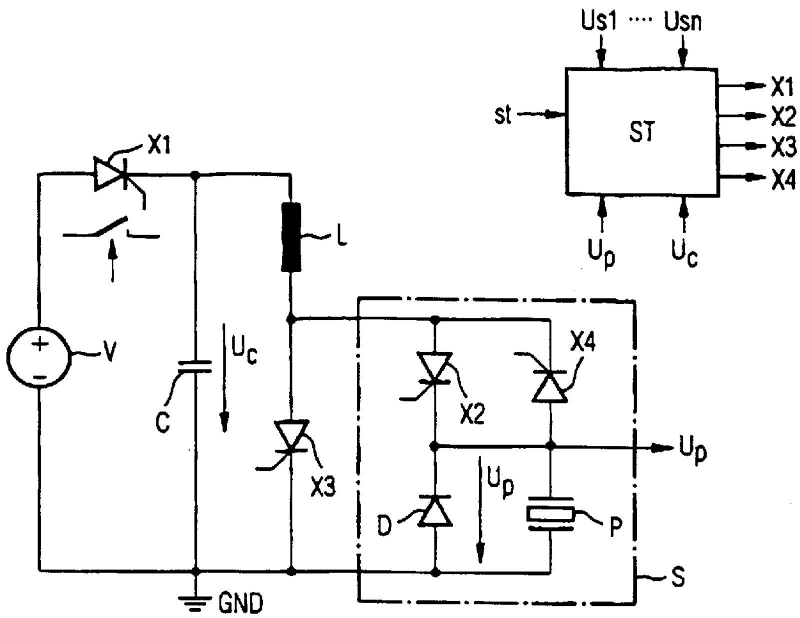
(21) (A1) **2,263,304**
(86) 1997/08/05
(87) 1998/02/19

(72) HOFFMANN, Christian, DE
(72) FREUDENBERG, Hellmut, DE
(72) GERKEN, Hartmut, DE
(72) BRASSEUR, Georg, AT
(72) PIRKL, Richard, DE
(71) SIEMENS AKTIENGESELLSCHAFT, DE

(51) Int.Cl.^{6} H01L 41/04
(30) 1996/08/14 (196 32 872.1) DE

(54) **DISPOSITIF PROCEDE POUR LA COMMANDE D'UN ACTIONNEUR CAPACITIF**

(54) **PROCESS AND DEVICE FOR DRIVING A CAPACITIVE ACTUATOR**



(57) L'invention concerne un procédé et un dispositif pour la commande d'au moins un actionneur capacitif (P), en particulier une soupape d'injection de carburant de moteur à combustion interne, actionnée piézoélectriquement, au moyen d'un circuit de commande (ST) commandé par microprocesseur, comprenant un condensateur de charge (C) rechargeable par une source d'énergie (V), lequel charge le ou les actionneurs par l'intermédiaire de commutateurs (X1 à X4) commandés par le circuit de commande, et dans lequel ledit actionneur se décharge de nouveau.

(57) A process and device are disclosed for driving at least one capacitive actuator (P), in particular a piezoelectrically driven fuel injection valve of an internal combustion engine, by means of a microprocessor-controlled control circuit (ST) with a charging capacitor (C) which can be recharged by an energy source (V), which charges the at least one actuator through switches (X1 to X4) controlled by the control circuit, and into which said actuator is again discharged.

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Internationales Büro

INTERNATIONALE ANMELDUNG VERÖFFENTLICHT NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT)

(51) Internationale Patentklassifikation 6 : H01L 41/04 — A1

(11) Internationale Veröffentlichungsnummer: WO 98/07199

(43) Internationales Veröffentlichungsdatum: 19. Februar 1998 (19.02.98)

(21) Internationales Aktenzeichen: PCT/DE97/01646

(22) Internationales Anmeldedatum: 5. August 1997 (05.08.97)

(30) Prioritätsdaten:
196 32 872.1 14. August 1996 (14.08.96) DE

(71) Anmelder *(für alle Bestimmungsstaaten ausser US)*: SIEMENS AKTIENGESELLSCHAFT [DE/DE]; Wittelsbacher Platz 2, D-80333 München (DE).

