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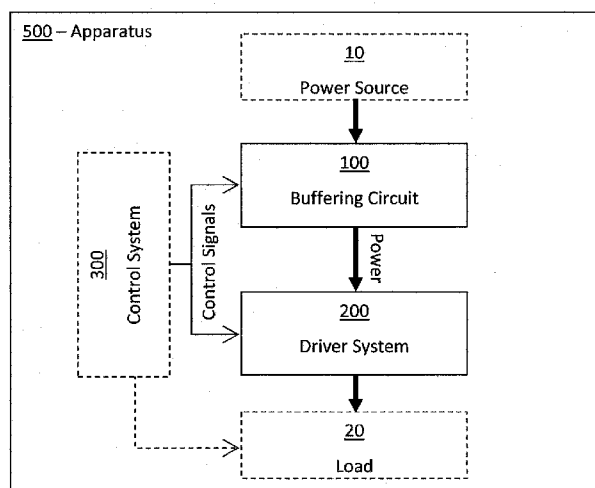


Fig. 1A

(57) **Abstract:** A light source system including a driver system and a light emitter (such as one or more laser diodes) connectable at the output of the driver system. The driver system includes: an energy limiter adapted for limiting the energy supply to the light emitter. The energy limiter includes: a current integrator circuitry adapted to measure and integrate a current supplied to the light emitter over time; and a comparator comparing the integrated value of the current with a reference signal for generating a *maximal energy exceeded* switching signal, in case a the energy supplied to the light source exceeded a predetermined threshold. The light source system may also include a buffering electric circuit connectable at a power input of the driver system for providing electrical power thereto. The buffering electric circuit includes an energy storage module electrically connected for supplying electric energy to the light emitter; and a controllable current source connectable to an electric power source and to the energy storage module. A control-ler controls the current flow through said controllable current source so as enable proper operation of said light source while restrict-ing the current drawn from the power source from exceeding a predetermined value.

LASER DRIVER SYSTEM AND METHOD

5 TECHNOLOGICAL FIELD

The present invention is in the field of electric driving circuits, and particularly relates to circuits for driving a load, such a laser system, in mobile devices.

BACKGROUND

Lasers and light emitting diodes (LEDs) are used in various applications to
10 illuminate the surrounding environment with spatial and/or temporal light patterns. For example, in various applications known as structured light patterns for 3D, the laser light is used to project the environment with a pattern which may then be captured (photographed) superposed on the environments and processed to determine the 3 dimensional structure of the surrounding environments. Other common applications,
15 utilize such laser light source for illumination of the environment and/or as pointer aids as well as in various other applications.

It is often required that the laser light source will have high optic power density substantially higher than that of ambient light so that the light from the laser light source will overcome the ambient light. In this regards, in many cases use of class I eye safe
20 laser system is required or preferred. The laser light source may be a continuous wave (CW) laser, and/or quasi CW laser operated in pulse mode, providing emission of light density higher compared to the ambient.

In various jurisdictions various Eye safety regulations for laser systems may apply. For example, in the U.S., the Federal Food, Drug and Cosmetic Act (FFDCA)
25 provide regulations that apply to manufacturers of laser products (see in particular Chapter V, Subchapter C - Electronic Product Radiation Control). This is also summarized in HHS Publication FDA 86-8260, and Section 1040.10 of FDA part 21- Laser products by the Food and Drug Administration (FDA). Also standards/regulations for laser safety are also defined in the ANSI Laser Safety Standard (ANSI Z136.1) and

- 2 -

the European standard IEC 60825. Under these regulations, as well as in the following description, the following definitions apply:

- A laser is a device capable of producing or amplifying electromagnetic radiation in the wavelength range from 180 to 1×10^6 nanometers by the process of controlled stimulated emission.
- A laser system consists of a laser in conjunction with its power supply.
- A laser product is any device that constitutes, incorporates, or is intended to incorporate a laser or laser system.

Typically, manufacturers of laser products are required to design and manufacture their products to be in compliance with the laser standard associated with the laser safety regulations, and should certify compliance of their products. In the U.S. for example, the laser standard establishes the following laser Classes which are given as functions of wavelength and emission duration, and are indicated in units of radiant energy (joules J), integrated radiance ($\text{J} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$, which is the energy density per steradian), and radiant exposure ($\text{J} \cdot \text{cm}^{-2}$ which is relates to the energy density of exposure). In some standards, such as the European standard, the average power [W] and power density as [$\text{W} \cdot \text{cm}^{-2}$] are limited.

Class I limits apply to devices that have emissions in the ultraviolet, visible, and infrared spectra, and are limits below which biological hazards have not been established (in the visible and near infra-red spectra there are separate Class I limits for quasi continuous wave (QCW) laser that works in pulse train mode the limitations are for : max average power [W/cm^{-2}] ,max single pulse Energy [$\text{J} \cdot \text{cm}^{-2}$] and max pulse Energy [$\text{J} \cdot \text{cm}^{-2}$] which is calculated for pulse train.

Class IIa limits apply to products whose visible emission does not exceed Class I limits for emission durations of 1000 seconds or less and are not intended for viewing (an example of a Class IIa laser product might be a supermarket scanner); Classes: II, IIIa, IIIb, and IV are considered a hazard (for example, class II lasers are considered a hazard for direct long-term ocular exposure, and class IV lasers are a hazard for scattered (diffuse) reflection as well as for direct exposure). Thus, Class I lasers are generally considered safe. The class notations: I, II, IIIa, IIIb and IV were replaced by numeric numbers 1-4 in newer standards such as the ICE 60825-1.

In various dedicated and/or general purpose laser produces, it is desired/required to incorporate safe laser systems (e.g. preferably class I (1) lasers). The drivers of such

- 3 -

lasers, are required to include safety modules (e.g. circuits), limiting the radiant energy (power) and the integrated radiance (radiance)) outputted from the laser. More particularly, various laser standard regulations, require that the Acceptable Emission Limits AELs) will not be exceeded due to single fault in the light source driver. This
5 single fault resilience practically requires that the safety modules in the laser driver will be based on analogue circuits and/or fixed/hard wired digital logic circuits (and not regular microcontrollers/software based modules for which single fault may result in harmful emissions). Indeed such hardwired logic devices (e.g. analogue and/or fixed digital gate circuits are considered more reliable and less prone to failure than software
10 based microcontrollers (the mean time between failures (MTBF) of a software based micro controller is generally lower than a logic or analog component).

In view of the above, controlling, adjusting and/or verifying, safe operation of laser devices (e.g. in accordance with certain desired safety class/regulation) typically require monitoring some operational parameters of the laser, such as the laser power
15 (i.e. its radiant energy), and/or the laser's integrated radiance, and/or its radiant exposure. In some laser systems, the laser driver, providing the input power to the laser also incorporates safety modules are configured and operable for monitoring certain of the laser's operational parameters. In some cases, in order to meet the appropriate safety regulations, such safety modules are configured as analogue devices and logic and/or at
20 least partially analogue-logic devices, which safety measures are not reliant on digital processing.

For example, U.S. patent No. 7,065,106 discloses a transmitter optical subassembly includes an optical emitter and a fiber receptacle within which an optical fiber is received. An optical limiting element is positioned between the optical emitter
25 and the fiber receptacle. When an optical signal is emitted from the optical emitter, the optical signal passes through the optical limiting element before the optical signal reaches the fiber receptacle and is received by the optical fiber. The optical limiting element has a property such that if the power of the optical signal entering the optical limiting element exceeds a predetermined limit, the power of the optical signal is
30 optically attenuated so that the power of the optical signal exiting the optical limiting element remains below a predetermined limit.

U.S. patent No. 6,661,820 discloses a system and method for controlling the operating parameters of a laser diode. The laser control system automatically optimizes

- 4 -

the laser diode operating characteristics while maintaining a safe peak power for pulse duration and pulse repetition frequency. The controlled level of output power is based on the laser diode gain determined during calibration of each laser diode projector as well as using the application of predetermined laser safety formulas. The laser control
5 system includes a laser diode that is powered by a laser drive current. The laser diode has a laser output having a peak power level. A detector is coupled to the laser diode for sensing the laser output. A laser driver including a primary control loop is operable, in response to the sensed laser output and a reference, to control the laser drive current such that the output power corresponds to the reference. A controller is coupled to the
10 laser driver. The controller includes a laser settings module for generating the reference in response to a laser output setting such that the laser output characteristic level is approximately a predetermined output level. The output characteristic of the laser diode is maintained within the predetermined standard. Another aspect of the invention provides an independent safety monitoring function based on the laser settings.

15 U.S. patent No. 6,252,893 discloses at least one monitor laser having an associated monitor diode. The monitor diode is connected to an electronic circuit that controls the monitor laser, while correspondingly driving the semiconductor lasers in parallel, in such a way that an electrical signal from the monitor diode constantly has a preset value. This value and a nominal signal corresponding to the nominal value of the
20 optical power of the monitor laser are used to form a correction variable. If a current flowing through a semiconductor laser exceeds the current through the monitor laser, weighted by the correction variable, then the power of the semiconductor laser is reduced. In this manner, the transmitting device is of simple construction and at the same time avoids unacceptably high powers in the semiconductor lasers.

25 International Patent application publication No. WO13/147753 discloses laser safety techniques and configurations. In one embodiment, an optical module includes a first die including a laser configured to transmit optical signals, a first node electrically coupled with the laser, and a second node electrically coupled with the laser, and a
30 second die including a power supply line configured to provide power to the laser, a third node electrically coupled with the power supply line and electrically coupled with the first node to provide the power to the laser, a fourth node electrically coupled with the second node of the first die, and a switch configured to prevent the power of the power supply line from reaching the laser through the third node based on a voltage of

- 5 -

the fourth node when a laser fault event occurs. Other embodiments may be described and/or claimed.

Mobile systems/products, such as mobile phones, tablets and laptops, are typically limited in the available real-estate/area for accommodating laser systems. Accordingly, laser(s) incorporated in such mobile products, should be fitted within a very limited space. To this end, laser drivers (driving circuit(s)) for such systems should preferably be configured with as small form factor as possible, while also provide the desired power management & control functionality, as well as verifying/regulating the safe operation of the laser in accordance with the desired safety class/standard.

As indicated above, some laser applications used in such mobile systems, require that the laser light source will have high optic power density. However, in many cases the mobile system which incorporate and/or which is connectable to the laser system (e.g. through external port such as USB port), has a limited power supply, or has limited output power, which it can provide to the laser system.

There are 3 types of power sources currently used in mobile devices: batteries, USB ports & DC power supplies. The stored energy of a battery is dependent on several factors, one of which is the output current. High-current battery discharge reduces the overall capacity of the battery, compared to a low-current discharge. When dealing with a DC power supply the cost and size of the power supply also depends on the peak output power. Lastly, USB ports have limited output power.

