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— *as to the identity of the inventor (Rule 4.17(i))*

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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(54) **Title**: DUAL VOLTAGE AND CURRENT CONTROL FEEDBACK LOOP FOR AN OPTICAL SENSOR SYSTEM

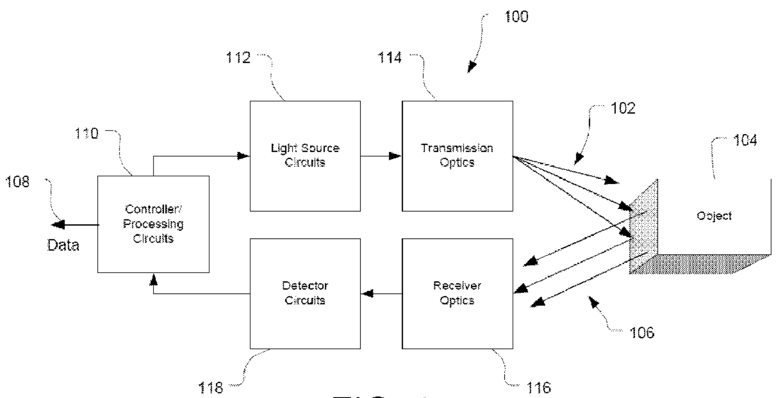

FIG. 1

(57) **Abstract**: A dual voltage and current control feedback control loop for an optical sensor system. A power supply provides a regulated DC voltage. A current source receives the regulated DC voltage and provides switched current to a light source. A current feedback representative of the current to the light source is provided to the power supply on a feedback path when the current source is driving the light source. A voltage feedback representative of the DC voltage is provided to the power supply on the feedback path when the current source is not driving the light source.

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DUAL VOLTAGE AND CURRENT CONTROL FEEDBACK LOOP FOR AN OPTICAL SENSOR SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from the following commonly owned United States Provisional Patent Applications: Serial No. 61/165,171, Serial No. 61/165,181, Serial No. 61/165,388, and Serial No. 61/165,159, all of which were filed on March 31, 2009.

[0002] This application is related to the following commonly-owned applications: United States Utility Patent Application Serial No. 12/652,083, entitled "CURRENT SOURCE TO DRIVE A LIGHT SOURCE IN AN OPTICAL SENSOR SYSTEM"; United States Utility Patent Application Serial No. 12/652,089, entitled "OPTICAL SENSOR SYSTEM INCLUDING SERIES CONNECTED LIGHT EMITTING DIODES"; and United States Utility Patent Application Serial No. 12/652,095, entitled "HIGH VOLTAGE SUPPLY TO INCREASE RISE TIME OF CURRENT THROUGH LIGHT SOURCE IN AN OPTICAL SENSOR SYSTEM"; all filed on January 5, 2010, and all of which are hereby incorporated by reference.

TECHNICAL FIELD

[0003] The present application relates to the sensors and, more particularly, to a dual voltage and current control feedback loop for an optical sensor system.

BACKGROUND

[0004] Optical sensor systems may be used to locate and/or image an object by detecting light reflected from the object. Such systems may include a light source that transmits light toward an object and a detector for detecting portions of the transmitted light reflected by the object. A characteristic of the reflected light may be analyzed by the sensor system to determine the distance to an object and/or to generate an electronic image of the object.

[0005] In one example, such a system may include a light source, such as one or more light emitting diodes (LEDs), configured to transmit modulated infrared light (IR), i.e. IR light that is rapidly turned on and off. The detector may receive the reflected light and calculate the phase shift imparted by reflection of the light back to the senor. The time of flight of the received light may be calculated from the phase shift and distance to various points in the sensor field of view may be calculated by multiplying the time of flight and the velocity of the signal in the transmission medium. By providing an array of receiving pixels in the detector, the distance signals associated with light received at each pixel may be mapped to generate a three-dimensional electronic image of the field of view.

[0006] The manner of modulation of the light source in such systems is a factor in system performance. To achieve useful and accurate imaging, it is desirable to modulate the light source at a high frequency, e.g. 40MHz. In addition, it is desirable in such systems to modulate the light source with high efficiency and reliability, while maintaining reasonable cost of manufacture and a relatively small package size.

SUMMARY

[0007] In an embodiment, there is provided a light source circuit for an optical sensor system. The light source circuit includes: a power supply to provide a regulated direct current (DC) voltage output; a voltage feedback circuit to provide a voltage feedback representative of the DC voltage output on a feedback path to the power supply; a current source coupled to the power supply to receive the regulated DC voltage output and to provide a current output to a light source, the current source being configured to provide a current feedback representative of the current output on the feedback path to the power supply; and a switch, whereby the current source is configured to provide the current output to the light source and the power supply is configured to adjust the DC voltage output in response to the current feedback when the switch is closed and the power supply is configured to adjust the DC voltage output in response to the voltage feedback when the switch is open.

[0008] In a related embodiment, the current source may include an inductor connected in series with a resistor; and a diode coupled in parallel with the inductor and resistor; and wherein the current source is configured to provide the current output through the inductor to the light source when the switch is closed and to divert current through the inductor to the diode when the switch is open. In a further related embodiment, the current source may include current monitor coupled to the resistor and configured to provide the current feedback.