(72) Erfinder; und
(75) Erfinder/Anmelder *(nur für US)*: HOFFMANN, Christian [DE/DE]; Am Nordheim 5, D-93057 Regensburg (DE). FREUDENBERG, Hellmut [DE/DE]; Tulpenweg 3B, D-93080 Pentling (DE). GERKEN, Hartmut [DE/DE]; Josef-Geller-Strasse 1, D-93152 Nittendorf (DE). BRASSEUR, Georg [AT/AT]; Elsslergasse 20, A-1130 Wien (AT). PIRKL, Richard [DE/DE]; Brunhuberstrasse 27, D-93053 Regensburg (DE).

(81) Bestimmungsstaaten: BR, CA, CN, CZ, JP, KR, MX, RU, UA, US, europäisches Patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

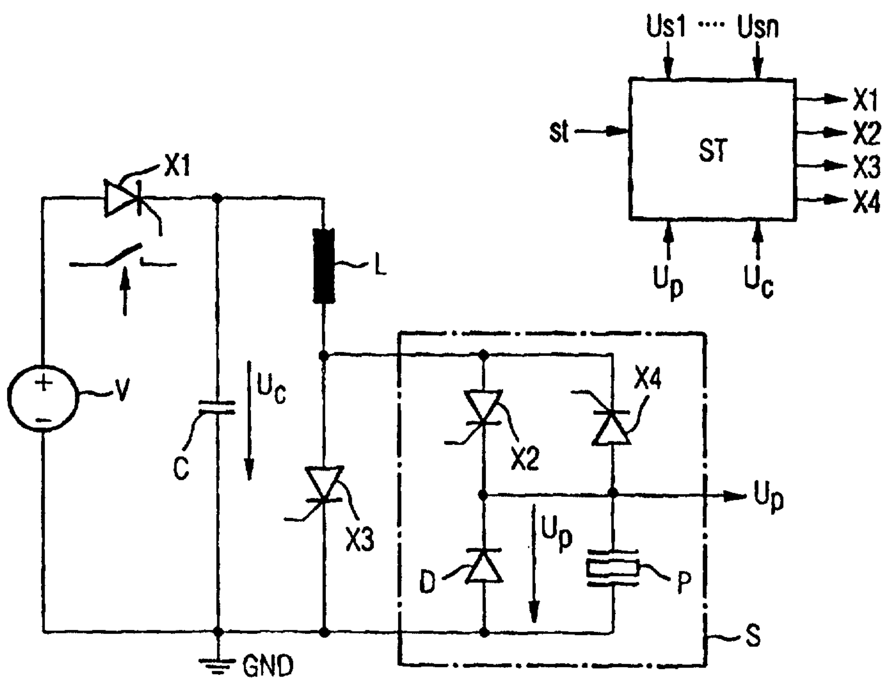
Veröffentlicht
Mit internationalem Recherchenbericht.
Vor Ablauf der für Änderungen der Ansprüche zugelassenen Frist. Veröffentlichung wird wiederholt falls Änderungen eintreffen.

(54) Title: PROCESS AND DEVICE FOR DRIVING A CAPACITIVE ACTUATOR

(54) Bezeichnung: VORRICHTUNG UND VERFAHREN ZUM ANSTEUERN EINES KAPAZITIVEN STELLGLIEDES

(57) Abstract

A process and device are disclosed for driving at least one capacitive actuator (P), in particular a piezoelectrically driven fuel injection valve of an internal combustion engine, by means of a microprocessor-controlled control circuit (ST) with a charging capacitor (C) which can be recharged by an energy source (V), which charges the at least one actuator through switches (X1 to X4) controlled by the control circuit, and into which said actuator is again discharged.



(57) Zusammenfassung

Vorrichtung und Verfahren zum Ansteuern wenigstens eines kapazitiven Stellgliedes (P), insbesondere eines piezoelektrisch betriebenen Kraftstoffeinspritzventils einer Brennkraftmaschine, mittels einer mikroprozessorgesteuerten Steuerschaltung (ST), mit einem von einer Energiequelle (V) nachladbaren Ladekondensator (C), von welchem über von der Steuerschaltung (ST) gesteuerte Schalter (X1 bis X4) das wenigstens eine Stellglied aufgeladen wird, und in welchen sich dieses wieder entlädt.

GR 96 P 8054 Foreign version

Description

Device and method for driving a capacitive actuator

The invention relates to a device for driving at least one capacitive actuator, in particular a piezoelectrically operated fuel injection valve of an internal combustion engine in accordance with the features of Patent Claim 1 or 2. The invention also relates to a method for operating this device.

