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(71) Applicant: **SANKEN ELECTRIC CO., LTD.**
Niiza-shi,
Saitama 352-8666 (JP)

(72) Inventors:

- **Kato, Junichi**
Niiza-shi, Saitama 352-8666 (JP)
- **Matsunaga, Yasuyuki**
Niiza-shi, Saitama 352-8666 (JP)

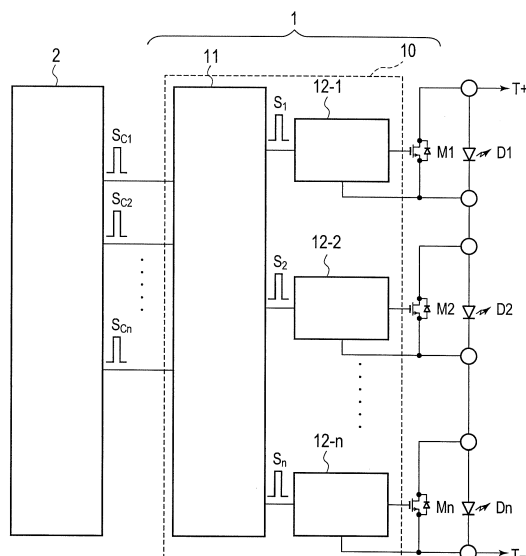
(74) Representative: **Grünecker Patent- und Rechtsanwälte**
PartG mbB
Leopoldstraße 4
80802 München (DE)

(54) **Driving apparatus of light emitting load and light emitting apparatus for vehicle**

(57) A light emitting load driving apparatus includes a first switching element, a second switching element, and a gate driver, to drive first and second light emitting loads connected in series. The first switching element, when in an ON state, bypasses a current to be passed to the first light emitting load. The second switching element, when in an ON state, bypasses a current to be

passed to the second light emitting load. The gate driver reduces at least one of an overshoot current caused when the first and second switching elements are simultaneously turned on and an undershoot current caused when the first and second switching elements are simultaneously turned off.

FIG. 3



Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a light emitting load driving apparatus for driving a light emitting load such as an LED (Light Emitting Diode) and a light emitting apparatus for a vehicle, having such a light emitting load driving apparatus.

2. Description of Related Art

[0002] Figure 1 is a circuit diagram illustrating a light emitting load driving apparatus and a light emitting apparatus for a vehicle disclosed in Japanese Unexamined Patent Application Publication No.2013-84635 (Patent Literature 1). The light emitting apparatus for a vehicle includes the light emitting load driving apparatus 1a and a plurality of light emitting loads D1 to Dn. The light emitting load driving apparatus 1a includes a plurality of switching elements M1 to Mn connected in parallel with the light emitting loads D1 to Dn, respectively, and a gate driver 10a that individually drives the switching elements M1 to Mn according to a PWM (Pulse Width Modulation) method. The light emitting loads D1 to Dn are connected in series between both ends of a constant current source IDD. The gate driver 10a outputs drive signals that oscillate between high and low levels to gate terminals of the switching elements M1 to Mn, respectively, thereby adjusting brightness levels of the light emitting loads D1 to Dn.

SUMMARY OF THE INVENTION

[0003] Figure 2 is a timing chart illustrating operation of the light emitting load driving apparatus described in Patent Literature 1. Waveforms M1 to Mn represent actions of the switching elements M1 to Mn. A waveform VDD represents voltage applied between a positive terminal T+ and a negative terminal T- of the constant current source IDD. A waveform IDD represents current passing between the positive and negative terminals T+ and T- of the constant current source IDD. At time t0 or t2, the switching elements M1 to Mn simultaneously change from OFF to ON, i.e., turn on at the same time to bypass the current passed to the light emitting loads D1 to Dn, thereby suddenly decreasing load on the constant current source IDD and causing an overshoot current Io. At time t1 or t3, the switching elements M1 to Mn simultaneously change from ON to OFF, i.e., turn off at the same time to pass the current to the light emitting load D1 to Dn, thereby suddenly increasing load on the constant current source IDD and causing an undershoot current Iu.

[0004] The overshoot and undershoot currents Io and Iu cause unnecessary electromagnetic radiation noises

and erroneous load-short or load-open detection by the constant current source IDD. The overshoot and undershoot currents Io and Iu must be suppressed as small as possible.

[0005] The present invention provides a light emitting load driving apparatus and a light emitting apparatus for a vehicle, capable of suppressing electromagnetic radiation noises and erroneous load-short or load-open detection by a constant current source.