Yet, mobile systems which require the operation of high optical power density laser systems, or other high power consumer devices, may be required to provide high input electric power to such laser devices/ consumers. In other words the required input electric power may be in the order of the power limits of the power source of the mobile system or may exceed it.

However, applying a relatively large energy consumer device (load), on mobile system which might be operating several consumer devices instantaneously, poses a significant challenge. This may be due to one or more of the following: (i) provision of high power to loads (e.g. which may be operated in pulses) may demand large power supply; (ii) when using high power Quasi-Continuous Wave (QCW) light sources with a high efficiency driver, output power reflects itself upon the input source, thus may cause voltage/current fluctuation at the input source, which may affect/disrupt the proper operation of other power consumers connected to the input source (in cases

- 6 -

where the momentary output power is reflected onto the power input, it will cause a voltage drop for every output pulse; this can disrupt other units that use the same input power (therefore interfering with operation of co-existing operating units/devices); (iii) Consumption of large currents in bursts, from an input source that is connected to the driver with wires may cause electrical interference and Electromagnetic Interference (EMI). Another challenge is when the output power varies with time, in which case it has unpredictable current and/or width. Therefore constant current source is not an option.

GENERAL DESCRIPTION

10 The present invention according to certain broad aspects thereof provides systems and method for operating light source, such as lasers or LEDs, while meeting the safety standards associated with the operation of such light sources. As indicated above, safety standards, particularly those associated with laser light source (e.g. laser safety classes) typically impose limitations on the peak power of the laser as well as its radiance energy.

15 Certain of the conventional techniques aimed for meeting these limitations utilize hard limits separately imposed on the peak power of the laser/light source and on the time duration of its operation (e.g. implementing current limit by the use of a comparator, and pulse width limit by the use of one shot(multi vibrator with a latch)). However such techniques, are rigid in the sense that even if the laser is operated below the allowed

20 peak power, still the limit on the operation time is imposed, even though, the maximal allowed energy may not be reached at that time when the laser is operated below the maximal peak power limit. Also, other techniques, utilize external sensors to sense the emitted radiation, and use the results of such sensing to impose the safety limits on the laser operation and disrupt/stop its operation in case the safety limits are exceeded.

25 However, such techniques may be costly and cumbersome, and may require relatively large space, and may thus be less suited for use with certain systems such as mobile devices.

Yet, for certain applications/systems, such as light projection systems, flexibility in operating laser light systems, with variable output power, and pulse time

30 duration/frequency may be needed, while also maintaining/ensuring eye safe operation of the laser.

- 7 -

To this end, according to certain broad aspects of the present invention there is provided a driver system and method for operating light sources such as lasers. The driver system includes an energy limiter module being an analogue module/circuit that is adapted to obtain an analogue measure/signal indicative of the electric energy provided to the laser and accordingly, based on this measure, stop/disrupt the laser's operation in case its energy exceeds a predetermined limit. Additionally, a power limiter module, which is also implemented as an analogue module/circuit, is used to obtain an analogue measure/signal indicative of the electric power provided to the laser and thereby provide for stopping/disrupting the laser's operation incases the power exceeds a predetermined safe limit. Accordingly safe and flexible operation of the laser is facilitated by separately limiting the laser's output power and energy utilizing analogue means.

According to one broad aspect of the present invention there is provided a driver system associated with an input for receiving electrical input power and an output connectable to a load to be activated by the driver system. The driver system includes an energy limiter adapted for limiting the energy supplied to the load. The energy limiter includes: a current integrator adapted to measure a current supply to the load, integrate a value of the current over time, and generate an integration signal indicative of the integrated value of said current over time; and a comparator connectable to the current integrator for receiving the integration signal, comparing it with a reference value, and, based on the comparing, generating a *maximal energy exceeded* switching signal. The driver system may also include or be associated with a switch module connectable to the load (e.g. to an output port of the driver system) and adapted for operating a switching function for operating the load based on a *maximal energy exceeded* switching signal to accordingly enable or disable electric current to said load.

According to some embodiments of the present invention the current integrator of the driver system further includes a current measurement circuit which is adapted to measure current associated with the output port of the driver system (the current to the load) and provide, at an output of the measurement circuit, a voltage signal indicative of the measured current. The current integrator also includes an RC circuit connectable to the output of the measurement circuit such that a voltage of a capacitor of the RC circuit associated with said integration signal is indicative of the measured current integrated over time. It should be noted that alternatively or additionally other types of

- 8 -

exponentially behaving circuits may be used instead or in addition to the RC circuit for the purpose of generating signal indicative of the integrated value of the current provided to the load over time. For instance, as further described below, an RL circuit may also be used. The comparator of the energy limiter of the driver system is
5 connected to measure a voltage on an element of the exponentially behaving circuit (e.g. to measure the voltage of the capacitor of the RC circuit, for comparing that voltage of with a reference voltage functioning as a reference to the maximally allowed integrated current value (namely to the maximally allowed energy supply to the load).

It should be understood that when utilizing an RC circuit for integration the
10 current, the values of the capacitance and resistance of the RC circuit are selected such that a time constant τ of the RC circuit is longer than an operation duration (pulse duration/width) of the load. This provides that during the operation/pulse of the load the current integrator operates in the linear regime of its response function for integrating measured current which is provided to the load. In other word, the integration period
15 (the pulse duration) is shorter than the circuit time constant, and thus the circuit operates in its linear regime. It should also be noted that in certain embodiments the specific values of the capacitance C and resistance R of the RC circuit of the energy limiter are selected the max energy [J] allowed for each pulse of the load, the max allowed pulse width, the minimal current threshold of the load (e.g. the minimal threshold current of the LASER), max current which should be enabled through the resistor, amplifier
20 driving capability denotes the resistor minimal value.

According to some embodiments of the present invention the driver system also includes a power limiter adapted for limiting the peak power supply to the load. The power limiter is associated with, or includes, a current measurement circuit adapted to
25 measure current provided to the load (e.g. the current through the output port) and provide a voltage signal indicative of the measured current. The power limiter includes a second comparator connectable to the current measurement circuit and adapted for comparing the voltage signal with a reference voltage indicative a maximal allowed value of the current which was measured. Based on that comparison, a *maximal power exceeded* switching signal may be generated by the comparator (incase the measured
30 current exceeded the permitted limits indicated by the reference signal). A switch module which is connected to the power path to the load is adapted to receive the *maximal power exceeded* switching signal. The switch is adapted for operating a

- 9 -

switching function based on both the *maximal energy exceeded* and the *maximal power exceeded* switching signals obtained from the energy and power limiters to accordingly enable or disable electric current to the load. In other words the switch module is configured to disable the operation of said load when at least one of a maximal power or
5 maximal energy provision to the load is exceeded.

In certain embodiments of the present invention the power limiter includes an RC circuit interconnected in between the current measurement circuit and the second comparator. The RC circuit may be configured and operable as a low pass filter (e.g. to remove switching noises). To this end the capacitance C2 and resistance R2 of said RC
10 are selected based on desired/allowed bandwidths for operation the load. For example R and C may be selected such that the time constant $R \cdot C = \tau > 2 \cdot \text{noise frequency}$. Also R and C themselves may be selected so that the current through the resistor R won't load the amplifier, and the capacitor C can withstand the voltage. To the end, the allowed bandwidth for operation of the load may be associated with the control system operation
15 the load and/or in case the load is a light source/laser, the allowed bandwidth may be defined by eye safety protection regulations.

It should be understood that in some embodiments the power limiter and the energy limiter are connectable and utilize the same/common current measurement circuit.

20 In some embodiments of the present invention the driver system is configured for driving a light source load. For example the load may include one or more LEDs and/or one or more laser diodes. To this end, the power limiter and the energy limiter modules of the driver system are configured and operable for ensuring safe operation of the light source (e.g. to ensure eye safe operation). Accordingly the *maximal energy exceeded*
25 and the *maximal power exceeded* switching signals are associated with maximal radiant power and maximal integrated radiance laser safety measures.

In some embodiments of the present invention the load may be configured for operation in pulse mode (in operation time intervals). The energy limiter may be adapted to reset the integration signal in the time duration between the pulses of the
30 loads operation.

Thus, according to another broad aspect of the present invention there is provided a method for determining/estimating an amount of electric energy supply to a load. The method includes: measuring an electric current provided to a load to obtain a first

- 10 -

voltage signal indicative of a value of said electric current; applying the first voltage signal to an analogue current integration circuit comprising at least one electric element comprising at least one of: a capacitor and an inductor; and obtaining a second signal associated with a voltage on the at least one of electric element; wherein the second
5 signal is indicative of an amount of electric energy supply to said load.

Another issue dealt with in the present invention is the use of relatively high power consuming loads/devices in mobile/or other systems, that are associated with a power source (e.g. battery), which has lower/limited power supply capacity. As will be appreciated from the description below, connecting such high power devices to the
10 limited power source directly, may result in reflection effects (reflection of the output current onto the input current) associated with voltage drops in the power source, and also with electromagnetic interference effects which may be caused by bursts of high current consumption from the power source. These effects may disrupt the operation of other devices/modules connected to the same power source.

Certain known solutions that address these types of problems include: using a capacitor bank in order to reduce the voltage drop over the power source, using an inrush current limiter, such as Negative and Positive Temperature Coefficients resistors (NTC, PTC) or inductors, and lastly, using a combination of the above solutions together. However, there are a few drawbacks to the existing solutions: The use of a
20 capacitor bank is a space and cost demanding solution. In addition, it does not solve the reflected output current. The inrush current limiter has low efficiency for the NTC solution, and is space demanding for the inductor solution. Furthermore, the limiter does not supply constant current. It only limits the inrush current to a specific value. Lack of dynamic response: that demands specific values (NTC, Inductor) for each duty cycle of
25 the load current (light source).

To this end, according to certain broad aspects of the present invention there is provided a buffering circuit and a method for buffering electric energy to be supplied to high power consuming loads. The buffering circuit includes a controllable current source and an energy storage module electrically connected and interposed between the
30 power source and the high power consuming load. A controller is adapted to monitor the operation of the load and determine/estimate expected average power consumption of the load, and to accordingly operate the controllable current source to collect the required power from the power source and store it in the energy storage module for

- 11 -

further use by the load. The technique of the present invention provides that the power consumption from the power source is completely controlled in a manner eliminating the above mentioned reflection and electromagnetic interference effects. Also, the use of the controller predicting/estimating the future power demands of the loads allows to
5 implement the buffering circuit and particularly the energy storage module thereof with relatively low energy storage capacity, since there is no need for large power bank/capacitor bank for averaging the power consumption, as this is controlled digitally by the controller. Accordingly, the buffering circuit of the present invention may be implemented with small form factor and may be easily integrated in compact mobile
10 devices. Optionally the buffering circuit of the present invention may be integrated together with the driver system which operates the loads itself (e.g. the driver system disclosed above).