EP 0 464 443 A1 discloses a piezoelectric actuator which is charged from a capacitor via a charging coil. During discharging of the piezoelectric actuator, part of the energy applied is fed back into the capacitor via a discharging coil, while the other part is converted into heat, likewise via the discharging coil. During discharging, a negative voltage is present across the piezoelectric actuator.

DE 36 21 541 C2 discloses a driver circuit for a piezoelectric actuator of a fuel injection valve which is charged via a series circuit, connected to a voltage source and composed of two capacitors, and a charging coil, and is discharged into one of the two capacitors via a discharging coil. In an alternative design, the actuator is charged via a capacitor, connected to a voltage source, and a charging coil; during discharging, the energy stored in the piezoelectric actuator is destroyed by a discharging coil.

It is the object of the invention to provide a device for driving at least one capacitive actuator which operates as far as possible without loss and is of simple design, and in which it is also possible to prescribe different desired values for the voltage occurring across the actuator, and in which negative voltages across the actuator are avoided.

This object is achieved according to the invention by means of the features of Patent Claim 1 or 2. Advantageous embodiments of the invention are to be gathered from the subclaims.

Exemplary embodiments of the invention are explained in more detail below with reference to the diagrammatic drawing, in which:

Figure 1: shows the circuit of a first exemplary embodiment,

Figure 2: a flowchart relating to the mode of operation of the exemplary embodiment according to Figure 1,

Figure 3: shows the circuit of a second exemplary embodiment, and

Figure 4: shows the circuit of a third exemplary embodiment.

Figure 1 shows a block diagram for driving an individual fuel injection valve (not shown in further detail) of an internal combustion engine via a piezoelectric actuator P by means of a control circuit ST which is usually controlled by microprocessor.

Connected between the positive pole +V and the negative pole GND of an energy source V is a series circuit composed of a charging capacitor C and a controlled, electronic energy switch X1 which passes current only in one direction.

In the further description, when switches X1 to X4 are mentioned they are electronic switches, preferably thyristor switches, which pass current only in one direction, consist of at least one semiconductor element and are driven by the control circuit ST.

In the conducting state of the energy switch X1, the charging capacitor C is charged by the energy source V. This can be performed in principle as long as the voltage Uc across the charging capacitor is lower than the voltage of the energy source V.

Connected in parallel with the charging capacitor C is a series circuit composed of a ring-around coil L connected to the energy switch X1, and a charging stop switch X3, whose function will be explained later.

Arranged in parallel with the charging stop switch X3 is an actuator circuit S which has a series circuit which is composed of a parallel circuit comprising a charging switch X2, which passes current in the direction away from the ring-around coil L, and a discharging switch X4 which passes current in the direction of the ring-around coil, and of a parallel circuit comprising the actuator P with a diode D, which passes current in the direction of the charging switch X2.

The switches X1 to X4 are controlled by a microprocessor-controlled circuit ST as a function of external control signals st of, in this exemplary embodiment, a prescribed desired value Us (there can also be a plurality which become active one after another, for example preinjection and main injection of fuel) for the voltage present across the actuator P, and of the actual value Up of this voltage. The position of the actuator can also be used instead of the actuator voltage.

A method for operating the device is described on the example of the circuit according to Figure 1 with the aid of the flow chart shown in Figure 2, starting from an initial state (state I) in which the charging capacitor C is fully loaded, all the switches X1 to X4 are non-conducting and the ring-around coil L is de-energized.

With the start of an external control signal st = 1 (state II), the charging switch X2 is triggered (controlled to be conducting). Consequently, the charging capacitor C starts to discharge via the ring-around coil L into the actuator (acting like a capacitor), and to charge said actuator (state III), the effect being to change the length of the piezoelectric actuator. There is an increase in the voltage Up present across the actuator, which is communicated to the control circuit ST (indicated by arrows in Figure 1).

As soon as the voltage Up reaches the desired value Us (state IV), the charging operation is terminated, the charging switch X2 becomes non-conducting, that is to say X2 = 0, and the charging stop switch X3 becomes conducting (X3 = 1, state V). The resonant circuit L-C continues to oscillate until the ring-around coil L is de-energized.

The state of charge of the actuator is maintained as long as the control signal st is present. When it vanishes (st = 0, state VI), the actuator must be discharged. For this purpose, the charging stop switch is controlled to be non-conducting, X3 = 0, and the discharging switch to be conducting, X4 = 1 (state VII). The actuator P is now discharged via the ring-around coil L into the charging capacitor C. If the actuator is discharged down to the threshold voltage of the diode D, the latter takes over the current; the resonant circuit L-C continues to oscillate until the ring-around coil is deenergized. The switch X4 is controlled to be non-conducting.