[0006] According to an aspect of the present invention, the light emitting load driving apparatus includes a first switching element, a second switching element, and a gate driver, to drive first and second light emitting loads connected in series. The first switching element, when in an ON state, bypasses a current to be passed to the first light emitting load. The second switching element, when in an ON state, bypasses a current to be passed to the second light emitting load. The gate driver reduces at least one of an overshoot current caused when the first and second switching elements are simultaneously turned on and an undershoot current caused when the first and second switching elements are simultaneously turned off.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007]

Figure 1 is a circuit diagram illustrating a light emitting load driving apparatus and a light emitting apparatus for a vehicle according to a related art;

Fig. 2 is a timing chart illustrating operation of the light emitting load driving apparatus according to the related art;

Fig. 3 is a circuit diagram illustrating a light emitting load driving apparatus and a light emitting apparatus for a vehicle according to embodiments of the present invention;

Fig. 4 is a circuit diagram illustrating the details of part of the light emitting load driving apparatus according to the embodiment of the present invention; and

Fig. 5 is a timing chart illustrating operation of the light emitting load driving apparatus according to the embodiment of the present invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0008] Embodiments of the present invention will be explained with reference to the drawings. Through the drawings, the same or like parts are represented with the same or like reference marks. It must be noted that circuits and parts illustrated in the drawings are typical and exemplary ones. The embodiments mentioned below are only examples of apparatuses or techniques that materialize the idea of the present invention and are not intended to limit the present invention. The embodiments mentioned below are modifiable in various ways within

the scope of claims of the present invention.

[0009] Figure 3 is a circuit diagram illustrating a light emitting load driving apparatus and a light emitting apparatus for a vehicle according to an embodiment of the present invention. The light emitting apparatus for a vehicle includes the light emitting load driving apparatus 1, a first light emitting load D1, and a second light emitting load D2. The light emitting load driving apparatus 1 includes a first switching element M1, a second switching element M2, and a gate driver 10. The first switching element M1, when in an ON state, bypasses a current of the first light emitting load D1. The second switching element M2, when in an ON state, bypasses a current of the second light emitting load D2. The gate driver 10 reduces at least one of an overshoot current I_o caused when the first and second switching elements M1 and M2 are simultaneously turned on and an undershoot current I_u caused when the first and second switching elements M1 and M2 are simultaneously turned off.

[0010] A light emitting apparatus for a vehicle according to another embodiment of the present invention (also illustrated in Fig. 3) includes a light emitting load driving apparatus 1 and a plurality of light emitting loads D1 to Dn. The light emitting apparatus is connected to an emission controller 2. The light emitting loads D1 to Dn are, for example, LEDs. The light emitting loads D1 to Dn are connected in series between a positive terminal T+ and a negative terminal T- of a constant current source IDD. According to control signals SC1 to SCn outputted from the emission controller 2, the light emitting apparatus supplies DC current from the constant current source IDD to the light emitting loads D1 to Dn. In the following explanation, the control signals SC1 to SCn are sometimes collectively referred to as the control signals {SCi}.

[0011] The light emitting load driving apparatus 1 installed in the light emitting apparatus includes a plurality of switching elements M1 to Mn and a gate driver 10. The light emitting load driving apparatus 1 is formed as, for example, a single semiconductor integrated circuit. The light emitting load driving apparatus 1 is connected to the light emitting loads D1 to Dn, emission controller 2, and constant current source IDD. According to the control signals {SCi} outputted from the emission controller 2, the light emitting load driving apparatus 1 adjusts brightness levels of the light emitting loads D1 to Dn. The emission controller 2 may be a digital circuit such as ASIC or FPGA, or a microcontroller. The control signals {SCi} outputted from the emission controller 2 are pulse signals to individually control brightness levels of the light emitting loads D1 to Dn.

[0012] The switching elements M1 to Mn are, for example, MOSFETs and are connected in series between the positive and negative terminals T+ and T- of the constant current source IDD. The switching elements M1 to Mn are connected in parallel with the light emitting loads D1 to Dn, respectively. When the switching elements M1 to Mn are OFF, DC current supplied from the constant current source IDD passes through the light emitting

loads D1 to Dn. When turned on, the switching elements M1 to Mn bypass the DC current passing through the light emitting loads D1 to Dn.

[0013] The gate driver 10 includes a phase shifter 11 and a plurality of signal output units 12-1 to 12-n. According to the control signals {SCi} outputted from the emission controller 2, the gate driver 10 generates drive signals S1 to Sn that are pulse signals oscillating between high and low levels. In the following explanation, the drive signals S1 to Sn are sometimes collectively referred to as the drive signals {Si}.