According to a broad aspect of the present invention there is provided a buffering electric circuit including an energy storage module to be connected to a load to which
15 electric energy is to be supplied; and a controllable current source, which is connectable to an electric power source and to the energy storage module. The buffering electric circuit also includes a controller for controlling a current of the controllable current source so as to maintain the energy stored in the energy storage device within a predetermined/prescribed range of energy values, while also restricting the current
20 consumed from the load via the controllable current source from exceeding a predetermined maximal current value. This provides for preventing reflection effects and electromagnetic interference effects from disrupting the operation of other power consumers connected to the source.

According to some embodiments of the present invention the buffering electric
25 circuit of controller is adapted to average the current consumed via the controllable current source, from the power source (e.g. such that a standard deviation of the averaged current does not exceed a predetermined standard deviation threshold). To this end, in some embodiments the controller of the buffering electric circuit is adapted to obtain data indicative of operational parameters of the load and of the energy stored in
30 the energy storage module, and to process that data to determine a value of the current to be provided/consumed from the power source by the controllable current source. Then the controller operates the controllable current source to provide current with said current value. For example in some cases the operational parameters of the load which

- 12 -

are used for this purpose may include certain properties of the load and/or parameters associated with an operational scheme used for operating the load. The one or more of operational parameters of the load may for example be determined in real time (e.g. during the operation of the load).

5 According to certain embodiments of the present invention the buffering electric circuit includes one or more measurement circuits which are associated-with the load (e.g. for measuring its power/current consumption) and connectable to the controller. The measurement circuits may be configured and operable to directly or indirectly measure data indicative of one or more of the following operational parameters of the
10 load (e.g. the voltage and/or current and/or power that us provided/consumed by the load). The measurement circuits are used to provide this data to the controller. The controller processes the data to estimate the average power consumption of the load and thereby determine the current value that needs to be consumed from the power source and stored in the energy storage device.

15 In certain embodiments of the present invention the power consumption of said load varies in time. For example the load may be operated in pulse mode, and the operational parameters of the load may include parameters indicative of the power consumption of the load during a pulse of operation and the duty cycle of the loads operation (of the pulses).

20 In certain embodiments of the present invention the load is a high power load having instantaneous power consumption in the order of the maximal output power of the power source or above (e.g. the power consumption of the load may exceed 20% of the total power that can be supplied by the power source and in some cases may exceed 50% or more). In some embodiments the power source is a limited power source whose
25 momentary output power is smaller than a momentary requirement of the load during operation thereof. The buffering circuit of the present invention also permits operating high power loads with limited power sources whose momentary output power is smaller than a momentary requirement of the load during its operation.

 The above features and advantages may be achieved while averaging the current
30 consumption from the load thus preventing reflection and/or electromagnetic interference effects. To this end, the buffering circuit may be configured for preventing the standard deviation of the current consumed from the power source from exceeding a predetermined standard deviation threshold. The later may be selected so as to reduce

- 13 -

interference effects between multiple power consumers connected to the power source. Also, alternatively or additionally, in some cases the predetermined maximal current value that is allowed to be consumed from the power source is selected so as to reduce the magnitude of voltage fluctuations in power source. To this end reducing the voltage
5 fluctuations (e.g. to below a certain value) provides for isolating the load from the power source and to prevent reflection of the load current onto the input source.

In certain embodiments, the current consumption of additional power consuming circuits, which are connected to the power source (e.g. directly/ not through the buffering circuit) are also considered when determining the current consumption of the
10 buffering circuit from the load. Specifically, in cases where the current consumption of such additional circuits is correlated with the loads operations, considering their power consumption enables improved flattening of the current consumption from the power source, thus allowing use of higher power consuming loads with smaller power sources while reducing the reflection and interference effects.

15 In certain embodiments of the present invention the power source may be for example a power source of a mobile system such as: a battery, a USB port and direct current (DC) Power supply. The energy storage module may for example include one or more energy reservoirs. These may for example include at least one of a capacitor and inductor modules.

20 In some embodiments the controller of the buffering electric circuit is adapted to determine the energy stored in said energy storage module based on the following: (i) energy stored in said energy storage module at certain time prior to one or more recent operational periods of the load; (ii) energy consumed by said load during said one or more recent operational periods; and (iii) energy provided to said by said controllable
25 current source in the time duration from said certain time. In some embodiments of the present invention the controller is adapted to determine/estimate (ii) and (iii) by utilizing data indicative of the following: (iv) the current provided by said controllable current source during operation of the load (during the pulse); (v) a duration of the operation of the load (e.g. the pulse duration); (vi) the current provided by the
30 controllable current source to the energy storage during non operation period of the load (e.g. during the time between pulses); (vii) a duration of the non operation period of the load (namely the time duration between pulses); (viii) power consumption of the load. In some cases the controller may be connected or connectable to a driver of the load for

- 14 -

obtaining therefrom data indicative of one or more of (v) and (vii) data pieces indicated above. Data indicative of (iv) and (vi) may for example be obtained from a measurement circuit adapted for measuring at least one of a voltage and a current at said energy storage module; and/or from pre-stored data indicative of value of current
5 previously provided by the current source to the energy storage module. Data indicative of (viii) (the power consumption of the load) may also be obtained from a driver associated with the load, and/or from a measurement circuit adapted for measuring at least one of a current and a voltage provided to the load, and/or it may be provided as a predetermined data indicating the power or current consumption of the load.

10 According to another broad aspect of the present invention there is provided a method for operating an electric load by an electric power source. The method includes: determining a magnitude of a substantially constant current that should be consumed from the power source for one or more next operation intervals of the electric load (for the next pulse operation(s) of the load); and operating a controllable current source for
15 charging an energy storage module, which is connectable to said power source, with electric current of the thus determined magnitude from the power source, so as to store in the energy storage energy for operating the electric load. More specifically according to some embodiments of the present invention determining the magnitude of a substantially constant current to be drawn from the source is performed by obtaining
20 data indicative of power consumption of the electric load during its operation; and estimating, based on that data, an expected energy consumption of the load in the one or more next operation intervals. Also, data indicative of a value of stored energy that is stored in said energy storage module is obtained. Then the magnitude of the electric current is estimated based on the estimated energy consumption of the load, the value of
25 the stored energy, and a time duration to said one or more next operations of the load.

According to yet another broad aspect of the present invention there is provided a light source system including a driver system such as that described above and a high power light emitter connectable at the output of the driver system. It should be noted that generally the high power light emitter may be any type of light source and
30 particular light source which emission should be controlled/regulated to ensure safe operation. For clarity in the following description and without loss of generality, the terms laser, laser light source and the like are used to designate any type of high power light emitter (e.g. including LED emitters arrangements of one or more laser diodes or

- 15 -

other emitters). The laser system may also include a control system configured for receiving operational instructions for operating the laser emitter and generating corresponding control signals for controlling the operation of said laser emitter. The driver system includes a switching module that is adapted for controlling the operating
5 the laser emitter based on *maximal energy exceeded* and *maximal power exceeded* control signals to thereby ensure safe operation of the laser emitter in accordance with a laser safety class associated with said laser system

In certain embodiments, the laser system further includes a buffering electric circuit similar to that described above. The buffering circuit may be connected to the
10 power input (e.g. input port) of the driver system for providing electrical input power the load/laser-emitter.

In some embodiments the control system may be configured for receiving operational instructions for operating the laser emitter, and generating corresponding control signals for controlling the operation of the laser emitter. To this end, in some
15 cases data indicative the operation of the laser emitter is used by the control system (e.g. provided to a controller of the buffering electric circuit) to facilitate adjusting the current of the controllable current source of the buffering electric circuit based on the operation of the laser emitter.

Further embodiments and features of the present invention are described in more
20 details in the following detailed description of the invention. It should be however understood that present invention is not limited by the description of the specific embodiments below and as will be readily appreciated by those versed in the art, it may be implemented differently without departing from the scope of the appended claims.

25 BRIEF DESCRIPTION OF THE DRAWINGS

In order to better understand the subject matter that is disclosed herein and to exemplify how it may be carried out in practice, embodiments will now be described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

30 **Fig. 1A** is a block diagram schematically illustrating an electric system **500** configuration according to an embodiment of the present invention;

- 16 -

Fig. 1B is a block diagram of an apparatus **500** according to an embodiment of the present invention configured to obtain distance data from a two-dimensional image of a scene;

Fig. 2A is a block diagram exemplifying a configuration of a buffering circuit
5 according to an embodiment of the present invention;

Fig. 2B is a graphical representation of the input and output currents and power consumptions provided by the buffering circuit **100** of the present invention;

Fig. 2C is a schematic illustration of a buffering circuit **100** according to an embodiment of the present invention;

10 **Fig. 2D** is a flow chart showing a method for buffering electric energy for operation a load according to an embodiment of the present invention;

Figs. 3A and **3B** are block diagrams exemplifying the operation of a buffering electric circuit **100** according to some embodiments of the present invention;

Figs. 3C to **3F** are flowcharts illustrating in self explanatory manner the control
15 flow/loop executed by a controller **150** of the buffering circuit according to certain embodiments of the present invention;

Fig. 3G is a graphical illustration of the operation of the buffering circuit according to some embodiments of the present invention;

Fig. 4A is a block diagram illustrating a driver system used according to some
20 embodiments of the present invention for operating a load;

Fig. 4B is an example of electric circuit of a driver system **200** according to an embodiment of the present invention;

Fig. 4C is a graphical representation of the operation of a current integration circuit according to some embodiments of the present invention; and

25 **Fig. 4D** is a flow chart of a method according to an embodiment of the present invention for determining and possibly limiting the energy supply and optionally also the power supply to a load.

30 DETAILED DESCRIPTION OF EMBODIMENTS

In the following detailed description, numerous specific details are set forth in order to provide a thorough understanding of the invention. However, it will be

- 17 -

understood by those skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known features, structures, characteristics, stages, methods, procedures, modules, components and systems, have not been described in detail so as not to obscure the present invention.

5 Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as "processing", "calculating", "computing", "determining", "generating", "setting", "configuring", "selecting", "defining", or the like, include action and/or processes of a computer that manipulate and/or transform data into other data, said data represented as
10 physical quantities, e.g. such as electronic quantities, and/or said data representing the physical objects. The terms "computer", "processor", "control system" and "controller" should be expansively construed to cover any kind of electronic with data processing capabilities, or a part thereof, which is made up of any combination of hardware, software and/or firmware and includes at least some hardware, even if not labeled as
15 such in the disclosure. It should be noted that the control systems and/or controllers indicated above may designate separate modules and/or all or some of them may be combined within one control modules (e.g. processor) or in a plurality of control modules.