In the absence of losses, the same voltage Uc would now be present across the charging capacitor C as in the initial state I. In fact, however, because of losses it has become somewhat lower, with the result that, in this exemplary embodiment, after termination of the discharging operation, when the switches X2 to X4 are once again non-conducting, the energy switch X1 is switched to be conducting to recharge the charging capacitor C (state VIII) before a new charging cycle begins.

Figure 3 shows a circuit corresponding in principle to the circuit according to Figure 1, but for driving a plurality of actuators P1 to Pn. In this circuit, the energy source V, energy switch X1, charging capacitor C, ring-around coil and charging stop switch X3 are connected as in the case of the circuit according to Figure 1 and acts just as described there. However, the control circuit ST is not represented again here.

For the first actuator P1, the actuator circuit S1 with the charging switch X2.1 instead of X2, the diode D and the discharging switch X4 has the same circuit as in Figure 1, with the difference that there is connected between the actuator P1 and discharging switch X4 a diode D2.1 which conducts current towards the discharging switch and is not required for driving only one actuator according to Figure 1, and that for each further actuator P2 to Pn a further charging switch X2.2 to X2.n and a further diode D2.2 to D2.n are provided in an appropriate circuit.

The charging switches X2.1 to X2.n driven by the control circuit select the actuator to be charged, while the diodes D2.1 to D2.n prevent other actuators than the selected one from also being charged. Each actuator is discharged via the diode D2.1 to D2.n assigned to it when the common discharging switch X4 is controlled to be conductive. If the respective actuator is discharged down to the threshold voltage of the diode D, the latter takes over the current; the resonant circuit L-C continues to oscillate until the ring-around coil L is de-energized.

Figure 4 shows a further circuit for driving a plurality of actuators which have a reduced component outlay by comparison with the circuit according to Figure 3. Once again, the control circuit ST is also not shown here.

The circuit according to Figure 3 requires an expensive transformer to trigger each of the thyristor switches X2.1 to X2.n. These transformers are dispensable if, instead of them, use is made of simple selector switches T1 to Tn, for example power MOSFET switches. The circuit is then essentially reduced to a circuit corresponding to the circuit according to Figure 1, in which the actuator P is replaced by a series circuit composed of an actuator P1 and an assigned selector switch T1, there being connected in parallel with the switching junction of the selector switch T1 a diode D1 which passes current in the discharging direction and is already integrated in MOSFET switches when they are used.

Such a series circuit composed of an actuator P2 to Pn, a selector switch T2 to Tn and a diode D2 to Dn is connected, for each further actuator P2 to Pn, in parallel with the series circuit P1-T1-D1 for the first actuator P1.

The mode of operation of this circuit corresponds to that of the circuits according to Figures 1 and 3, it being the case that during charging of an actuator, for example P1, the assigned selector switch T1 must be controlled to be conducting for at least as long as the charging switch X2 is controlled to be conducting.

During discharging of the actuator P1, the current flows from the actuator via the discharging switch X4, ring-around coil L, charging capacitor C and diode D1. If the actuator is discharged down to the threshold voltage of the diode D, the latter takes over the current and the resonant circuit L-C continues to oscillate until the ring-around coil is de-energized.

By means of simple changes both to the charging and discharging switches and to the selector switches, the circuits shown in Figures 1, 3 and 4 can be designed such that, depending on the preconditions, the actuators are either connected to the negative pole GND (low side, see Figures 1 and 3), or are situated closer to the positive pole +V (high side, see Figure 4).

Patent Claims

1. Device for driving at least one capacitive actuator (P),

- having a charging capacitor (C), which is arranged between the positive pole (+V) and negative pole (GND) of an energy source (V) and can be re-charged by the energy source (V) via an energy switch (X1),
- having a series circuit, which is arranged in parallel with the charging capacitor (C) and comprises a ring-around coil (L), connected to the energy switch (X1), and a charging stop switch (X3), and
- having an actuator circuit (S, S1) arranged in parallel with the charging stop switch (X3), comprising
- a discharging switch (X4), which is connected on one side to the ring-around coil (L) and conducts current to it,
- for each actuator, a series circuit composed of a charging switch (X2.1 to X2.n), which is connected to the ring-around coil (L) and conducts current away from it, and the actuator (P1 to Pn) itself, and a diode (D2.1 to D2.n), which is arranged between the actuator (P1 to Pn) and the other side of the discharging switch (X4) and conducts current in the discharging direction, and
- a diode (D) which is connected in parallel with one of the actuators (P1) and passes current in the direction of the charging switch (X2.1) assigned to the actuator.