[0014] A ratio of high and low levels, i.e., a duty ratio of each of the drive signals {Si} is changed according to a corresponding one of the control signals {SCi}. The drive signals {Si} are transmitted through the signal output units 12-1 to 12-n to gate terminals of the switching elements M1 to Mn. The gate driver 10 individually controls the switching elements M1 to Mn according to the PWM method. For example, when the first drive signal S1 is high, the first switching element M1 turns on to turn off the light emitting load D1. When the first drive signal S1 is low, the first switching element M1 turns off to turn on the light emitting load D1. The gate driver 10 controls the ON time and OFF time of each of the switching elements M1 to Mn according to the control signals {SCi}, thereby adjusting brightness levels of the light emitting loads D1 to Dn.

[0015] The phase shifter 11 is connected to the emission controller 2 and signal output units 12-1 to 12-n. The phase shifter 11 detects the control signals {SCi} that may simultaneously turn on or off the switching elements M1 to Mn. Simultaneously turning on the switching elements M1 to Mn is equivalent to shifting the switching elements M1 to Mn from an OFF state to an ON state at the same time. Simultaneously turning off the switching elements M1 to Mn is equivalent to shifting the switching elements M1 to Mn from an ON state to an OFF state at the same time.

[0016] If the phase shifter 11 detects the control signals {SCi} that simultaneously turn on the switching elements M1 to Mn, the phase shifter 11 uses the rise timing of the first drive signal S1 that is based on the first control signal SC1, to successively delay the rise timing of the other drive signals S2 to Sn and outputs the drive signal S1 and successively delayed drive signals S2 to Sn to the signal output units 12-1 to 12-n, respectively. If the phase shifter 11 detects the control signals {SCi} that simultaneously turn off the switching elements M1 to Mn, the phase shifter 11 uses the fall timing of the first drive signal S1 that is based on the first control signal SC1, to successively delay the fall timing of the other drive signals S2 to Sn.

[0017] The signal output units 12-1 to 12-n are connected to the phase shifter 11 and switching elements M1 to Mn. When the drive signals {Si} are high, the signal output units 12-1 to 12-n turn on the switching elements M1 to Mn. When the drive signals {Si} are low, the signal output units 12-1 to 12-n turn off the switching elements

M1 to Mn.

[0018] Figure 4 is a circuit diagram illustrating the details of part of the light emitting load driving apparatus 1 according to the embodiment of the present invention. The light emitting load driving apparatus 1 includes a first charging unit 13-1 connected to the first signal output unit 12-1. The first signal output unit 12-1 includes a first switch SW1, a second switch SW2, and an inverter INV. According to the first drive signal S1, the first switch SW1 opens and closes a path between the first charging unit 13-1 and the gate terminal of the first switching element M1. The inverter INV inverts the first drive signal S1 and outputs the inverted signal to the second switch SW2. According to the inverted signal, the second switch SW2 opens and closes both ends of a parasitic capacitance C2 of the first switching element M1.

[0019] Potential at a source terminal of the first switching element M1 varies depending on actions of the other switching elements. Accordingly, the first charging unit 13-1 stabilizes operation of the first switching element M1 driven by the first signal output unit 12-1. The first charging unit 13-1 includes a current source ICC, first and second diodes Di1 and Di2, a zener diode ZDi, a first capacitor C1, and a driver DRV. The current source ICC is connected through the first diode Di1 to a first end of the first capacitor C1. The first end of the first capacitor C1 is connected through the second diode Di2 to the signal output unit 12-1. A second end of the first capacitor C1 is connected to an output end of the driver DRV. The bidirectional zener diode ZDi is a protective element and is connected in parallel with the first capacitor C1. The driver DRV outputs a drive pulse signal SD that is independent of the drive signals {Si} and oscillates between high and low levels at a frequency of several hundreds kHz. When the drive pulse signal SD is low, the current source ICC charges the first capacitor C1. When the drive pulse signal SD is high, potential at the second end of the first capacitor C1 is lifted.

[0020] When the first switch SW1 is turned on in the first signal output unit 12-1, charges accumulated in the first capacitor C1 shift through the second diode Di2 to the second capacitor C2 to increase potential across the second capacitor C2. This results in turning on the first switching element M1. When the second switch SW2 is turned on, the second capacitor C2 is discharged to turn off the first switching element M1.

[0021] Each of the signal output units 12-1 to 12-n is provided with a charging unit that is the same as the charging unit 13-1 explained above and illustrated in Fig. 4.

[0022] Figure 5 is a timing chart illustrating operation of the light emitting load driving apparatus 1 according to the embodiment of the present invention. A waveform M1 represents operation of the first switching element M1, a waveform M2 operation of the second switching element M2, a waveform Mn operation of the "n"th switching element Mn, a waveform VDD voltage applied between the positive and negative terminals T+ and T- of

the constant current source IDD, and a waveform IDD current passing between the positive and negative terminals T+ and T- of the constant current source IDD.