[0009] In another related embodiment, the voltage feedback circuit may include a voltage divider coupled to the DC voltage output. In yet another related embodiment, the light source may include a plurality of series connected light emitting diodes. In still another related embodiment, the circuit may further include a drive circuit to open and close the switch at a predetermined frequency. In a further related embodiment, the predetermined frequency may be about 40MHz.

[0010] In another embodiment, there is provided an optical sensor system. The optical sensor system includes a controller; a light source circuit coupled to the controller to drive a light source in response to control signals from the controller, the light source circuit comprising: a power supply to provide a regulated direct current (DC) voltage output; a voltage feedback circuit to provide a voltage feedback representative of the DC voltage output on a feedback path to the power supply; a current source coupled to the power supply to receive the regulated DC voltage output and to provide a current output to the light source, the current source being configured to provide a current feedback representative of the current output on the feedback path to the power supply; and a switch, whereby the current source is configured to provide the current output to the light source and the power supply is configured to adjust the DC voltage output in response to the current feedback when the switch is closed and the power supply is configured to adjust the DC voltage output in response to the voltage feedback when the switch is open; transmission optics to direct light from the light source toward an object; receiver optics to receive light reflected from the object; and detector circuits to convert the reflected light to one or more electrical signals, the controller being configured to provide a data signal output representative of a distance to at least one point on the object in response to the one or more electrical signals.

[0011] In a related embodiment, the current source may include an inductor connected in series with a resistor; and a diode coupled in parallel with the inductor and resistor; and wherein the current source is configured to provide the current output through the inductor to the light source when the switch is closed and divert current through the inductor to the diode when the switch is open. In a further related embodiment, the current source may include a current monitor coupled to the resistor and configured to provide the current feedback.

[0012] In another related embodiment, the voltage feedback circuit may include a voltage divider coupled to the DC voltage output. In yet another related embodiment, the light source may include a plurality of series connected light emitting diodes. In still yet another related embodiment, the system may further include a drive circuit to open and close the switch at a predetermined frequency. In a further related embodiment, the predetermined frequency may be about 40MHz.

[0013] In another embodiment, there is provided a method of providing current to a light source under the control of a switch in an optical sensor system. The method includes providing the current through a current source to the light source when the switch is closed; adjusting a DC input voltage to the current source in response to a current feedback signal provided on a feedback path when the switch is closed, the current feedback signal being representative of current provided to the light source; and adjusting the DC input voltage to the current source in response to a voltage feedback signal provided on the feedback path when the switch is open, the voltage feedback signal being representative of the DC input voltage.

[0014] In a related embodiment, providing may include providing the current through a current source to the light source when the switch is closed, wherein the current source comprises an inductor connected in series with a resistor, a diode coupled in parallel with the inductor and resistor, and a current monitor coupled to the resistor and configured to provide the current feedback signal. In another related embodiment, the method may further include opening and closing the switch at a predetermined frequency. In a further related embodiment, opening and closing may include opening and closing the switch at a predetermined frequency that is about 40MHz.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The foregoing and other objects, features and advantages disclosed herein will be apparent from the following description of particular embodiments disclosed herein, as illustrated in the accompanying drawings in which like reference characters refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed upon illustrating the principles disclosed herein.

[0016] FIG. 1 is a block diagram of an optical sensor system according to embodiments described herein.

[0017] FIG. 2 is a block diagram of optical sensor system light source circuits according to embodiments described herein.

[0018] FIG. 3 is a block diagram of optical sensor system light source circuits including a dual voltage and current control feedback loop according to embodiments described herein.

[0019] FIG. 4 is a block diagram of optical sensor system light source circuits including a dual voltage and current control feedback loop to drive a light source including a plurality of series connected LEDs according to embodiments described herein.

DETAILED DESCRIPTION

[0020] FIG. 1 is a simplified block diagram of an optical sensor system 100 according to embodiments disclosed herein. In general, the optical sensor system 100 emits light 102, e.g. infrared (IR) light, that is reflected by an object 104, and receives the reflected light 106 to identify the distance to the object 104 and/or to map an image of the object 104. In some embodiments, for example, the system may be implemented as a collision avoidance sensor, e.g. a back-up sensor, for an automotive vehicle. In a back-up sensor application, for example, the system provides a data output 108 indicating distance from the rear of the vehicle to an object 104 for assisting a driver of the vehicle in avoiding inadvertent contact with the object 104 when moving in reverse. Although systems and methods consistent with the present disclosure may be described in connection with a particular application, those of ordinary skill in the art will recognize that a wide variety of applications are possible. For example, systems and methods consistent with the present disclosure may be implemented in optical sensors for range finding applications, or any application involving identification and/or imaging of a target object.

[0021] Those of ordinary skilled in the art will recognize that the optical sensor system 100 has been depicted in highly simplified form for ease of explanation. The optical sensor system 100 shown in FIG. 1 includes controller/processing circuits 110, light source circuits 112, transmission optics 114, receiver optics 116 and detector circuits 118. The controller/processing circuits 110 may be known circuits for controlling modulation of a light source of the light source circuits and for processing received data to generate an output data stream representative of the distance from the sensor to the object and/or an electronic image of the object. Controller/processing circuits 110 may, for example, be any of the depth sensor controller/processing circuits commercially available from Canesta, Inc. of Sunnyvale, CA.