2. Device for driving at least one capacitive actuator (P1 to Pn) by means of a control circuit (ST), in particular a piezoelectrically operated fuel injection valve of an internal combustion engine,

- having a charging capacitor (C), which is arranged between the positive pole (+V) and negative pole (GND) of an energy source (V) and can be re-charged by the energy source (V) via an energy switch (X1),
- having a series circuit, which is arranged in parallel with the charging capacitor (C) and comprises a ring-around coil (L), connected to the energy switch (X1), and a charging stop switch (X3),

- having an actuator circuit (S2) which is arranged in parallel with the charging stop switch (X3) and contains a series circuit composed of a parallel circuit of a discharging switch (X4), which passes current to the ring-around coil (L), and a charging switch (X2), which passes current away from the ring-around coil (L), and of a diode (D), and

- having a series circuit, provided for each actuator (P1 to Pn) and arranged in parallel with the diode (D), which is composed of the actuator (P1 to Pn) itself and of an electronic selector switch (T1 to Tn), which is assigned to said actuator, is controlled by the control circuit (ST) and whose switching junction is bridged by a diode D1 to Dn which conducts current in the discharging direction.

3. Device according to one of Claims 1 or 2, characterized in that the energy switch (X1), charging switch (X2, X2*, X2.1 to X2.n) and discharging switch (X4, X4*) comprise controlled, electronic switches which pass current only in one direction and have at least one semiconductor element.

4. Device according to one of Claims 1 or 2, characterized in that at least one desired value (Us1 to Usn) for the position of the respective actuator (P, P1 to Pn) or for the voltage (Up) present across it can be prescribed for the control circuit (ST) or stored in it, and

- in that the control circuit (ST) outputs the control commands for the charging switches (X2, X2.1 to X2.n), charging stop switch (X3), discharging switch (X4) and selector switches (T1 to Tn) as a function of external control signals (st) from the position of the respective actuator (P, P1 to Pn) or of the voltage (Up) present across it, and from the respectively prescribed desired value (Us1 to Usn) for the position or voltage of the actuator.

5. Method for operating the device according to one of Claims 1 or 2, characterized

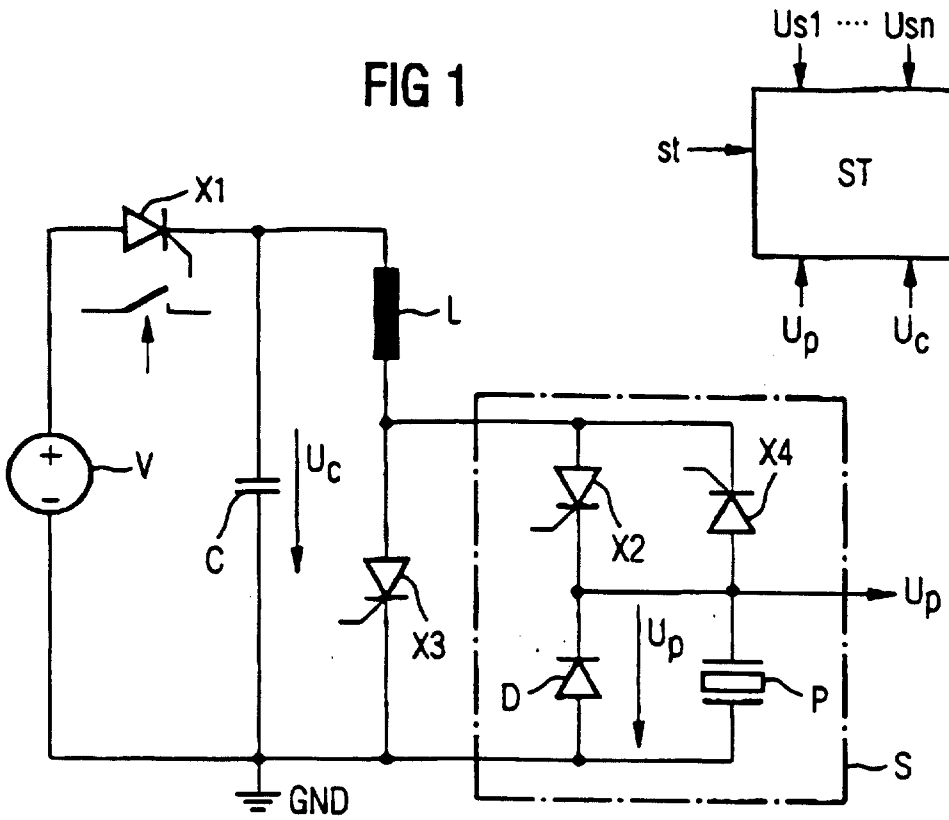
in that with the start of a control signal (st) the actuator (P, P1 to Pn) to be driven is recharged from the charging capacitor (C), charged by the energy source (V) via the ring-around coil (L) until the voltage (Up) present across it reaches a prescribed desired value (Us),