 Certain operations in accordance with the teachings herein may be performed by
20 a computer specially constructed for the desired purposes or by a general purpose computer specially configured for the desired purpose by a computer program stored in a non-transitory computer readable storage medium. The term "non-transitory" is used herein to exclude transitory, propagating signals, but to otherwise include any volatile or non-volatile computer memory technology suitable to the application.

25 As used herein the term "memory" refers to any readable medium for storing data for the short and/or long term, locally and/or remotely. Examples of memory include inter-alia: any type of disk including floppy disk, hard disk, optical disk, CD-ROMs, magnetic-optical disk, magnetic tape, flash memory, random access memory (RAMs), dynamic random access memory (DRAM), static random access memory
30 (SRAM), read-only memory (ROMs), programmable read only memory PROM, electrically programmable read-only memory (EPROMs), electrically erasable and programmable read only memory (EEPROMs), magnetic card, optical card, any other

- 18 -

type of media suitable for storing electronic instructions and capable of being coupled to a system bus, a combination of any of the above, etc.

As used herein, the phrase "for example," "such as", "for instance" and variants thereof describe non-limiting embodiments of the presently disclosed subject matter.

5 Reference in the specification to "one case", "some cases", "other cases" or variants thereof means that a particular feature, structure or characteristic described in connection with the embodiment(s) is included in at least one embodiment of the presently disclosed subject matter. Thus the appearance of the phrase "one case", "some cases", "other cases" or variants thereof does not necessarily refer to the same
10 embodiment(s).

It is appreciated that, unless specifically stated otherwise, certain features of the presently disclosed subject matter, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the presently disclosed subject matter, which are, for
15 brevity, described in the context of a single embodiment, may also be provided separately or in any suitable sub-combination.

Any trademark occurring in the text or drawings is the property of its owner and occurs herein merely to explain or illustrate one example of how the presently discussed subject matter may be implemented.

20 Reference is made to **Fig. 1A**, which is a block diagram schematically illustrating an electric system (apparatus) **500** configuration according to an embodiment of the present invention. The apparatus **500** includes is electrically interconnected between a power source **10**, such as AC power source (e.g. electricity outlet), DC power source (e.g. battery, DC transformer, USB outlet and the like), and a
25 load **20**, which may generally be any power consuming device/system, but in the present example is a laser device/module. To this end, apparatus **500** may be, or may be a part of, a mobile device associated with a power source of limited power capacity, and the load may be any power consuming device associated with the mobile device (e.g. included therein and/or electrically connectable thereto) and controlled/operated and/or
30 powered thereby. Apparatus **500** includes an electric power buffering circuit **500** (hereinafter also referred to as buffering circuit) adapted for adjusting the consumption of power **PW** from the power source **10** and a driver system **200** adapted for handling/controlling power supply to the load **20**. Optionally the apparatus **500** also

- 19 -

includes a control system **300** connectable to the buffering circuit **500** and/or to the driver system **200** and adapted for generating and providing control signals **CS** controlling the power consumption of apparatus **500** and the load **20** from the power source **10** and/or controlling the operation of the load **20**.

5 In some embodiments of the present invention the load **20** is an electric power consuming device, which instantaneous power consumption during operation is in the order of, comparable to, or even higher, than the instantaneous amount of power that can be provided/supplied by the power source **10**. Accordingly, typical power sources are not ideal (e.g. may have internal resistance), connecting and operating such a load
10 **20** to the power source **10** may significantly affect the output voltage of the power source **10** due to the relatively high power consumption of the load **20**, relative to the power of the power source. This problem is referred to in the following as *reflection* of the load's operation on the power source. Consequently, due to such reflection, when operation the load, other devices/electric power consumers connected to the power
15 source may experience a reduction in the voltage and/or current (e.g. in the power) supplied thereto and thus their operation may be disrupted or even stopped.

 In certain embodiments of the present invention the load may be of a non-continuous operation character, for example it may be operated in pulses/time intervals, during which it requires high power consumption, and un-operated in times between
20 these time intervals, during these times may not consume any power from the power source **10**, or its power consumption may be negligible (e.g. power consumption associated standby operation for example of its driver/driving circuit (e.g. **200**) and/or it controller (e.g. **300**)). For example, the load **20** may be a pulsed laser system, such as a quasi continuous-wave (QCW) laser operated in pulses, where during each pulse high
25 power is required. In case such a load is connected to the power source (e.g. directly or even through a so called capacitor bank), the high power consumption bursts from the load may be *reflected* on the power source (may affect voltage and/or current supply of the power source), and may interfere with the regular or continuous operation and power consumption of other devices **600.1** to **600.n**, such as communication module
30 (e.g. Wi-Fi) or internal measurement unit (IMU; e.g. digital compass), which may be connected and powered by the power source **10**. This may be caused due to irregular voltage/current supply to such devices, or due to electromagnetic interference which

- 20 -

might arise due to the irregular/non-continuous operation of the load **20**. This problem is referred to in the following as *interference*.

Buffering circuit **100**, is electrically interconnected between the power source **10** and the load **20**, and is configured and operable to control/regulate the power consumption from the power source **10**, while decoupling this power consumption of the load from the power source. This provides for reducing and/or entirely eliminating reflections of the load's **20** operation on the power source **10** and/or interferences of the load's **20** operation with other devices (e.g. **600.1-600.n**) connected to the power source **10**. The configurations and methods of operation of the buffering circuit **100**, according to certain embodiments of the present invention are described in more details below with reference to **Figs. 2A to 3G**.

As indicated above, in certain embodiments of the present invention the load **20**, is actually a laser system/module including a laser emitter (e.g. LED and/or laser diode and/or quasi CW laser and/or pulsed laser; in the following generally termed laser). Safety regulations associated with laser operation typically impose limitations on both the power and integrated radiance (energy) of the laser according to the IEC 608251 classification the limitations are as described Accessible emission limits (e.g. AEL for Class 1) max pulse energy [$J \cdot cm^{-2}$] measured at 70cm and 100mm via aperture of 7mm. These limits are calculated for average power [W] single pulse and pulse train during time parameter T1 and are also based on the optical design. Furthermore, as also indicated above, many safety regulations require that light safety limitations are reliably imposed by analogue and/or hardwired digital logic circuits controlling the laser's operation, and not via software (firmware-software) processing.

Certain conventional techniques for meeting such safety regulations limit the power supply PS to the laser to a certain value so as not to exceed the maximal laser power limitation MPL imposed by the regulations for the required laser safety class PS: $\eta \cdot PS \leq MPL$ (where η designates the laser's efficiency in percentage), while also limit the maximal operation time T (e.g. pulse duration) of the laser to conform with the laser's safety class limitation associated with the maximal radiance energy allowed MRE: $\eta \cdot PS \cdot T \leq MRE$. MRPE is "the level of laser radiation energy to which, under normal circumstances, persons may be exposed without suffering adverse effects". Although such techniques may be used to ensure the laser safety, they are often more restrictive than the required safety regulation since instead of the maximal radiance

- 21 -

energy MRE of the laser they take into consideration a certain maximal operational output power of the laser and limit the operation time T of the laser.

However, for some laser applications (e.g. where the instantaneous laser power may vary; for example in laser based projection applications), it may be advantageous
5 to meet the safety regulations' limits, and particularly that associated with the laser radiance energy, while not restricting the operation time T to not exceed a fix value, but to restrict the actual radiance energy emitted from the laser.

The present invention according to some of its aspects provides a driver system
200 and a method for measuring and limiting the radiance energy emitting from a laser.
10 In certain embodiments, the system is implemented as an analogue device/circuit for measuring and integrating the current/power supply to the laser, and switching off the laser's operation once the integrated measured power exceeds a certain predetermined threshold associated with the maximal radiance energy MRE allowed by the respective safety class of the laser. In certain embodiments of the present invention the driver
15 system 200 includes an energy limiter module/circuit for limiting the radiance energy of the laser, by analogue means. Optionally, additionally the driver system 200 may also include a power limiter module/circuit for limiting the instantaneous power of the laser by analogue means. Yet optionally, the driver system 200 may include, or be associated with, a controller (control system) for receiving signals indicative of the power and/or
20 the total energy provided to the laser. In some embodiments, the controller may also serve as a secondary (backup) safety assuring device and may operate for controlling the laser operation and/or stopping the laser's operation in case any of the above safety limits is exceeded (e.g. due to failure in the above mentioned analogue modules. The configurations and methods of operation of the driver system 100, according to certain
25 embodiments of the present invention are described in more details below with reference to **Figs. 4A to 4D**.

It should be noted that the apparatus 500 described above with reference to **Fig. 1A** may be associated with a mobile device such as a mobile phone, a tablet, a handheld/laptop computer device and the like. The technique of the present invention
30 enables to connect to the mobile device, or integrate therewith, modules/devices of relatively high power consumption (relative to the limited power source of the mobile device). This is achieved by utilizing the buffering circuit of the present invention to interconnect between the relatively high power consuming module/device (e.g. which

- 22 -

power consumption is in the order of 20% or more of that provided by the power source). It should be understood that the use and/or integration of the buffering circuit **100** in the apparatus **500** is optional and is used/required in embodiments of the present invention in which the high power consuming module/device (the load) **20** may require
5 more than about 20% of the power supply that can be instantaneously provided by the power source **10**. For example such high power consuming modules may be constituted by the Driver system **200** alone or when in co-existence with one or more additional power consumers attached to the power source **10**. The technique of the present invention also enables the flexible operation of laser systems/modules, while within the
10 boundaries of required safety limits associated with the specific laser application used. To this end, the present invention provide a driver system facilitating the use of Safety Class I laser systems in mobile devices while enabling to flexibly using this lasers for projection of patterns/images on the external scene with sufficient power and/or energy. As indicated above, the safety regulations and associated limitations on the output
15 power and energy of the laser are maintained within safety limits by determining/measuring these parameters of the laser's operation accurately and separately based on dedicated analogue circuit(s). It should be understood that the use and/or integration of the driver system **200** in the apparatus **500** is optional and is used/required in embodiments of the present invention where the energy (e.g. power integrated over time) that is provided to a load associated with the apparatus **500** is to be
20 accurately monitored (e.g. by analogue means) and possibly used for regulating/controlling the operation of the load.