[0022] The light source circuits 112 may include known circuitry for driving the light source in response to control outputs from the controller/processing circuits 110, and may include circuitry consistent with the present disclosure. The transmission optics 114 may include known optical components for directing light output from the light source to provide a system field of view encompassing the object(s) of interest. The receiver optics 116 may include known optical components for receiving light reflected from the object of interest and directing the received light to the detector circuits 118. The detector circuits 118 may include known light detectors, e.g. arranged in an array of pixels, for converting the received light into electrical signals provided to the control/processing circuits 110. The detector circuits 118 may, for example, be any of the detector circuits commercially available from Canesta, Inc. of Sunnyvale, CA. The control processing circuits 110 may calculate distance to various points on the object and within the system field of view, e.g. using phase shift in the received light to calculate time of flight and distance, to provide the data output indicating distance to the object and/or mapping the object to provide a three-dimensional image thereof.

[0023] FIG. 2 is a simplified block diagram of the light source circuits 112 according to embodiments described herein. The light source circuits 112 include a power supply 202, a current source 204 coupled to the output of the power supply 202, one or more light sources 206 coupled to the current source 204, an optional high voltage supply 208 coupled to the current source 204, and driver circuits 210 for controlling switches S1 and S2 to turn the one or more light sources 206 off and on at a predetermined frequency, i.e. modulate the one or more light sources 206. The term “coupled" as used herein refers to any connection, coupling, link or the like by which signals carried by one system element are imparted to the "coupled" element. Such “coupled" devices, or signals and devices, are not necessarily directly connected to one another and may be separated by intermediate components or devices that may manipulate or modify such signals. The driver circuits 210 may take one of any known configuration or configuration described herein.

[0024] The power supply 202 may take any known configuration for receiving an input voltage from an input voltage source 212 and providing a regulated direct current (DC) voltage output. The input voltage source 212 may be, for example as shown in FIG. 2, a DC source, e.g. a vehicle battery, and the power supply 202 may be, for example as shown in FIG. 2, a known DC-DC converter for converting the DC source voltage to a regulated DC voltage at the output of the power supply 202. Known DC-DC converters include, for example, buck converters, boost converters, single ended primary inductor converter (SEPIC), etc. In some embodiments, a SEPIC converter may be used to allow a regulated DC output voltage that is greater than, less than, or equal to the input voltage. SEPIC converter and SEPIC converter controller configurations are well-known to those of ordinary skill in the art. One SEPIC converter controller useful in connection a system consistent with the present disclosure is commercially available from Linear Technology Corporation, as model number LTC1871®. Although FIG. 2 shows a DC source voltage, those of ordinary skill in the art will recognize that an alternating current (AC) input may be used, and the power supply 202 may then include a known AC-DC converter for providing a regulated DC output voltage.

[0025] The current source 204 may provide a constant current to the one or more light sources 206 for energizing the one or more light sources 206 when the switch S1 is closed by the driver circuits 210. The switch S1 is illustrated in diagrammatic form for ease of explanation, but may take the form of any of a variety of configurations known to those of ordinary skill in the art. For example, the switch S1 may be a transistor configuration that conducts current under the control of the driver circuit output.

[0026] The driver circuits 210 may be configured to open and close the switch S1 at a predetermined frequency under the control of control signals 214 from the controller/processing circuits 110. In some embodiments, for example, the driver circuits 210 may open and close the switch S1 at a frequency of about 40MHz. The current source 204 may thus provide a driving current to the one or more light sources 206 at the predetermined frequency for modulating the one or more light sources 206, i.e. turning the one or more light sources 206 on and off.

[0027] The optional high voltage supply 208 may be coupled to the one or more light sources 206 through the switch S2. The switch S2 may be closed by the driver circuits 210 under the control of control signals from the controller/processing circuits 110 during the start of the "on" time for the one or more light sources 206. The optional high voltage supply 208 may thus increase the voltage across the one or more light sources 206 to a voltage higher than can be established by the current source 204 to decrease the rise time of the current through the one or more light sources 206. After the start of the "on" time for the one or more light sources 206, the switch S2 may open to disconnect the optional high voltage supply 208 from the one or more light sources 206, and the current source 204 may drive the one or more light sources 206 through the rest of the "on" time.

[0028] The switch S2 is illustrated in diagrammatic form for ease of explanation, but may take the any of a variety of configurations known to those of ordinary skill in the art. For example, the switch S2 may be a transistor configuration that conducts current under the control of an output of the driver circuits 210. In addition, the switch S2 may be incorporated into the optional high voltage supply 208 or be separate therefrom.

[0029] According to embodiments described herein, the current source 204 may provide current feedback V_C to the power supply 202. The current feedback V_C is representative of the current provided by the current source 204 to the one or more light sources 206 when the switch S1 is closed by the driver circuits 210. In addition, a voltage feedback circuit may provide a voltage feedback V_F to the power supply representative of the regulated output voltage Vs of the power supply 202. A variety of voltage feedback circuit configurations will be known to those of ordinary skill in the art. In FIG. 3, the voltage feedback circuit is a voltage divider between a voltage V_s and ground established by series connection of a resistor R2 and a resistor R3. The values of the resistor R2 and the resistor R3 may be selected in a known manner to scale the voltage feedback V_F to a range that meets the requirements of the power supply 202. It is to be understood, however, that any voltage feedback circuit known to those of ordinary skill in the art may be implemented.