in that subsequently this state of charge (Up = Us) is maintained up to the end of the control signal (st),

in that with the end of the control signal (st) the actuator is discharged into the charging capacitor (C), and

in that the charging capacitor (C) is recharged by the energy source (V) following the discharging operation.

FIG 1


Us1 ···· Usn
st
ST
X1
X2
X3
X4
Up
Uc
X1
L
V
C
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X3
X2
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Up
D
Up
P
S
GND

FIG 3

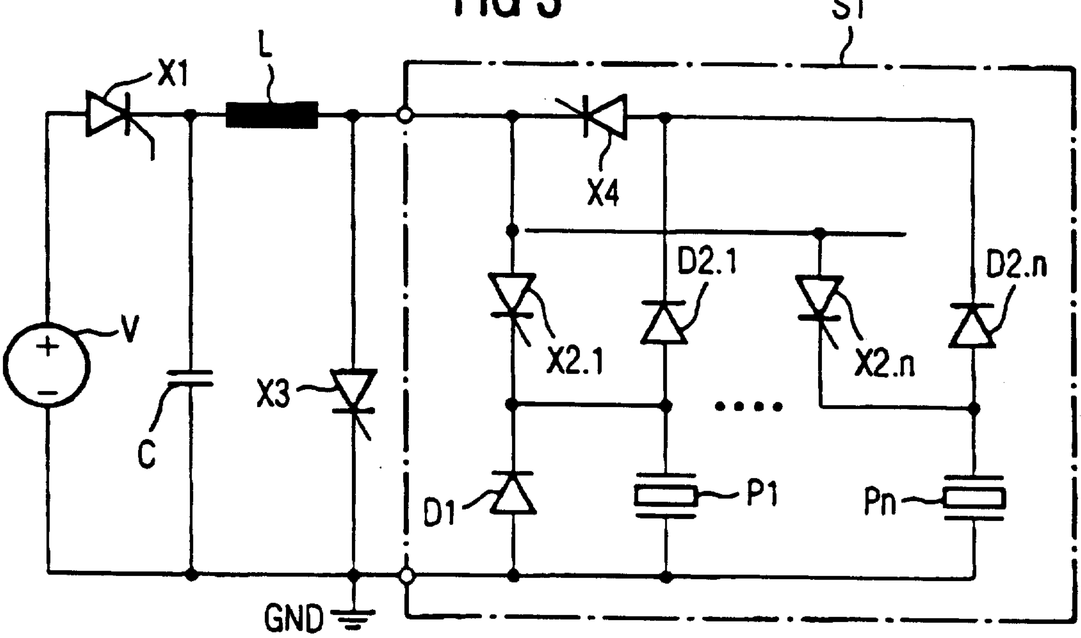

S1
X1
L
X4
V
C
X3
D2.1
X2.1
X2.n
D2.n
D1
P1
Pn
GND

FIG 2

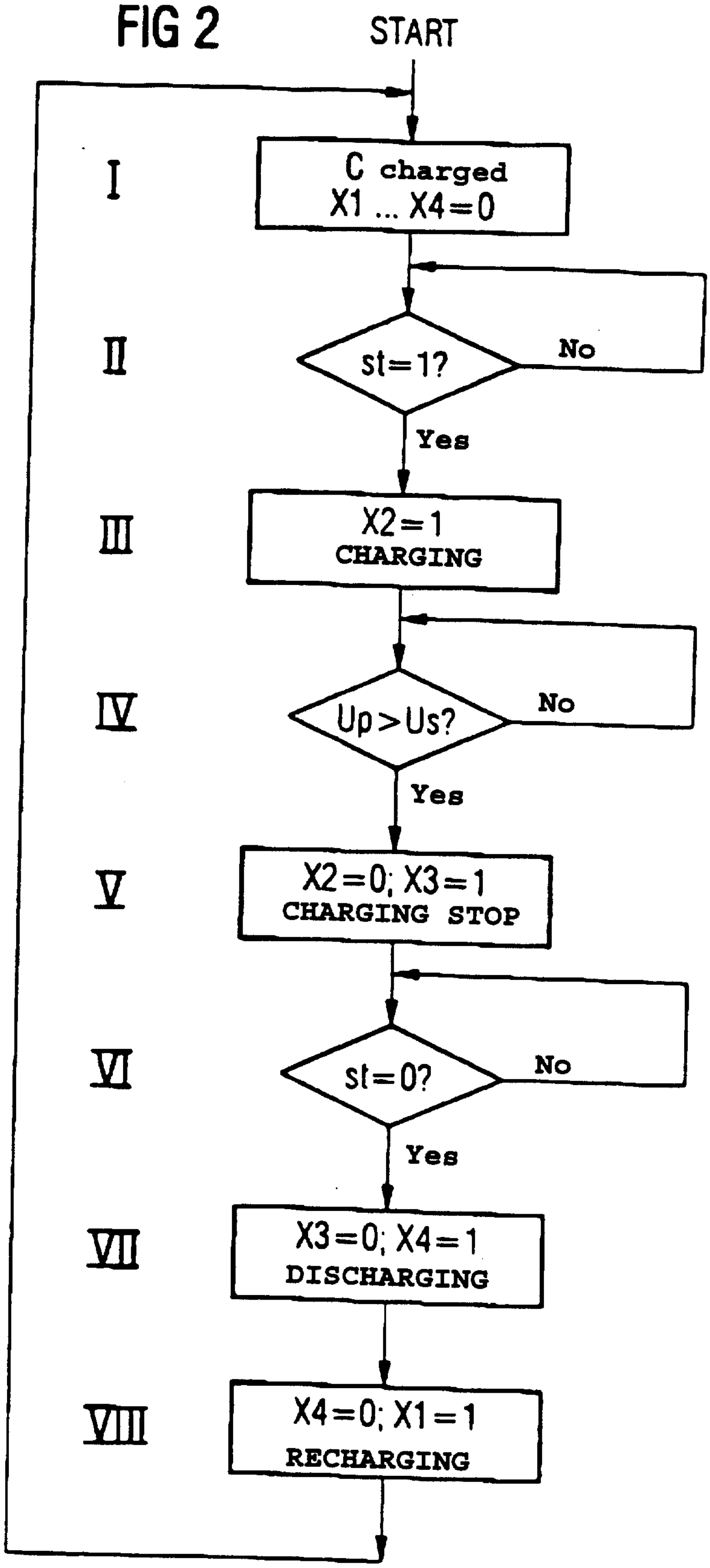
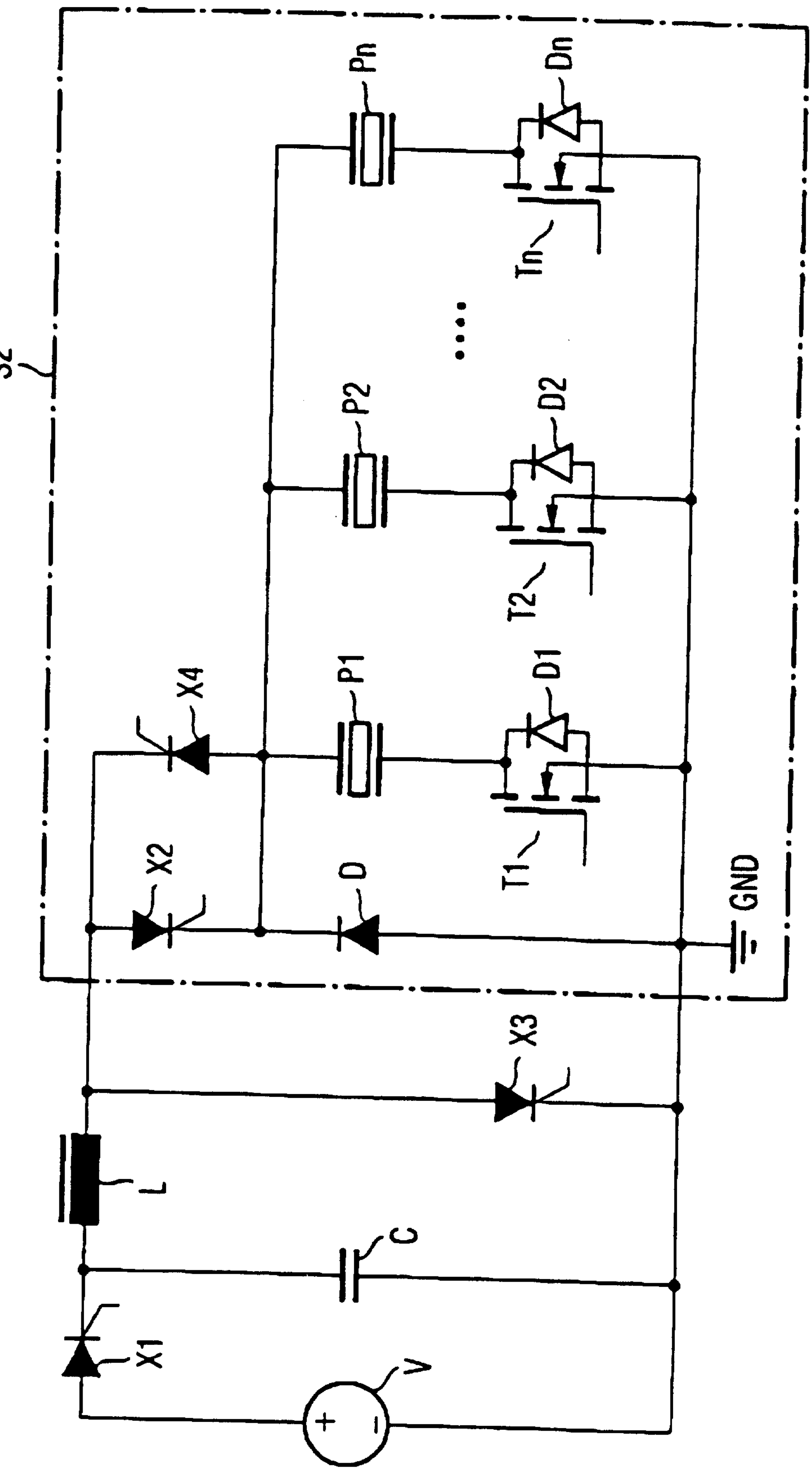