As aforementioned, the buffering circuit and/or the driving systems of the present invention may be used in various systems. For example, hand-held apparatus
25 configured to obtain distance data from a 2D image of a scene (e.g. implemented in a Smartphone or tablet) may include the buffering electric circuit **100** and/or the disclosed driver system **200** disclosed herein. For example, any of the apparatuses disclosed in U.S. patent application serial number 11/837,553 entitled "3D Geometric Modeling And Motion Capture Using Both Single And Dual Imaging", U.S. patent application serial
30 number 12/515,715 entitled "3D Geometric Modeling And 3D Video Content Creation", which are incorporated herein in their entirety by reference, may utilize the any or both of the buffering electric circuit and/or the driver system disclosed herein. To this end reference is made to **Fig. 1B**, which is a block diagram showing an apparatus

- 23 -

500 according to an embodiment of the present invention configured to obtain distance data from a two-dimensional image of a scene. The apparatus **500** includes a projector system **510**, including a laser system **20** (being an example corresponding to the load of **Fig. 1A**), a buffering circuit **100** according to the present invention for providing power to the laser system **20**, and a driver system **200** for controlling and ensuring safe operation of the laser **20**. The buffering circuit **100** and the driver system may be configured according to the present invention as described above and further described in more details below. It should be understood that the buffering circuit is optional and may not be included in certain embodiments of the present invention where sufficiently powerful power source **10** is utilized. The projection system **510** is configured to operate the laser system **20** for projecting a coded light pattern on a scene. The system also includes/or is connectable to an imager **520** capable of capturing and storing (e.g. in a memory) a two-dimensional image of the scene with the coded light pattern projected thereupon, and an image processing module **530** adapted to process the two-dimensional image to obtain distance data of the scene from the from said two-dimensional image of the scene with the coded light pattern projected thereupon.

In certain embodiments of the present invention the projector system **510** includes a control system **512** adapted to operate the laser system for projecting a desired coded light pattern (in the form of bi-dimensional coded light pattern. The bi-dimensional coded light pattern may be a predetermined patterned (e.g. stored in memory associated with the control system **512** or it may be selected/generated based on the properties of the scene (e.g. selected in real-time). Control system **300** described above may be included in the projection system **510** and may be implemented as a part of the control system **512** or as a separate module.

According to some embodiments of the present invention the bi-dimensional coded light pattern includes multiple appearances of a finite set of feature types. Each feature type is distinguishable from other feature types by its unique bi-dimensional formation. In certain embodiments of the present invention the bi-dimensional coded light pattern is projected on the scene such that a distance between adjacent epipolar lines associated with substantially identical appearances of any given feature type in the pattern is minimized according to a limiting epipolar separation factor. This gives rise to a plurality of distinguishable epipolar lines projected on the scene wherein the projected

- 24 -

epipolar lines are separated by approximately or at least, a minimum safe distance for epipolar line distinction.

In certain embodiments of the present invention the load **20** is a laser system and the control system **512** is adapted to operate the laser system **20** in accordance with the teachings of U.S. patent application No. 2008/0118143 assigned to the assignee of the present application. More specifically, the control system **512** is adapted to operate the laser system **20** for projecting at least a first bi-dimensional coded light pattern and a second bi dimensional light pattern. The first bi-dimensional coded light pattern includes a plurality of feature types, each feature type being distinguishable according to a unique bi-dimensional formation. To this end a feature type includes a plurality of elements of the pattern projected with varying light intensity. The plurality of elements of the feature types include: (i) at least one maximum element; (ii) at least one minimum element; and (iii) at least one saddle element. The second bi dimensional light pattern may be generally similar to the first bi-dimensional coded pattern and may include a similar plurality of feature types, each being distinguishable according to a unique bi-dimensional formation. According to certain embodiments of the present invention feature types in the second dimensional light pattern are inverted with respect to the first bi dimensional light pattern in the sense that one or more maximum elements in the first pattern are inverted to appear as minimum elements in the second pattern; and/or one or more minimum elements in the first pattern are inverted to appear as maximum elements in the second pattern. Saddle elements may remain similar in both patterns. By projecting the first and second patterns on to the scene (using projector system **510**), capturing images of the scene (using imager **520**) with these patterns projected thereon to, and processing by these images (by the image processing module **530**) the locations of the projected elements in the scene can be determined. More specifically, in some embodiments of the resent invention, two images of the scene with the two respective first and second patterns projected thereon are captured and a subtraction/resultant image of the scene is generated by the image processing module **530**, by subtracting one of the first and second images, which are associated with projections of the first and second bi-dimensional coded light patterns, from the other one of the first and second images of the scene. The subtraction image is then processed to determine data indicative of three dimensional parameters of the scene. The subtraction/resultant image includes maximum, minimum and saddle points resulting

- 25 -

from the subtraction. The image processing module **530** extracts from the resultant image, feature types' elements locations in the first and/or second image, based on the maximum, saddle and/or minimum elements locations in the resultant image.

It is noted that the buffering electric circuit **100** may be implemented in all the
5 claimed variations of the embodiments/apparatuses disclosed in U.S. patent applications Nos. 11/837,553 and 12/515,715 by supplying power to a driver of the projection module or otherwise. Alternatively or additionally the disclosed driver system **200** may be implemented in or as a part of the driver system of the projector/laser in all the claimed variations of the embodiments/apparatuses disclosed in U.S. patent applications
10 Nos. 11/837,553 and 12/515,715 and may be used for regulating the safe operation of the laser/projector.

Reference is made to **Fig. 2A** exemplifying a configuration of the buffering circuit **100**, according to an embodiment of the present invention. The buffering circuit/system **100** of the present invention provides for balancing of input power
15 consumed from the power source vs. output power provided to the load while flattening the time profile of the current consumption from the power source. This is achieved by utilizing a controllable current source **110** for adjusting the current consumption from the power source **10**, an energy storage module **120**, providing storage of electric energy to be provided to the load, and a controller **150** adapted to obtain/estimate the
20 operational parameters of the load and controlling the operation of the controllable current source **110**. Certain prominent goals achieved by the system/circuit **100** of the present invention are associated with the following:

- Reducing the input inrush current consumed from the power source **10** when connecting high power consuming load(s) **20**.
- 25 - Reducing the voltage drop over the input voltage when operating the load **20**.

The buffering circuit system **100** utilizes a controllable current source **110** to consume a semi-constant current or power from the power source and thus achieve a low input inrush current from the power source **10** and a low voltage drop over the input voltage of the power source **10**. The power from the input power source may be stored in an
30 energy storage module **120**, for consumption by the load **20** when needed. The power/current consumed from the power source **10** may be determined by the controller **150** based on the expected operation of the load and/or the properties/characteristics of the load's operation so as to maintain balance between the energy consumed for the

- 26 -

power source and the energy used by the load. To this end, in certain embodiments the controller **150** is used to determine/predict the amount of energy that needs to be stored in the energy storage module **120** and the controllable current source **110** is operated accordingly to store the required amount of energy. As a result the current/power
5 consumption from the power source may be averaged (e.g. flattened) in time while the load **20** is permitted to operate in high power consuming pulses/time-intervals without affecting the voltage of the power source **20** and/or without consuming high inrush currents therefrom. The buffering circuit system **100** may be implemented as a low-cost, space-saving solution that can be integrated in small portable devices to enable
10 operation of relatively large power consumers (loads) by such devices. Resulting from the low inrush current consumption and low voltage drop of the power sources, the solution can also be used to reduce electrical interference, electromagnetic Interference (EMI) and electromagnetic Conduction (EMC) effects which may disrupt the operation of other devices connected to the load **20**.

15 The buffering circuit system **100** may be used for providing power to a wide variety of loads in hand held device. For example, the system may be implemented in mobile systems which include a light source which has higher optic power density than ambient light, such as the ones discussed in the background. Furthermore, the system may be used, for example, in mobile systems such as mobile phones, tablets and laptops
20 that have limited power supply, or have limited output power for external ports such as USB port. The proposed systems and methods may also be used for reducing co-interference to electronic circuits caused by the inrush current of the high-power load (for example a light source) as discussed below in greater detail, the output power may vary with time, in which case it has unpredictable current and/or width. It is noted that
25 the buffering electric circuit disclosed may be used in systems in which the load power consumption is Quasi Continuous Wave. It is noted that the buffering electric circuit disclosed may be used to provide energy to a load which operates in pulses (e.g. a repetitive pulse load). Such a load may be, for example, a light source (such as LED, LASER or VCSEL); another example is an RF beacon transmitter in portable hand-held
30 devices. As discussed below in greater detail, the power source from which the controllable current source obtains power is usually a direct current (DC) power source.

Fig. 2A is a block diagram showing a buffering electric circuit **100** according to an embodiment of the present invention including: an energy storage module **120**

- 27 -

electrically connectable/connected to a load **20**, to which electric energy is to be supplied from the energy storage module **120**. The energy storage module **120** is used according to the present invention to provide temporary storage of electric energy to be consumed by the load, even at times where inadequate electric energy supply is available, or can be practically consumed from the power source **10** without causing the
5 aforementioned *reflection* and/or *interference* effects.

The energy storage module **120** may be implemented in many ways, as will be clear to a person who is of skill in the art. For example, the energy storage medium may include a capacitor (e.g. utilizing one or more capacitors/capacitor-bank), an
10 inductor (e.g. one or more coils/solenoids), or any combination of one or more inductors and capacitors. To this end the energy storage module **120** may for example be adapted for storing electric energy in the form of stored electric charge (e.g. stored by capacitor(s) and/or electric current (e.g. stored by inductor(s)). The buffering electric circuit **100** also includes a controllable current source **110** connectable/connected to an
15 electric power source **10** and to the energy storage module **120**. The controllable current source **110** is configured and operable to enable control on the current consumed from the power source **10** and thereby providing for decoupling between the power consumption of the load **20** and the power consumed by from the power source **10**, thus preventing the aforementioned *reflection* and/or *interference* effects.

20 As will be readily appreciated by a person skilled, in various embodiments of the present invention, the controllable current source **110** may be implemented utilizing various techniques. For example the controllable current source **110** can be implemented utilizing a non-switching or switching power supply techniques for example in one of the following ways: (i) non-switching Linear- via a power transistor, FET, MOSFET or LDO; (ii) Switching power supplies: such as Buck, Boost, Sepic,
25 switching capacitor, etcetera.

The buffering electric circuit **100** also includes a controller **150** connectable to the controllable current source **110** and adapted for controlling a current consumption from the power source **10** (namely the current through the controllable current source **110**).
30 The controller **150**, which may be implemented utilizing a processor and/or any other signal processing apparatus, is configured so as to enable operation of the load **20** with the desired power consumption, while reducing/preventing the aforementioned *reflection* and/or *interference* effects.

- 28 -

In this regards it should be noted that the load, may be a device which is associated with time changing/variable power consumption (e.g. pulsed/quasi-CW laser system, and or other device which operation is initiated and stopped and/or which power consumption may vary in time and may be controlled by a certain control system associated therewith). Accordingly, the controller **150**, may adapt and regulate in real time the profile of the current consumption from the power source **10**, so as to average the power consumed from the power source **10** over time, while maintaining sufficient energy stored in the energy storage module **120** for the required operation of the load **20**.