[0030] The voltage feedback V_F and current feedback V_C may be coupled to power supply 202 on a feedback path 216, which in some embodiments is the same feedback path and in other embodiments may be a different feedback path. In this configuration, the power supply 202 may be configured to adjust its output voltage V_s (also referred to throughout as supply voltage V_s) in response to the higher of the current feedback V_C and the voltage feedback V_F. For example, when the switch S1 is closed, the current feedback V_C may be greater than the voltage feedback V_F and the power supply 202 may be configured to adjust the supply voltage V_s in response to the current feedback V_C to a voltage that will maintain a constant current from the current source to the light source(s). When the switch S1 is open, the voltage feedback V_F may be greater than current feedback V_C and the power supply 202 may be configured to adjust the supply voltage V_s in response to the voltage feedback V_F to maintain a constant supply voltage V_s.

[0031] A variety of configurations for providing an adjustable supply voltage in response to the feedback on the feedback path 216 are well-known to those of ordinary skill the art. In one embodiment, the power supply 202 may be configured as a known converter, e.g. a SEPIC converter, and a known converter controller, e.g. a SEPIC controller configured to control the converter voltage output in response to the feedback. For example, the voltage feedback V_F and the current feedback V_C may be coupled on the feedback path 216 to the F_B input of an LTC1871® SEPIC converter controller available from Linear Technology Corporation (not shown), which is configured to regulate the output voltage of a SEPIC converter based on an internal reference.

[0032] FIG. 3 illustrates a block diagram of optical sensor system light source circuits including a dual voltage and current control loop according to embodiments described herein. In FIG. 3, the current source 204a includes a resistor R1 in series with an inductor L1, and a diode D1 coupled in parallel across the series combination of the resistor R1 and the inductor L1.

[0033] As shown, the regulated DC output V_s of the power supply 202 may be coupled to the input of the current source 204a at the resistor R1. The driver circuits 210 may open and close the switch S1 at a high frequency, e.g. 40MHz. When the switch S1 is closed, a current I_s flows through the series combination of the resistor R1 and the inductor L1 and to the one or more light sources 206 for energizing the one or more light sources 206. The inductor L1 thus establishes a constant current source and limits the current I_s through the one or more light sources 206 when the switch S1 is closed. When the switch S1 is open, however, no current flows through the one or more light sources 206, and a current I_L through the inductor L1 is diverted through the diode D1 to maintain current through the inductor L1.

[0034] As shown, a current monitor 304 may be coupled across the resistor R1 for sensing the voltage drop across the resistor R1 and providing the current feedback voltage output V_C representative of the current through the resistor R1. The current monitor 304 may take any configuration known to those of ordinary skill in the art. In some embodiments, for example, the current monitor 304 may be configured using a current shunt monitor available from Texas Instruments® under model number INA138. The current monitor 304 may provide the current feedback output voltage V_C to the power supply 202, e.g. through the diode D2. In some embodiments, the diode D2 may be provided in a known ideal diode configuration to minimize the voltage drop across the diode.

[0035] The current feedback V_C and voltage feedback V_F may be coupled to the power supply 202 on the common path 216. In response to the feedback from the current monitor 304 and during the time when the switch S1 is closed, the current feedback V_C may be greater than the voltage feedback V_F. The diode D2 may then conduct and the power supply 202 may be configured to adjust the supply voltage V_s in response to the current feedback V_C to a voltage that will allow the inductor L1 to recharge. When the switch S1 is open, the voltage feedback V_F may be greater than the current feedback V_C and the diode D2 may be in a non-conducting state. The power supply 202 may then adjust the supply voltage V_s in response to the voltage feedback V_F to maintain a constant supply voltage V_s.

[0036] A constant current may thus be established through the inductor L1 when the switch S1 is closed, i.e. when the one or more light sources is/are "on" and emitting light. As shown in FIG. 4, a current source 204a consistent with the present disclosure may be implemented in a system wherein a light source 206a includes a plurality of infrared light-emitting diodes (LEDs) D3, D4, D5, and D6 connected in series. Although, as shown in FIG. 4, there are four series connected LEDs D3, D4, D5, and D6, it is to be understood that any number of LEDs may be connected in series to provide a light source consistent with the present disclosure. As shown in FIG. 4, driving current from the current source 204a is provided to the plurality of infrared LEDs D3, D5, D5, and D6 through a diode D7, and diodes D8, D9, D10, D11 are coupled across the plurality of infrared LEDs D3, D4, D5, and D6, respectively, to take up any back voltage across the series connected plurality of infrared LEDs D3, D4, D5, and D6. The current source 204a may thus provide constant current through the series connected plurality of infrared LEDs D3, D4, D5, and D6 to allow switching/modulation of the LED output at relatively high frequency, e.g. 40MHz. Connecting the plurality of infrared LEDs D3, D4, D5, and D6 in series avoids phase differences between LED outputs and provides cost efficiency.

[0037] Unless otherwise stated, use of the word "substantially" may be construed to include a precise relationship, condition, arrangement, orientation, and/or other characteristic, and deviations thereof as understood by one of ordinary skill in the art, to the extent that such deviations do not materially affect the disclosed methods and systems.

[0038] Throughout the entirety of the present disclosure, use of the articles "a" or "an" to modify a noun may be understood to be used for convenience and to include one, or more than one, of the modified noun, unless otherwise specifically stated.