[0023] Operation when the emission controller 2 provides at time t01 the gate driver 10 with the control signals SC1 to SCn that may simultaneously turn on the switching elements M1 to Mn will be explained. At time t01, the phase shifter 11 outputs the first drive signal S1 to the first signal output unit 12-1 to turn on the first switching element M1 that is the closest switching element to the positive terminal of the constant current source IDD. At this time, the phase shifter 11 successively delays the second to "n"th drive signals S2 to Sn with respect to the first drive signal S1. For example, at time t02, the phase shifter 11 outputs the second drive signal S2 to the second signal output unit 12-2 to turn on the second switching element M2 that is closer to the negative terminal of the constant current source IDD with respect to the first switching element M1. At time t0n, the phase shifter 11 outputs the "n"th drive signal Sn to the "n"th signal output unit 12-n to turn on the "n"th switching element Mn. From time t0n to t11, all of the switching elements M1 to Mn are ON.

[0024] Operation when the emission controller 2 provides at time t11 the gate driver 10 with the control signals SC1 to SCn that may simultaneously turn off the switching elements M1 to Mn will be explained. At time t11, the phase shifter 11 outputs the first drive signal S1 to the first signal output unit 12-1 to turn off the first switching element M1. At time t12, the phase shifter 11 outputs the second drive signal S2 to the second signal output unit 12-2 to turn off the second switching element M2. In this way, at time t1n, the phase shifter 11 outputs the "n"th drive signal Sn to the "n"th signal output unit 12-n to turn off the "n"th switching element Mn. The voltage VDD rises and falls in steps when the switching elements M1 to Mn are successively turned on and off.

[0025] The light emitting load driving apparatus 1a of the related art described in Patent Literature 1 and illustrated in Figs. 1 and 2 suddenly decreases and increases load on the constant current source IDD whenever simultaneously turning on and off the switching elements M1 to Mn. Unlike the related art, the light emitting load driving apparatus 1 and gate driver 10 according to the present invention employ the phase shifter 11 to manage at least one of the simultaneous turning on and simultaneous turning off of the first and second switching elements M1 and M2 (or M1 to Mn). Accordingly, the present invention is able to reduce load fluctuations of the constant current source IDD and cancel at least one of overshoot and undershoot currents.

[0026] The light emitting load driving apparatus 1 and gate driver 10 according to the present invention employ the charging unit 13 that increases operating potential of the signal output unit 12 according to the drive pulse signal SD that is independent of the drive signals {Si}. This configuration of the present invention moderates restrictions the related art of Patent Literature 1 must apply

when turning on and off the switching elements M1 to Mn in the light emitting load driving apparatus 1a.

[0027] The light emitting load driving apparatus 1 and gate driver 10 according to the present invention may replace the phase shifter 11 with a ramp generator that successively elongates the rise time and fall time of the second to "n"th drive signals S2 to Sn with respect to the rise time and fall time of the first drive signal S1 of the switching element M1 that is the closest switching element to the positive terminal of the constant current source IDD. This modification successively delays the turning-on or -off speeds of the switching elements M1 to Mn when receiving simultaneous turn-on or -off drive signals, thereby reducing load fluctuations of the constant current source IDD.

[0028] Although the present invention has been explained above by reference to certain embodiments of the present invention, the present invention is not limited to the embodiments explained above or the accompanying drawings. Modifications and variations of the embodiments will occur to those skilled in the art in light of the teachings. The scope of the present invention is defined with reference to the appended claims. For example, the light emitting load driving apparatus 1 according to the present invention may include a plurality of switching elements M1 to Mn that are formed as discrete devices and a gate driver 10 that is formed as a semiconductor integrated circuit. Alternatively, the light emitting load driving apparatus 1 according to the present invention may include at least one of the emission controller 2 and constant current source IDD. Each of the light emitting loads D1 to Dn may include a plurality of LEDs.

[0029] In this way, the light emitting load driving apparatus and the light emitting apparatus for a vehicle provided by the present invention are capable of suppressing unnecessary electromagnetic radiation noises and erroneous load-short or load-open detection by a constant current source IDD.

Claims

1. A driving apparatus (1) of a light emitting load comprising a first switching element (M1), a second switching element (M2), and a gate driver (10), to drive first (D1) and second (D2) light emitting loads connected in series, **characterized in that:**

the first switching element (M1), when in an ON state, bypasses a current to pass through the first light emitting load (D1);

the second switching element (M2), when in an ON state, bypasses a current to pass through the second light emitting load (D2); and

the gate driver (10) reduces at least one of an overshoot current caused when the first (M1) and second (M2) switching elements are simultaneously turned on and an undershoot current

caused when the first and second switching elements are simultaneously turned off.