To this end, according to certain embodiments of the present invention the controller **150** may be configured and operable for controlling the current through the controllable current source **110** to maintain an energy stored in said energy storage device **120** within a certain range of energy values, which may be predetermined in advance and/or determined based on prediction/estimation of the expected power consumption of the load **20**.

Additionally, in certain embodiments of the present invention the controller **150** may be configured and operable for restricting the current from the power source **10** from exceeding a certain maximal current value (which may be a predetermined value). Also, in certain embodiments the controller is configured and operable to reduce and/or prevent rapid changes of current consumption from the power source **10** (namely restricting the absolute value of the time derivative of the current to be below a certain value).

In certain embodiments of the present invention the controller **150** is adapted to flatten peak current consumption from the power source **10** (e.g. flatten the time profile of the current consumption from the source **10**), such that a standard deviation of the current does not exceed a predetermined standard deviation threshold. In other words the controller operates the controllable current source **110**, which is connected to the power source **10**, so as to obtain average power consumption from the source.

The controller **150** may be connected to one or more measurement module(s) **130** (illustratively shown in the figure) providing data/signals indicating the status of the energy storage module **120** (e.g. the amount of energy stored therein), and/or data/signals indicative of the operational parameters/characteristics of the load **20** (e.g. the energy and/or power and/or current and/or voltage consumed thereby). The

- 29 -

controller **150** may use these data signals to estimate the expected power/energy consumption of the load **20** in a certain timeframe ahead, determine the amount of energy stored in the energy storage module **120**, use this information to deduce the nominal/average current to be consumed from the power source **10** and stored in the energy storage module **120** to enable the operation of the load **20**. The controller **150** then operates the controllable current source accordingly to consume about that nominal current from the power source, so that the respective energy is stored in the energy storage module **120**.

In some cases predetermined parameters associated with the properties of the load **20**, and/or with the operational scheme, by which the load **20** operates or is operated, are used (possibly after being retrieved from a memory associated with the controller), to determine/estimate the operational parameters/characteristics of the load **20** and the expected energy consumption thereof.

Alternatively, or additionally as indicated above, the measurement module(s) **130** may be configured to measure and provide signals/or data indicative of such operational parameters/characteristics of the load **20**, or of some of them. The latter may be used to estimate the future operation of the load and accordingly the amount of energy that needs to be stored in the energy storage module **120**. For example, the operational parameters of the load **20** may be determined by the measurement module **130**, (e.g. in real time) during the operation of the load. To this end, the measurement module **130** may include one or more measurement circuits associated with the load **20** (not specifically shown in the figure) and connectable to the controller **150**. The one or more measurement circuits may be adapted to directly or indirectly measure data indicative of one or more of the following operational parameters of the load: voltage provided to the load, current provided to the load, and/or the power consumed by the load. Data indicative of these one or more operational parameters are obtained by controller and are used/processed thereby to determine/estimate the value of the current that needs to be supplied from the power source **10** to the energy storage module **120**, in order to replenish the energy stored in the energy storage module **120** by an energy amount sufficient for further operation of the load **20**. Several methods of operation of the controller **150** for determining that current value are disclosed in the following with reference to **Fig. 2D** and **Figs. 3A to 3D**.

- 30 -

In this regards it should be noted than in certain embodiments of the present invention the power provided to the energy storage module (i.e. the value of the current to which the controllable current source is set) is determined based on an estimated average power consumption of the load such that a substantially constant current is collected from the power source **10** (e.g. being "constant in the sense that the standard deviation of the current value does not exceed a certain threshold).

Reference is made to the **Fig. 2B**, which is a graphical representation of the operation and the input and output current and power consumptions provided by the buffering circuit/module **100** of the present invention. Here the operation of the buffering circuit/module **100** is exemplified when operating a load **20**, such as a pulsed laser system, in pulses. Upper graphs **G1**, **G2** and **G3** show respectively: the input power obtained from the power source **10** (**G1**), the output current provided to the load **20** (**G2**), and the input power which would have been consumed from the power source in case the load was directly connected thereto thro high efficiency power supply (η is about 85%) (**G3**). The abscissa (x axis) units are Time [mSec], and the ordinate units (y axis) of **G1** to **G3** are power units [Watts]. The lower graphs **G4** to **G6** are the electric currents associated with the electric powers of the graphs **G1** to **G3** respectively. Here the ordinate is in electric current units [Ampere].

The load is operated in pulses of widths 2[mSec], with 10% duty cycle and current set for 10[A] during the pulses. The input voltage from the power source is, in this example, a DC voltage of 4.2V volts) and is higher than the voltage provided to the load which is about 2V DC of volts in this example. As can be seen, Graph **G2** shows that the output power peaks during a pulse operation of the load and reduces (e.g. to zero and/or to a certain standby power of the load **20**) during the time intervals between pulses. However, due to the operation of the buffering circuit **100** of the present invention, the input power shown in graph **G1**, which is consumed form the power source, is substantially fixed and equals about the average value of the power consumption of the load (averaged over time).

More specifically, the controller **150** operates to maintain the input current within a predetermined range of values such that the standard deviation of the current does not exceed a certain value and/or such that the maximal current consumption from the power source does not exceed a certain value. As will be further described below, this may be performed by utilizing predetermined data and/or predication on the

- 31 -

power/energy that will be consumed by the load. Graph **G3** is provided as a reference to show the time profile of the power consumption from the power source **10** in systems in which the load **20** is directly connected to the power source. Accordingly this graph is similar to **G2**, illustration the reflection problem indicated above. The reflected current
5 shown in **G6** is the practical reflected current that would have being taken from the power source **10** by high efficiency load drivers in case buffering circuit **100** had not being used. However, according to the present invention the current consumed from the power source **10** (graph is controlled and set by the controller **150**. As will be further described below the controller may be a simple PID controller (namely proportional-
10 integral-derivative controller) and may utilize a control loop based on a fuzzy logic to determine and set the current of graph **G4** (the input current from the power source).

Reference is made to **Fig. 2C** is a schematic illustration of a buffering circuit **100** according to an embodiment of the present invention. Certain modules **110**, **120**, **130** and **150** of the buffering circuit **100**, which are described above with reference to
15 **Fig. 2A**, as well as the power source **10** and the load **20** are shown encircled in the figure, and their configuration and interconnection in the circle **100** is briefly further described in the following.

The power source **10** (e.g. battery or DC power supply) providing voltage **V_{in}** is connected to the controllable current source **110**, which is used to adjusted the current
20 drawn from the power source **10**. In the present example the controllable current source **110** in the form of a linear controlled P-channel MOSFET based current source, and is formed as a *Shunt Resistor Amplifier* including two transistors, **Q1A** and **Q1B**, (e.g. Metal Oxide Semiconductor Field Effect Transistors (MOSFETs)) interconnected between them via resistors. The controllable current source **110** is connected to the
25 controller **150** (e.g. via Gate leg **1** of transistor **Q1A**) for receiving from the controller operational signal **PWM_DAC** indicating the value of the current to output towards the energy storage module **120** (current outputted at Drain leg **4** of transistor **Q1B**). The operation and configuration of the controllable current source **110** illustrated in the figure as well as various modifications that may be applied thereto without departing
30 from the propose of this module **110** and the scope of the present invention will be readily appreciated by those versed in the art. Also, it should be understood that according to the present invention module **110** may be implemented by any suitable technique/circuit providing control over the current drawn from the source **10**, without

- 32 -

departing from the scope of the present invention. For example, as indicated above the controllable current source **110** may be implemented utilizing non-switching or switching power supply techniques. It should be noted that implementing the controllable current source **110** utilizing a *Shunt Resistor Amplifier* (i.e. SR-Amp) may be advantageous in certain cases since the resistor that is being used has a low value (for low voltage drop) and the amplifier has high gain the voltage produced by the amplifier is high enough for the Controller **150**. The SR-Amp has extremely low current consumption compared to other solution, the use of the combination of low ohm resistor and high gain SR-Amp yields high efficient circuit. One can replace the SR-Amp with any combinations of amplifiers (e.g. OP-Amp) or instrumental amplifiers. Another option is to do dual measurements before and after the resistor this will require a resistor with high ohm value resulting in high voltage drop.

The controllable current source **110** is connected (e.g. here via leg **4** of transistor **Q1B**) to the energy storage module **120** for providing the controlled current to energize this module **120**. In the present example module **120** is implemented utilizing one or more capacitors **C2** (for the purpose of operation the specific load **20** or its driver system module **200** as in **Figs. 1A and 1B**). For the load **20** considered in this circuit, capacitor(s) **C2** of 120mF/3.5V are used. It will be readily appreciated by those versed in the art that in various implementations, and without departing from the scope of the present invention, the electric energy storage module **120** can be implemented by utilizing coil(s)/solenoid(s) to store the electric energy in the form of magnetic field /current in the coil/solenoid and/or utilizing capacitor(s) to store energy in the form of electric-field/charge in the capacitor(s) and/or by combination of capacitors and coils. Nevertheless, it should be noted that for some cases using capacitors may be advantageous since the capacitors can hold the energy with less losses for longer period of time and the circuit needed to withdraw the energy is less complex. To this end, new type of high density capacitors, known as super capacitor, ultra capacitors and best cap, etcetera were introduced in the recent years which require small space and which have low *equivalent series resistance* (ESR). Accordingly using this type of capacitors may be preferable in certain embodiments of the buffering circuit of the present invention.

The control system, which operates to determine the current to be provided to the energy storage module **120** by the controllable current source **110**, includes

- 33 -

measurement circuits/modules **130**, and the controller **150**. In some embodiments of the present invention data indicative of both the status of the energy storage module **120** and the operation characteristics of the load **20** are used/measured by the controller to determine current to be supplied to the energy storage module **120**. The controller **150**
5 processes the data of the status of the energy storage module **120** and of the operation characteristics of the load **20**, determines a value of the current to be provided by the controllable current source **110**, and operates the controllable current source to provide electric current of that value so as to replenish the energy stored in the energy storage module **120**.

10 The controller **150** is configured to determine the current commands based on which the controllable current source operates. The controller **150** may be implemented in an analog fashion, in a digital fashion, or in any combination thereof. The term controller as used herein should be expansively construed to cover any kind of electronic device with data processing capabilities, including, by way of non-limiting
15 example, a personal computer, a server, a computing system, a communication device, a processor (e.g. digital signal processor (DSP), a microcontroller, a field programmable gate array (FPGA), an application specific integrated circuit (ASIC), etc.), any other electronic computing device, and or any combination thereof. In addition, the controller can be implemented by analog circuit or analog control loop.