[0039] Elements, components, modules, and/or parts thereof that are described and/or otherwise portrayed through the figures to communicate with, be associated with, and/or be based on, something else, may be understood to so communicate, be associated with, and or be based on in a direct and/or indirect manner, unless otherwise stipulated herein.

[0040] Although the methods and systems have been described relative to a specific embodiment thereof, they are not so limited. Obviously many modifications and variations may become apparent in light of the above teachings. Many additional changes in the details, materials, and arrangement of parts, herein described and illustrated, may be made by those skilled in the art.

What is claimed is:

1. A light source circuit for an optical sensor system, the circuit comprising:

a power supply to provide a regulated direct current (DC) voltage output;

a voltage feedback circuit to provide a voltage feedback representative of the DC voltage output on a feedback path to the power supply;

a current source coupled to the power supply to receive the regulated DC voltage output and to provide a current output to a light source, the current source being configured to provide a current feedback representative of the current output on the feedback path to the power supply; and

a switch, whereby the current source is configured to provide the current output to the light source and the power supply is configured to adjust the DC voltage output in response to the current feedback when the switch is closed and the power supply is configured to adjust the DC voltage output in response to the voltage feedback when the switch is open.

2. The light source circuit according to claim 1, wherein the current source comprises:

an inductor connected in series with a resistor; and

a diode coupled in parallel with the inductor and resistor;

and wherein the current source is configured to provide the current output through the inductor to the light source when the switch is closed and to divert current through the inductor to the diode when the switch is open.

3. The light source circuit according to claim 2, wherein the current source comprises a current monitor coupled to the resistor and configured to provide the current feedback.

4. The light source circuit according to claim 1, wherein the voltage feedback circuit comprises a voltage divider coupled to the DC voltage output.

5. The light source circuit according to claim 1, wherein the light source comprises a plurality of series connected light emitting diodes.

6. The light source circuit according to claim 1, further comprising a drive circuit to open and close the switch at a predetermined frequency.

7. The light source circuit according to claim 6, wherein the predetermined frequency is about 40MHz.

8. An optical sensor system comprising:

a controller;

a light source circuit coupled to the controller to drive a light source in response to control signals from the controller, the light source circuit comprising:

a power supply to provide a regulated direct current (DC) voltage output;

a voltage feedback circuit to provide a voltage feedback representative of the DC voltage output on a feedback path to the power supply,

a current source coupled to the power supply to receive the regulated DC voltage output and to provide a current output to the light source, the current source being configured to provide a current feedback representative of the current output on the feedback path to the power supply, and

a switch, whereby the current source is configured to provide the current output to the light source and the power supply is configured to adjust the DC voltage output in response to the current feedback when the switch is closed and the power supply is configured to adjust the DC voltage output in response to the voltage feedback when the switch is open;

transmission optics to direct light from the light source toward an object;

receiver optics to receive light reflected from the object; and

detector circuits to convert the reflected light to one or more electrical signals, the controller being configured to provide a data signal output representative of a distance to at least one point on the object in response to the one or more electrical signals.

9. The optical sensor system according to claim 8, wherein the current source comprises:

an inductor connected in series with a resistor; and

a diode coupled in parallel with the inductor and resistor;

and wherein the current source is configured to provide the current output through the inductor to the light source when the switch is closed and divert current through the inductor to the diode when the switch is open.

10. The optical sensor system according to claim 9, wherein the current source comprises a current monitor coupled to the resistor and configured to provide the current feedback.

11. The optical sensor system according to claim 8, wherein the voltage feedback circuit comprises a voltage divider coupled to the DC voltage output.

12. The optical sensor system according to claim 8, wherein the light source comprises a plurality of series connected light emitting diodes.

13. The optical sensor system according to claim 8, further comprising a drive circuit to open and close the switch at a predetermined frequency.

14. The optical sensor system according to claim 13, wherein the predetermined frequency is about 40MHz.

15. A method of providing current to a light source under the control of a switch in an optical sensor system, the method comprising:

providing the current through a current source to the light source when the switch is closed;

adjusting a DC input voltage to the current source in response to a current feedback signal provided on a feedback path when the switch is closed, the current feedback signal being representative of current provided to the light source; and

adjusting the DC input voltage to the current source in response to a voltage feedback signal provided on the feedback path when the switch is open, the voltage feedback signal being representative of the DC input voltage.

16. The method according to claim 15, wherein providing comprises:

providing the current through a current source to the light source when the switch is closed, wherein the current source comprises an inductor connected in series with a resistor, a diode coupled in parallel with the inductor and resistor, and a current monitor coupled to the resistor and configured to provide the current feedback signal.

17. The method according to claim 15, further comprising opening and closing the switch at a predetermined frequency.

18. The method according to claim 17, wherein opening and closing comprises opening and closing the switch at a predetermined frequency that is about 40MHz.