2. The driving apparatus of claim 1, **characterized in that** the first (D1) and second (D2) light emitting loads are connected in series between positive and negative terminals of a constant current source (IDD).
3. The driving apparatus of claim 2, **characterized in that** the gate driver (10) puts both the first (M1) and second (M2) switching elements in an ON state during a predetermined period (t0n-t11, t2n-t31).
4. The driving apparatus of claim 3, **characterized in that** the gate driver (10) generates, according to control signals ({SCi}) provided by an emission controller (2), a first drive signal (S1) for driving the first switching element (M1) and a second drive signal (S2) for driving the second switching element (M2).
5. The driving apparatus of claim 4, **characterized in that** the gate driver (10) detects the control signals ({SCi}) that may cause at least one of the simultaneous turning on of the first (M1) and second (M2) switching elements and the simultaneous turning off of the first and second switching elements.
6. The driving apparatus of claim 5, **characterized in that** the gate driver (10) suppresses at least one of the simultaneous turning on of the first (M1) and second (M2) switching elements and the simultaneous turning off of the first and second switching elements.
7. The driving apparatus of claim 6, **characterized in that** the gate driver (10) delays at least one of the ON and OFF timing of one of the first (M1) and second (M2) switching elements that is connected to the negative terminal of the constant current source (IDD), wherein the second switching element (M2) is closer to the negative terminal of the constant current source (IDD) than the first switching element (M1).
8. The driving apparatus of claim 5, **characterized in that** the gate driver (10) decreases at least one of the turn-on and turn-off speeds of at least one of the first (M1) and second (M2) switching elements.
9. The driving apparatus of claim 8, **characterized in that** the gate driver (10) decreases at least one of the turn-on and turn-off speeds of one of the first (M1) and second (M2) switching elements that is connected to the negative terminal of the constant current source (IDD), wherein the second switching element (M2) is closer to the negative terminal of the constant current source (IDD) than the first switching element (M1).

10. A light emitting apparatus for a vehicle, **characterized in that** the apparatus comprises the driving apparatus (1) of any one of claims 1 to 9, the first light emitting load (D1), and the second light emitting load (D2).