20 The controller **150** may be configured to determine the current command by utilizing the method **400** illustrated in the flow chart of **Fig. 2D**. In operation **410** data indicative of the operation of the load is determined (e.g. obtained/estimated). This data may be obtained from a controller/control system associated with/operating the load **20**, and/or from a memory associated with the controller **150**, and/or by measuring the
25 power/current/voltage consumed by the load **20** during its operation and possibly recording the operation times/intervals of the load **20**. In **420**, the time to the next one or more operation intervals/pulses of the load are determined/estimated/extracted based on the data obtained in **410**. Also, in **430** the expected energy consumption in the next one or more operation of the load are determined/estimated/extracted from/based on the
30 obtained in **410**. According to some embodiments of the present invention, the average power consumption of the load is determined/estimated based on the expected energy consumption and the time to the next one or more operation intervals/pulses of the load. In operation **440**, the amount of energy stored in the energy storage module **120** is

- 34 -

determined (e.g. by measuring the voltage of an energy storing capacitor associated with module **120**, and/or measuring the current of an energy storing inductor associated with module **120**). Then, in **450** the required current to be drawn from the power source **10** to replenish the energy of the energy storage module **120** is determined based on the expected energy consumption of the load, the expected time at which it is to be consumed, and the energy already stored in the energy storage module **120**. For example, considering that in **410** to **440** the following was obtained (measured/determined/estimated): the time T_L to the next one or more operations/pulses of the load **20**, the energy E_{out} to be consumed by the load **20**, the energy E_S already stored in the energy storage module, and considering the voltage of the source is V_{in} and the efficiency of the load (e.g. of the load's driver) is η , the current I_{in} to be drawn from the power source may be calculated as follows in order to balance between the energy consumption from the power source and the energy requirements of the load while time averaging the power consumption from the power source **10**:

Eq. (1): $I_{in} = (E_{out}/\eta - E_S)/(T_L * V_{in})$

Here E_{out}/η is the actual energy that needs to be supplied to the load or to its driver, taking into account the efficiency of the load (e.g. of the driver of the load). It should be noted that in the present example the duration of the operation/pulse of the load was not taken into account and was considered negligible with respect to other time scales. Accordingly in **450** a current command may be provided to the controllable current source **110** to supply current I_{in} in order to charge the energy storage module **120** with power $I_{in} * V$.

It should be noted that in some embodiments other parameters of the load's operation may be considered in order to balance the input and output energies. For example the duty-cycle D_{Cycle} of the load's operation may be considered and used to determine the average power consumption of the load and thus the average current that needs to be drawn from the power source **10**. In such cases for example I_{in} may be calculated as follows:

Eq. (2): $I_{in} = (D_{Cycle} * P_{out})/(\eta * V_{in})$;

where η is the efficacy; V_{in} and I_{in} are the voltage and nominal/average current to be drawn from the power source **10** ($P_{in}[W] = V_{in} * I_{in}$ is the nominal power consumption from the power source **10**), P_{out} is the power consumption of the load during a pulse ($P_{out} [W] = V_{out} * I_{out}$ where V_{out} and I_{out} are the voltage and current to be consumed by

- 35 -

the load **20** during operation/pulse); D_{Cycle} is the duty cycle of the loads operation expressed in the percentage of time duration of the loads operation from the total time.

Thus, in any of the above examples, the current command I_{in} is determined such as to maintain a balance between the energy consumption of the load and the energy supply from the power source while time averaging the power consumption from the power source.

As a numerical example to the operation of the controller based on Eq. (2) above is provide in the following. Here the load is considered as a light source associated with a high efficacy driver, having 85% efficiency ($\eta=0.85$) and operating the light source in 10% duty cycle ($D_{\text{cycle}}=0.1$). The light source is operated with operational voltage and current of respectively: $V_{\text{out}}=2\text{V}$ and $I_{\text{out}}=10\text{A}$ and operating in). The input voltage V_{in} of the power source **10** may be for example $V_{\text{in}}=4.2\text{V}$. Utilizing equation 2 above the controller may determine the current command I_{in} as follows:

$$I_{\text{in}} = (D_{\text{Cycle}} * P_{\text{out}}) / (\eta * V_{\text{in}}) = (0.1 * 2\text{V} * 10\text{A}) / (0.85 * 4.2) = 0.56\text{A}.$$

Such a current may be consumed from a power source (battery/USB) of a mobile device thus enabling using mobile devices for operation light projection modules such as laser based laser projectors, without interrupting other modules/devices associated with the mobile device. It should be noted even lower input current may be consumed when operation in lower duty cycle (DC). It should also be noted that the values of the load, input voltage, efficacy, and duty cycle indicated above are provided only as an example and may vary, depending on the configuration of the system and the working conditions.

The controller **150** may be configured to implement method **400** described above by implementing any one or more of the algorithms discussed with reference to **Figs. 3A to 3G**.

Fig 3A is a block diagram illustrating an example of a buffering electric circuit **100** according to an embodiment of the present invention in which between the input voltage (battery, USB port or DC supply) and load there is a buffer. This buffer is a controllable current source. The current source is connected to an energy storage module (such as a capacitor), at the input of the load (e.g. light source driver). This capacitor delivers the peak power needed for the driver, instead of the input source directly. The controller **150** is configured to obtain: (a) Information indicative of the amount of energy stored in the energy storage module; (b) Information indicative of the amount of energy consumed by the load in the last pulse; and (c) Information indicative

- 36 -

of the time between the last pulse (operating time interval of the load) and a consecutive pulse (operating time interval of the load). The controller is configured to compute the current command to the controllable current source based on (a), (b), and (c). As can be seen, since the parameters used by the controller may change from time to time, the current control commands issued by the controller may also change during an operation of the buffering electric circuit.

It is noted that different systems of measurements may be used for implementing the invention, and therefore different units of measurements may be used. For example, under the International System of Units (SI), the following units may be used for the above identified parameters (a), (b) and (c):

- (a) Information indicative of the size of energy stored unit [J].
- (b) Information indicative of the Load output energy [J] or power [W]
- (c) Information indicative of the time between the pulses [mSec] or [S]

Fig. 3B is a block diagram illustrating an example of a buffering electric circuit **100** on which different types of measurements that can be extracted are illustrated, denoted as **K1-K6**, in accordance with an embodiment of the present invention. Here **K1** and **K2** are the input current and voltage (e.g. of the power source **10**) respectively ($K1=I_{in}$ $K2=V_{in}$); **K3** and **K4** are respectively the current and voltage provided to the energy storage module **120** (e.g. **K3** being a current $I_{inductor}$ through an inductor of the energy storage module **120** (for a magnetic storage) and/or **K4** being a voltage $V_{capacitor}$ on a capacitor of the energy storage module **120**; and **K5** and **K6** are the current and voltage used by the load **10** ($K5=I_{out}$ $K6=V_{out}$). It is noted that not necessarily all of **K1** through **K6** are measured in each implementation of the system, nor that each such system necessarily include sensor/measurement circuits **130** for measuring all of the parameters **K1** through **K6**. Different combinations may be measured in different implementation, and other sources of information may also be used, as long as parameters (a), (b) and (c) above are available for the controller. The parameters for the equations can be extracted from optional sensors/measurement circuits such as those illustrated in circuits **130** in **Fig. 2C**. In **Fig. 2C** measurement circuits **130** for measuring **K2**, **K3** and **K4** are shown).

The energy E_s stored in the energy storage module **120** may be determined based on **K3** and/or **K4** (being the current and voltage on the energy storage module) according to the following. In case the energy storage module is implemented for

- 37 -

storing energy by using/including capacitor(s): $E_S = E_{\text{capacitor}} = 0.5 \cdot C \cdot V_{\text{capacitor}}^2 = 0.5 \cdot C \cdot (K4)^2$; where C is a predetermined/estimated capacitance of an energy storing capacitor of the energy storage module 120 the energy in the capacitor can also be calculated using the K3 for measuring the capacitor Q (e.g. charge). In case the energy storage module is implemented for storing energy by using/including inductor(s): $E_S = E_{\text{inductor}} = 0.5 \cdot L \cdot I_{\text{inductor}}^2 = 0.5 \cdot L \cdot (K3)^2$ where L is a predetermined/estimated inductance of an energy storing capacitor of the energy storage module 120.

The values of C and/or L may be determined/estimated (e.g. in advance and/or by the controller 150) a parameter (schematic value associated with the capacitor/inductor) or by inducing current to the energy storage module till is full (e.g. until a certain stopping condition is fulfilled – a certain voltage V_{max} on the capacitor is reached or a certain current I_{max} in the inductor is obtained) and measuring the amount of energy needed for the task.

Figs. 3C to 3F are flowcharts illustrating in self explanatory manner the control flow/loop executed by controller 150 according to certain embodiments of the present invention. **Fig. 3C** shows the main control flow/loop of the controller 150. The main control loop incorporates three sub control loops which are illustrated respectively in **Figs. 3D, 3E and 3F**. These control loops/processes are aimed at determining/calculating the parameters/set-values X and Y (being the current control commands I_m) for the controllable current source 110 during a pulse/operation-interval of the load 20 and in between pulses (when the load is not operated) respectively. In some cases different current control commands/set-values X and Y are provided to the controllable current source 110 during the loads operation/pulse and in between pulses. This is because the calculation of the current command takes in to account not only the current consumption of the Load 20 but also the additional current consumption associated with the driver system 200 itself (e.g. the controller 150 and/or additional circuitry), which may not be consumed via the buffering circuit but directly from the power source 10. In such cases, distinct current set values values/current commands X and Y may be calculated for the period during and in between pulses respectively, so as to maintain a substantially constant current consumption from the power source to both the buffering circuit 100 and the driver system 200. This is specifically significant in cases where the operation and power consumption of certain devices, such as the driver system 200, that are connected to the power source directly (not via the buffering

- 38 -

circuit) depends on the operation of the load **20** (e.g. and is different during pulse operation of the load and in between pulses). For example cases where in time periods between pulses the driver system **200** and/or the controller **150** are operated in idle/low-power to preserve energy, while during the pulse of the load they operate regularly with
5 higher power consumption.

In such cases the set-values X and Y may be calculated as follows:

(i) Determine/obtain data indicative the current/power consumptions of devices (e.g. driver system **200** itself), which are connected to the directly power source not through the buffering circuit **100**, during an
10 operation period/pulse of the load and when the laod is not operating.

For example considering the curret consumed by the driver system **200** is $I_{drive}(in-pulse) = 0.05A$ during the pulse, and $I_{drive}(out-of-pulse) = 0.003A$.

(ii) Determine/obtain data indicative the average current consumptions I_{in} of the load **20** from the power source **10**, for example based on Eq. 2 above.
15 For example, for certain laser system loads operating at 10% DutyCycle, I_{in} may be about 0.1A.