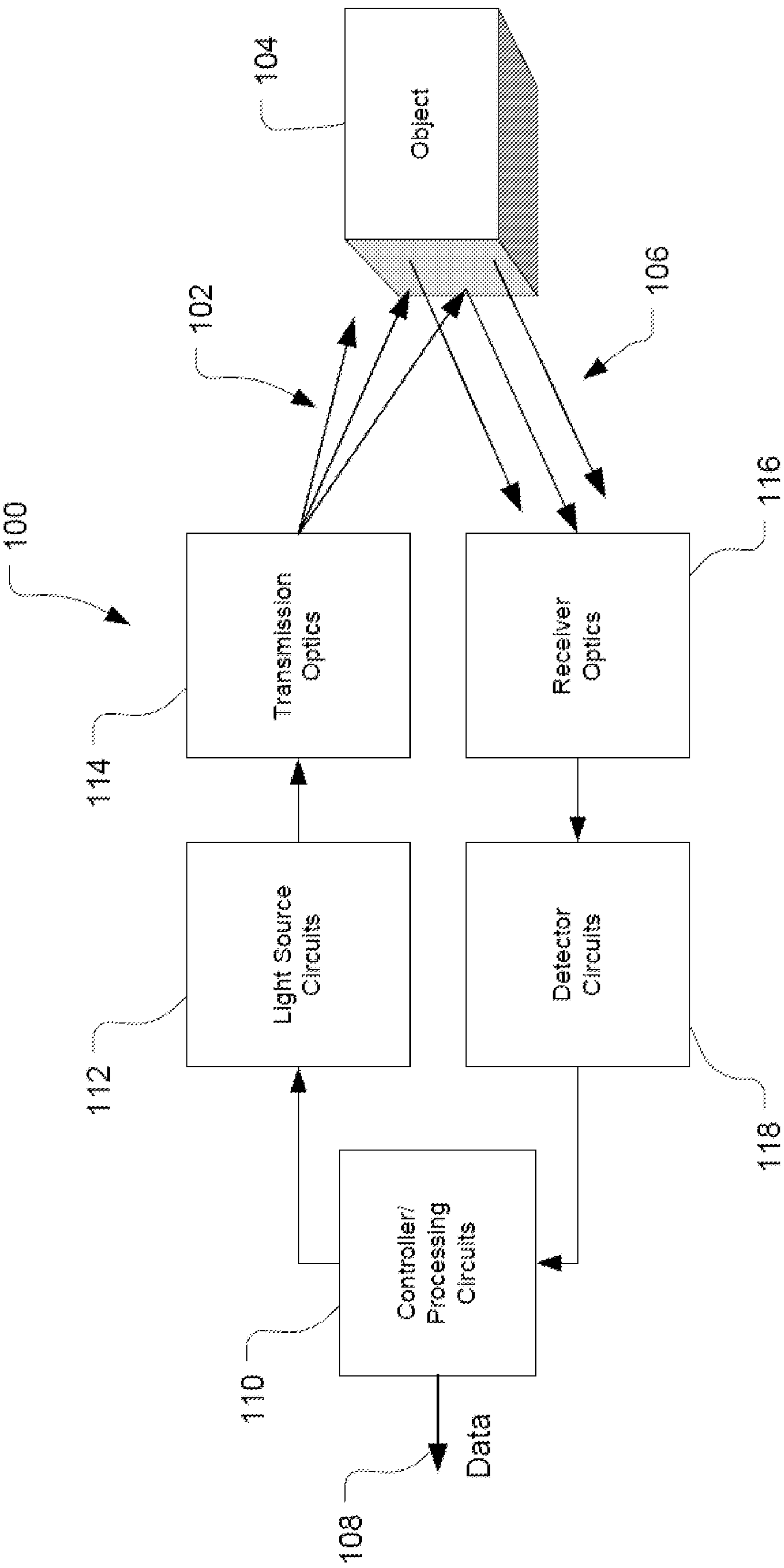
Object
104
102
106
100
Transmission Optics
114
Receiver Optics
116
Light Source Circuits
112
Detector Circuits
118
Controller/ Processing Circuits
110
Data
108