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FIG. 1

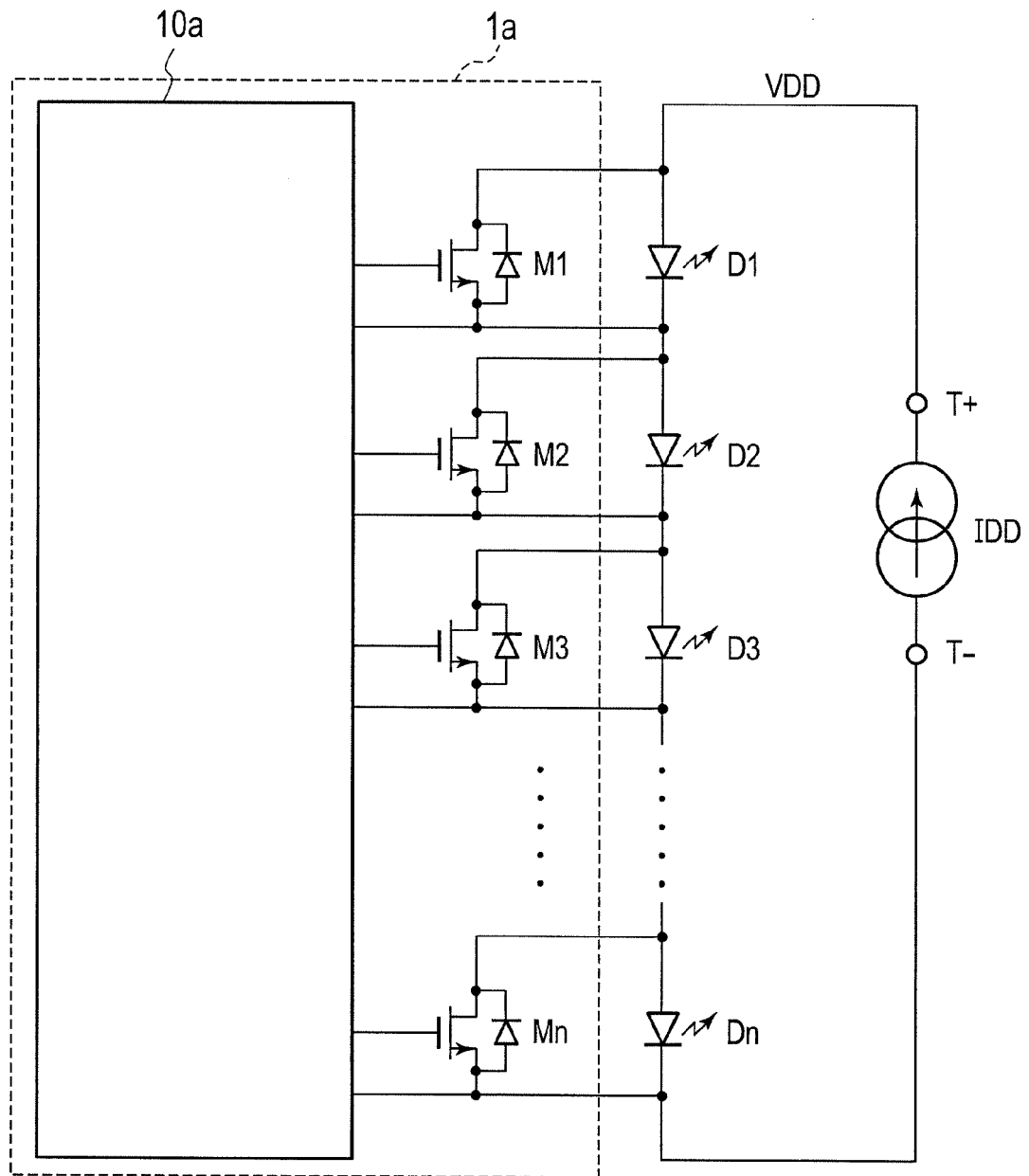


FIG. 2

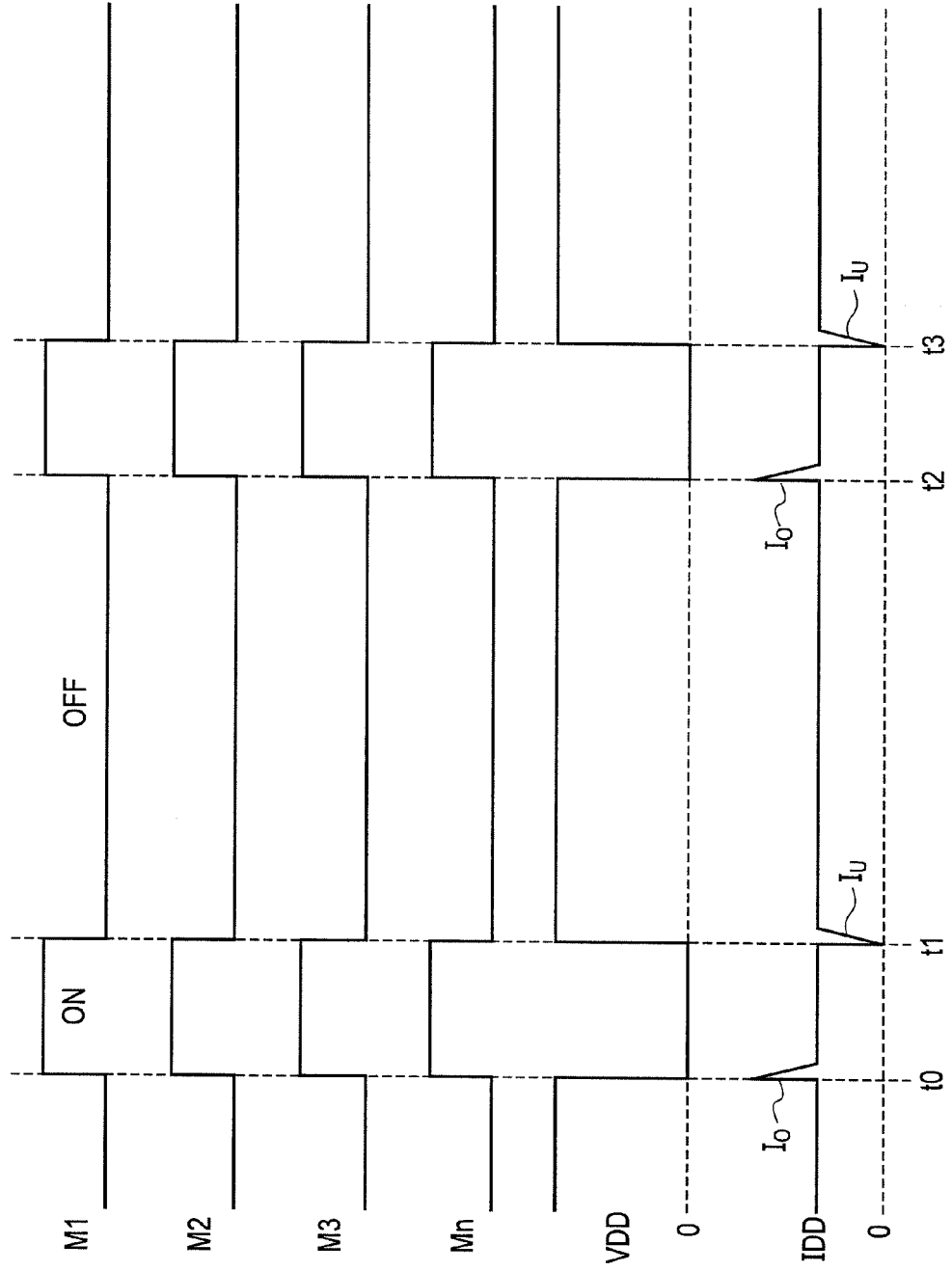