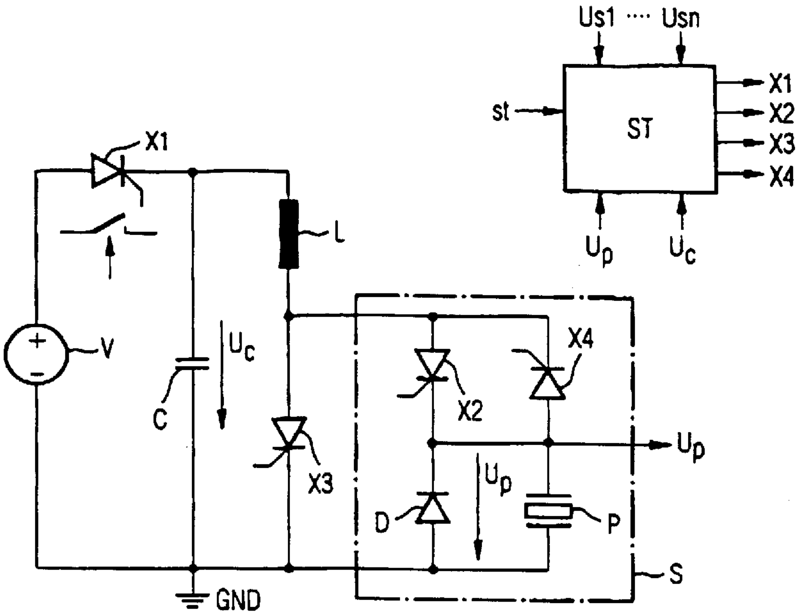

START
I
C charged
X1 ... X4=0
II
st=1?
No
Yes
III
X2=1
CHARGING
IV
Up>Us?
No
Yes
V
X2=0; X3=1
CHARGING STOP
VI
st=0?
No
Yes
VII
X3=0; X4=1
DISCHARGING
VIII
X4=0; X1=1
RECHARGING

FIG 4





Us1 ···· Usn
st
ST
X1
X2
X3
X4
Up
Uc
X1
L
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Uc
X3
X2
X4
Up
D
Up
P
S
GND