FIG. 1

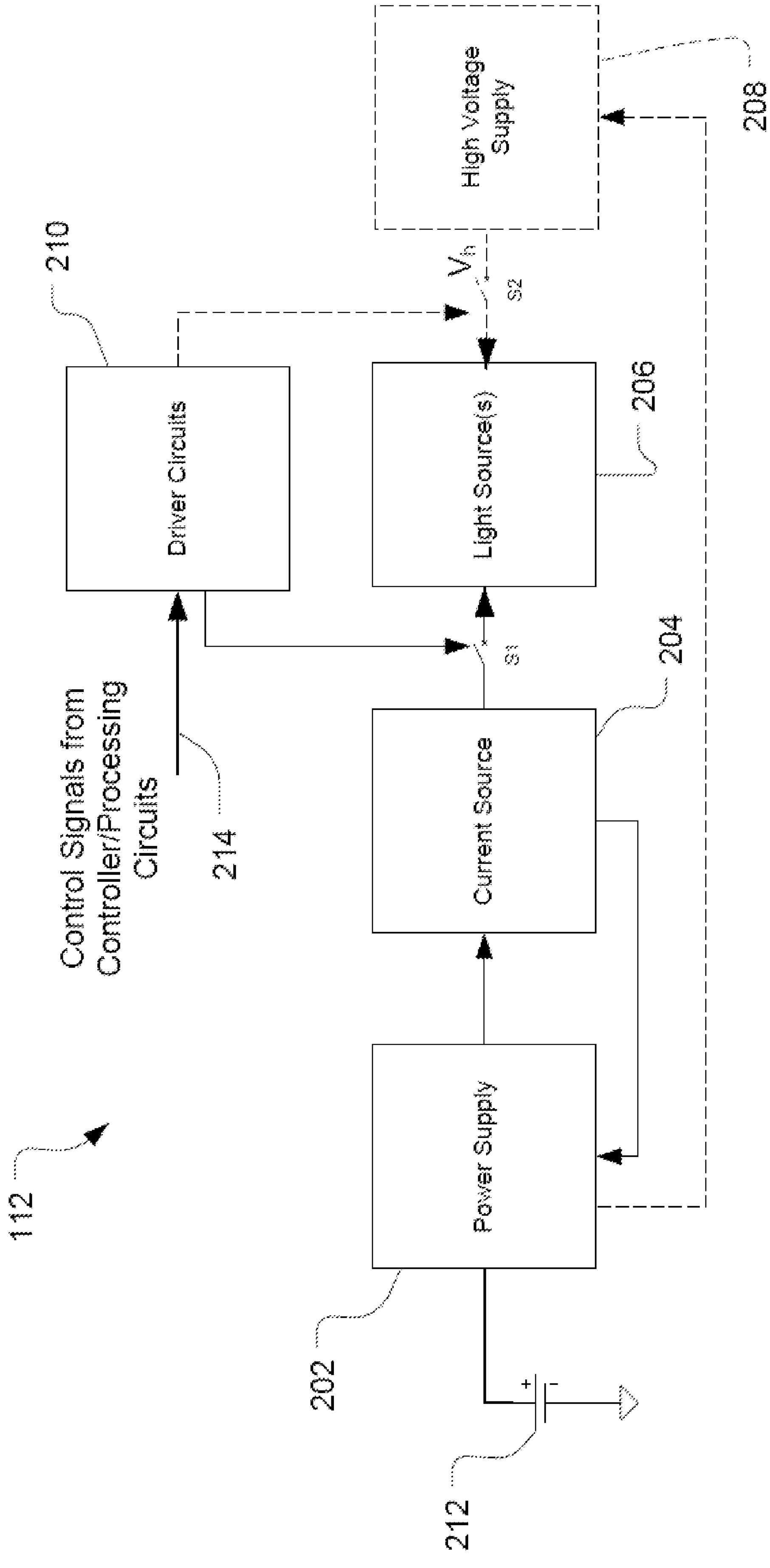
112
Control Signals from
Controller/Processing
Circuits
214
210
Driver Circuits
High Voltage
Supply
208
Vh
S2
Light Source(s)
206
S1
Current Source
204
Power Supply
202
212

FIG. 2

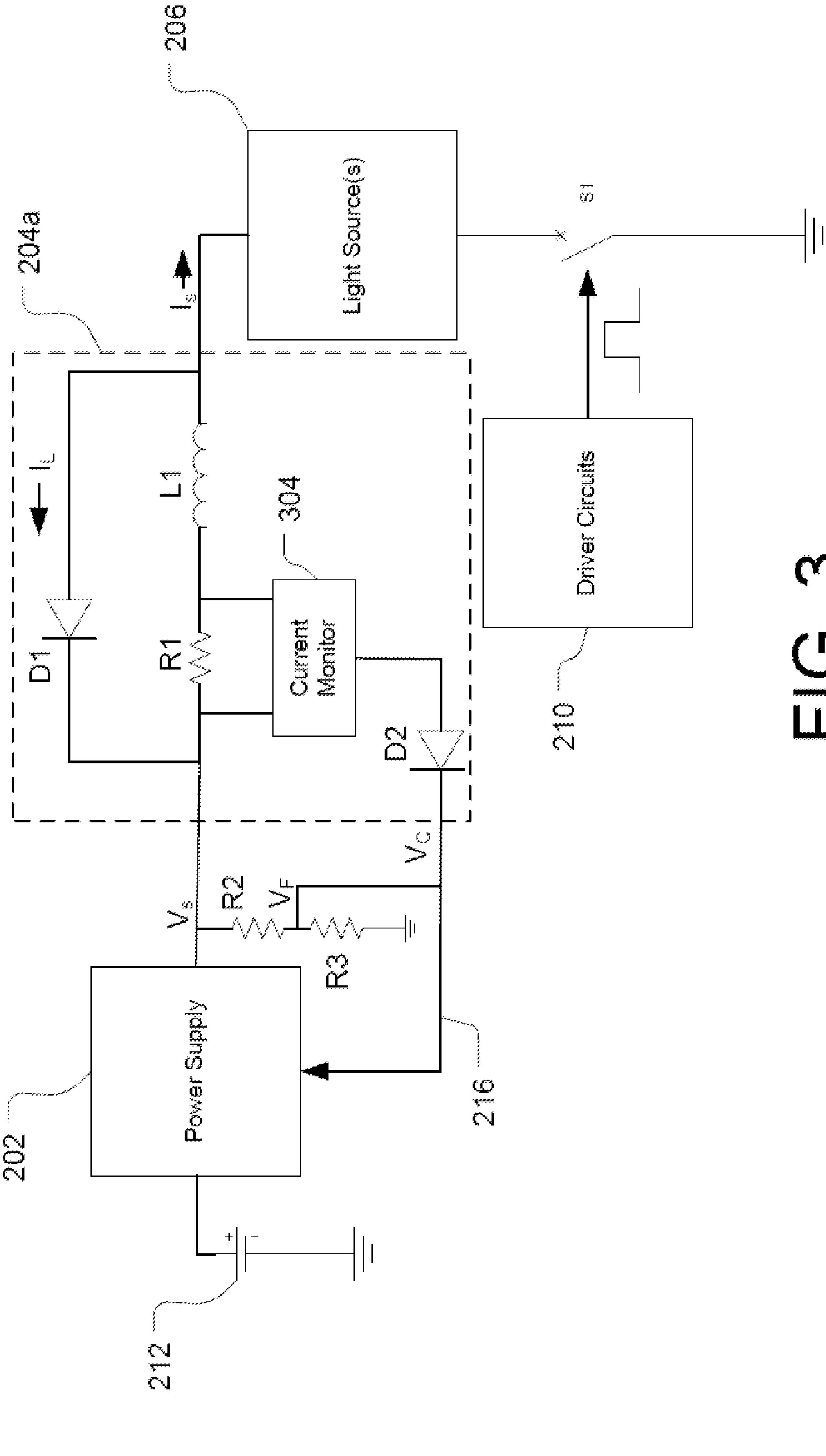
206
204a
Light Source(s)
S1
I_s
I_L
L1
304
D1
R1
Current Monitor
D2
Driver Circuits
210
V_C
V_s
R2
V_F
R3
Power Supply
202
216
212