FIG. 3

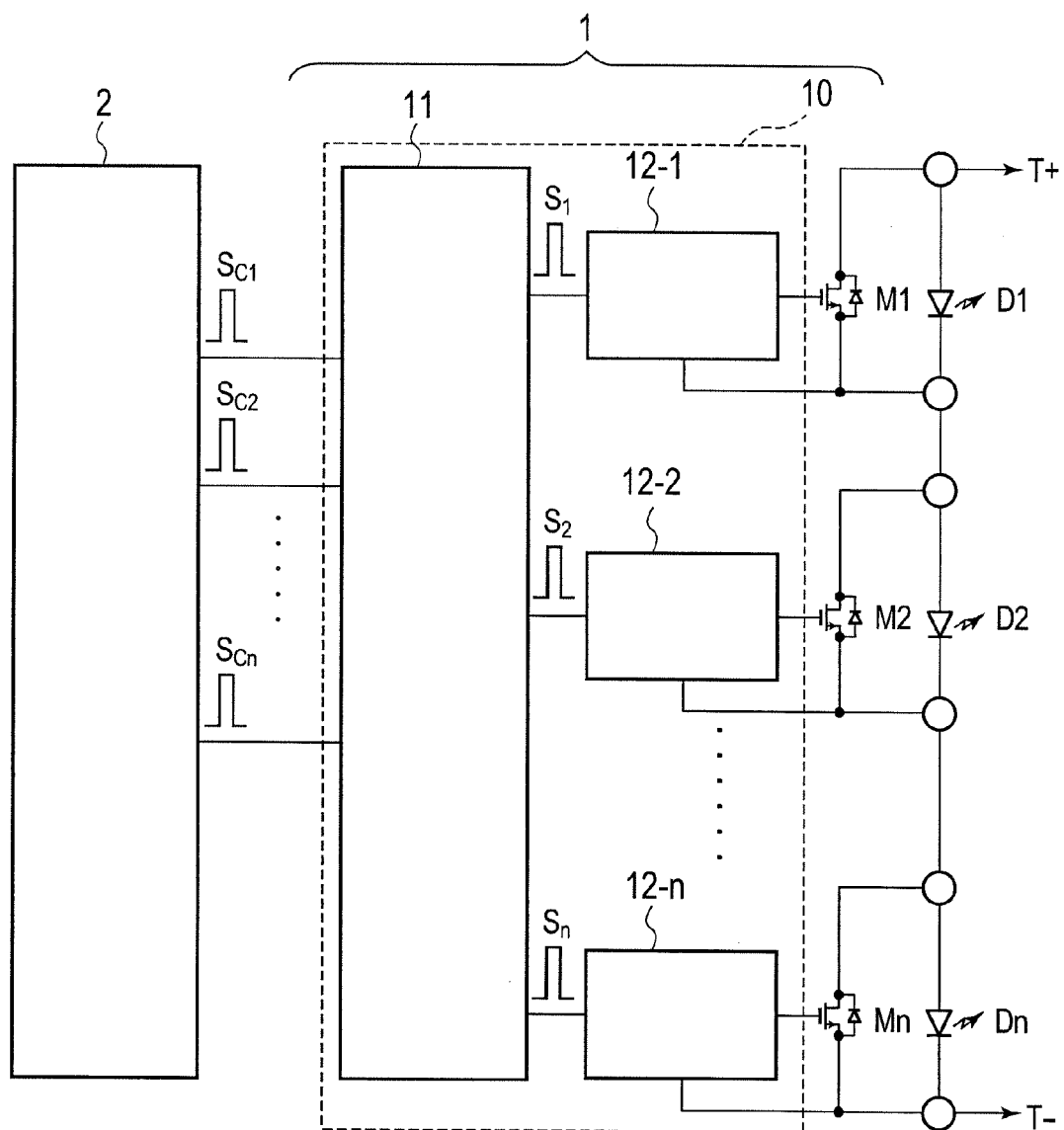


FIG. 4

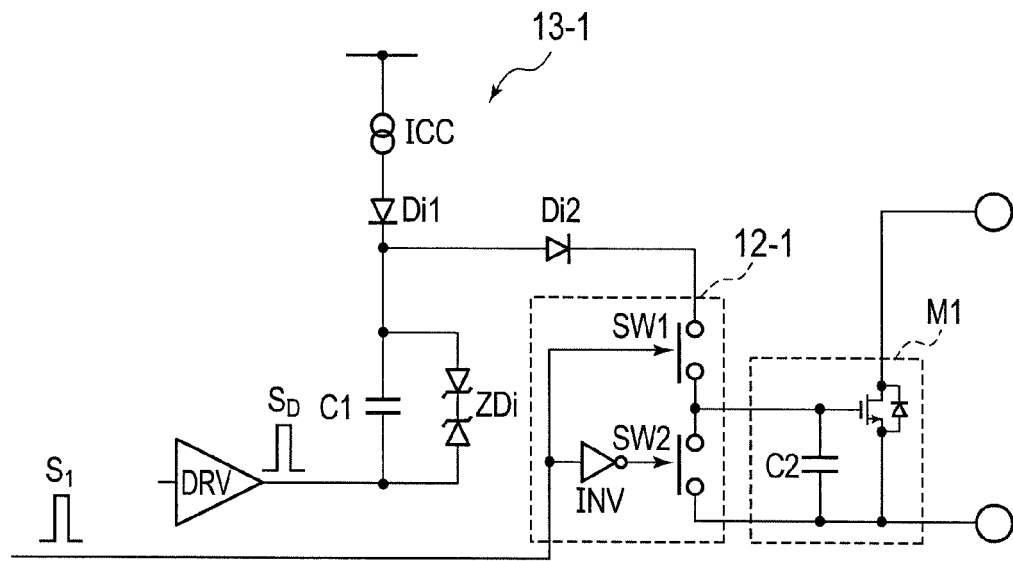
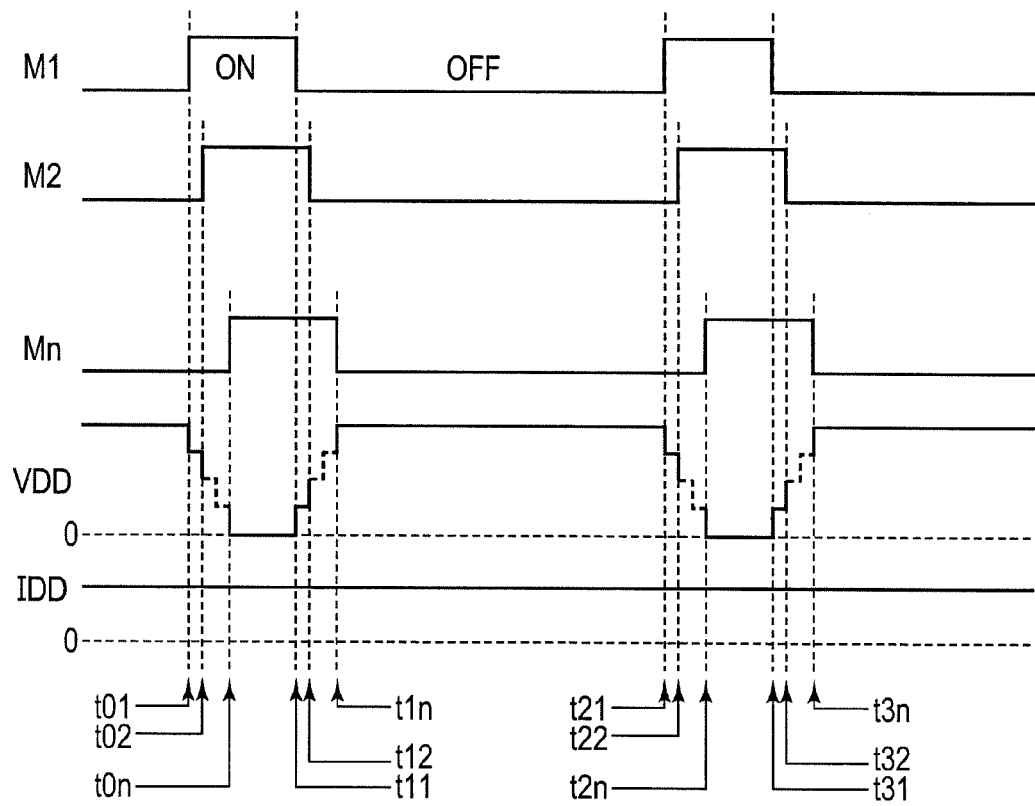


FIG. 5



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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