FIG. 3

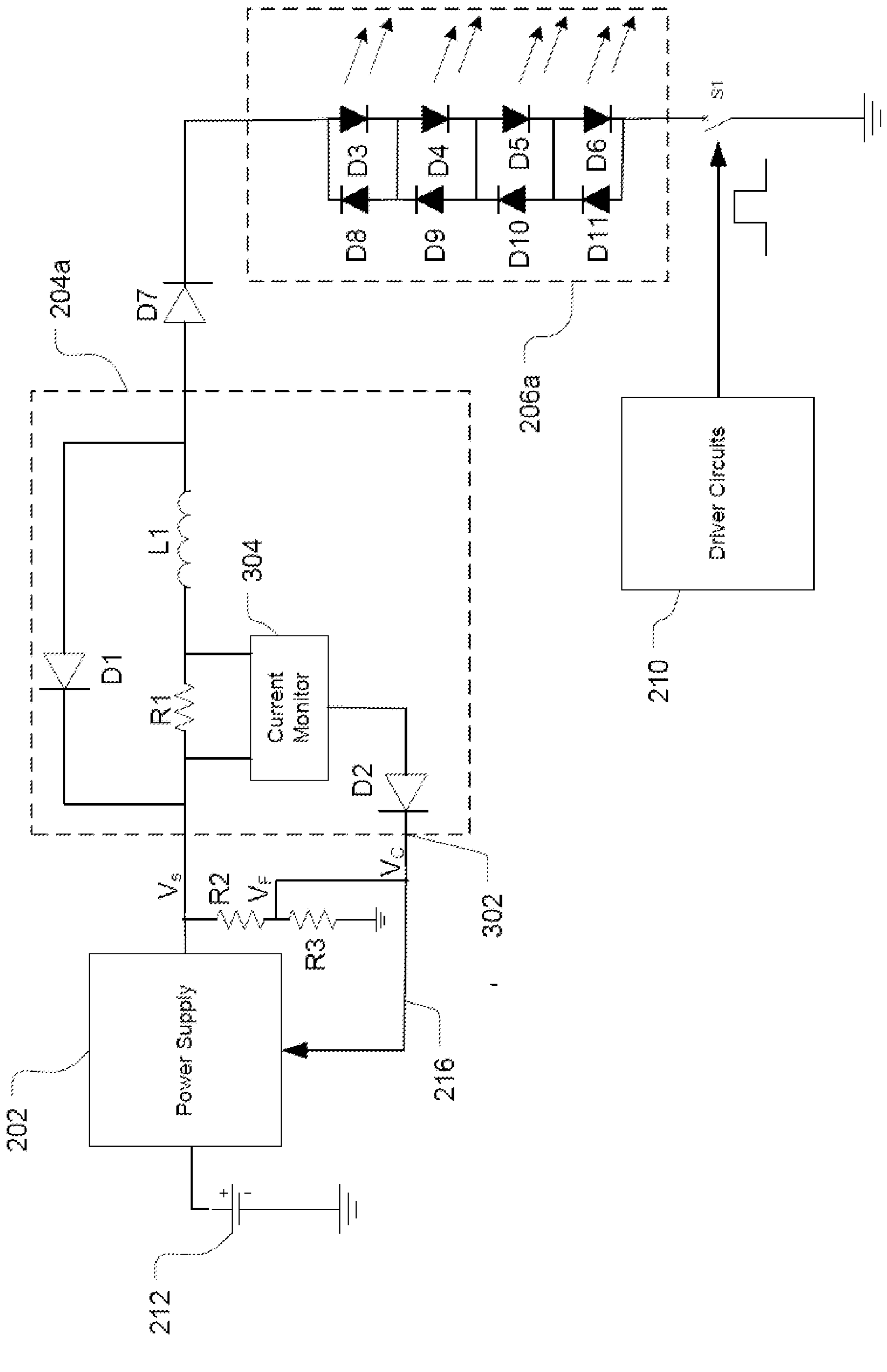
204a
D7
D3
D4
D5
D6
D8
D9
D10
D11
S1
206a
Driver Circuits
210
D1
L1
304
R1
Current Monitor
D2
Vs
R2
VF
VC
R3
302
Power Supply
202
216
212

FIG. 4