(iii) Utilize the values of I_{in} , $I_{drive}(in-pulse)$, and $I_{drive}(out-of-pulse)$ to determine the current commands X and Y for suplyying current to the energy storage of the buffering circuit **100** during the load's operation,
20 and when it is not operated respectively, while also maintaining constant current consumption from the power source. This may be determined utilizing the following equation (I) and (II) to satisfy that :

$$(I) \quad X * D_{Cycle} + Y * (1 - D_{Cycle}) = I_{in}$$

$$25 \quad (II) \quad X + I_{drive}(in-pulse) = Y + I_{drive}(out-of-pulse)$$

Where equation (I) ensures that the needed amount of energy is stored in the energy stroage module **120**, and (II) provides that the current consumption from the power source (taking into account all/additional devices which are connected to the power source and which current consumption varies in accordance with the load's operation) is
30 maintained substantially fixed/constant when the load **20** is in operation and when it is not operating.

- 39 -

At the first pulse predetermined values may be used for X & Y (instead of calculating them, as may be done in later pulses). Optionally, the predetermined values used for X and Y may be calculated for a soft start (minimal needed current).

The main control loop **160** may start with an “enable” signal (**162**), at which
5 point the energy storage module may be full. In **164**, the controller **150** obtains data/signal indicative of whether the load currently operates. In case the load is not currently operated, the controller continues by executing the process illustrated in **Fig. 3D**. In case it does operate, the controller **150** continues by executing process **180** or process **190** which are illustrated in **Figs. 3E** and **3F** respectively, and at which the
10 controller **150** determines/estimates the operational parameters of the load (e.g. the power consumption of the load during a pulse, the duration of the pulse and a pulse duty cycle). In this regards to should be noted that the power/energy consumption of the load may vary in time and may be different at different pulses. Thus, for example in optional operation **166**, the controller determines if the pulse energy is different than that of the
15 previous one or more pulses and if so continues by executing the process **190** illustrated in **Fig. 3F**. Alternatively, in case the load operates at regular pulses of with similar energy at each pulse, the controller continues executes the process **180** illustrated in **Fig. 3E**.

In this connection it should be noted that in **164** data/signals indicating the
20 existence of the pulse as well as its energy (which may be calculated/evaluated from the time duration (widths) of the pulse and its power), may be obtained by measurements or from a controller/control system operation the load **20**. At time when the load is not operating, the controller continues by executing the process **170** of **Fig. 3D**.

Turning now to **Fig. 3E**, when the load **20** operates in regular (e.g. even) pulses, the
25 process **180** is executed. In **182**, several parameters are gathered/determined in order to determent the current that is required from the input current source. Some or all of the following parameters are gathered: (a) the amount of energy stored in the energy storage module; (b) the of amount of energy consumed by the load in the last pulse; (c) the time between the last pulse and a consecutive pulse; (d) the energy consumed by the
30 auxiliary circuit: load (e.g. driver) and buffer (e.g. energy storage module). This information can be calculated or estimated using some or all of the following measured parameters as indicated above: K1- Input current (is known by a formula), K2-Input voltage, K3- Output current (is known as being set by the current source), K4- Output

- 40 -

voltage, K5- Load current, K6- Input voltage, Projector pulse width. It should be noted that under as specific conditions some or all the parameters K1-K6: can be given as constants and used as described above to evaluate the output average power. To this end, the energy and/or pulse power P_{out} used by the load **20** is calculated/determined by the controller **150** in order to determine/calculate the parameters/set-values X for the controllable current source **110** during a pulse/operation-interval of the load **20**.

In **184**, the *pulse_width* (time duration), the *time_between_pulses* and the pulse power P_{out} may be measured (e.g. determined digitally or analogically) by the controller monitoring the load's operation, and/or these parameters or some of them may be predetermined (e.g. known constants) which can be obtained/used by the controller. The duty cycle D_{Cycle} of the load **20** (considering the case the load operates in regular evenly spaced pulses), may be calculated by the controller **150** based on the following:

$$\text{Eq. 3} \quad D_{Cycle} = \text{pulse_width} / \text{time_between_pulses}.$$

In **186** and **187**, the value of current control command I_{in} (e.g. the X set value) to the controllable current source **110** may be determined. For example the set-value X may be determined based on Eq. 2 above in which the average current to the load is determined I_{in} . In case additional devices which power consumption is time correlated with the loads operation, are connected to the power source (e.g. directly – not through the buffer circuit), such as the drive system itself, then Equations I and II above may be used to determine the values of X and Y separately. Otherwise, the X and Y set values may equal to the I_{in} value of Eq. 2. The X set value is then provided to the controllable current source **110**.

Also, in some embodiments, **SLEEP** operation (which is shown in all of the figures **3C** to **3F**) is implemented. More specifically, in cases where the time between pulses exceeds a certain threshold (whether a predetermined or a dynamically calculated threshold), the controller **150** may execute a sleep command during which power may not be consumed from the power source **10**. This may be used to reduce power consumption from the power source **10**. The decision whether a sleep command should be issued may be determined/calculated based on the value of I_{in} or Y, as the case may be, such that a sleep command will be issued in cases where the current I_{in} / Y to be consumed from the power source at time intervals between pulses without such sleep, is lower than a certain minimal efficient current I_{min} . How to determine the value of such minimal efficient current threshold will be clear to a person who is of skill in the art,

based on the actual implementation of the system used. In case a sleep command should be issued, the sleep duration *Sleep_Time* may be calculated as follows, so as to raise the current I_{in} / Y consumed during the time intervals between pulses to the minimum I_{min} .

$$\text{Eq. 4} \quad \text{Sleep_Time} = \text{time_between_pulses}(1 - I_{in}/I_{min})$$

5 Turning now to **Fig. 3F**, process **190** is associated with a more a complex mode of operation in which the pulses of the load's operation may have different widths and/or utilize different electric currents. If this is the case, operations **192** and **194** may be generally similar to operations **182** and **184** described above except that the controller **150** may be configured to take a measurement of at least two pulses and to calculate the
10 average energy being consumed by the load. This value is then used in **197** instead of the momentary pulse energy, to calculate the current source set value X. See for example **Fig. 3G** which graphically illustrates the operation of the process **190** as compared with that of **180**. Graph **G1** shows a complex pulse time pattern including high and low intensity pulses interlaced in time. The system of the present invention
15 may operate in such case according to method **190** to determine the average power consumption of the load based on the various intensities of the pulses in the expected pulse sequence, and accordingly operate the controllable current source to consume a substantially constant current/power. The time profile of the substantially constant power consumption obtained by process **190** is illustrated in graph **G2**. Graph **G3**
20 illustrates the operation of process **180** in case pulses of different intensities are used. Here the controllable current source is operate to consume higher and lower currents from the power sources in accordance with the intensity of the last operation pulse of the load. Thus using the operation mode 190 provides better averaging of the power consumption from the power source in case variable pulse intensities are used.

25 To this end, in **197**, (as in operations **186** and **187** above) X is calculated based on equation 2 above, and in cases where additional power consumers which are time correlated with the load. X and Y are determined based on Eq. I and II above. However here P_{out} in equation 2 is determined as the average power consumption of a plurality of pulses which may have different intensities, wherein in process **180**, P_{out} may be determined
30 based on the last pulse only. It should be noted that the expected/predicted value of P_{out} may be estimated based on the power consumption of the last pulses, and/or it may be given as an input from the control system, which is used for operating the load/laser.

- 42 -

The electric buffering circuit and the methods of operation thereof as described above in **Figs. 2A to 3F** may be used in various systems and conditions for operation various types of loads and with various and optionally changing powering schemes. The proposed buffering circuit may be used to reduce or diminish effects associated with the momentary output power being reflected onto the power input. Such reflection which may cause a voltage drop for every output pulse and may thus disrupt other units that use the same input power, and also Electromagnetic Interference (EMI) (which may be due to EMI emissions resulting from the consumption of bursts of large currents from the input source) may be entirely diminished or at least reduced. Additionally, the proposed buffering circuit may be associated with one or more of the following advantages, as well as additional advantages as will be clear to a person who is of skill in the art: High efficiency, less heat dissipation, longer battery life, smaller size (It takes less space: less than 0.1 the size of an NTC inductor solution). Also operation of the load in variable working condition (such as: variable output power, variable pulse width and variable frequency), can be achieved without adjusting the hardware, by utilizing one or more of the processes described above with reference to **Figs. 3C to 3F**, and particularly process **190**. When using none static working conditions, the dynamic control can offer special modes of operation that overcomes the sporadic demands for power. Co existence: if the momentary output power is reflected onto the power input, it will cause a voltage drop for every output pulse. This can disrupt other units that use the same input power. Electromagnetic Interference (EMI): Consumption of large currents in bursts, from an input source that is connected to the driver with wires may cause EMI emissions.

The use of the above described techniques is beneficial for at least the following types of power sources: battery, USB port & DC power supply. By using the proposed technique, the power source (battery, USB port or DC power supply) will supply only the average output power instead of the momentary output power. It can reduce the power source output current by a factor of at least 10 (depend on the output duty cycle). To this end, in many situations, without the proposed buffering circuit it won't be possible to use USB port as the power supply, for a driver of a high power device. The buffering circuit provides for reducing the peak output power which is consumed by the load or driver thereof. The circuit is suitable for use in mobile systems and can be produced with cost effectively and with small form factor and physical size.

- 43 -

Reference is made to **Fig. 4A** which is a block diagram illustrating a driver system (herein after driver) **200** for operating a load according to an embodiment of the present invention. The driver system **200** may be used of operation a load while limiting the energy consumed by the load, and optionally also the power consumption of the load. In the present example the driver system is configured and operable for safe operation of a light source, such as a laser. In this example, the load **20** is a laser system. The driver system **200** is associated with electrical power input **PWR_IN** for receiving electrical power (e.g. from a power source **10** or from a buffering circuit **100** as that described above) and an electrical power output **PWR_OUT** connected/connectable to the load (e.g. to the laser light source) to be activated by the driver system, and an energy limiter **230** adapted for limiting the energy supplied to the load. According to the present invention the energy limiter **230** is implemented as an analogue device including: a current integrator **232** adapted to obtain a measure signal indicative of the current supplied to the load, integrate the value of the measured current over time, and generate an integration signal indicative of the integrated value of the current over time; and a comparator **234** connectable to the current integrator for receiving the integration signal (e.g. voltage signal), and comparing it with a reference value/signal (e.g. voltage signal) indicative of the maximal energy that can be provided to the load. Based on that comparison (e.g. in case the integration signal is greater than the reference signal), the comparator generates a *maximal energy exceeded* switching signal. The driver system **200** also includes a switch module **210** (herein also referred to as switch) associated with the output port **PWR_OUT**. The switch is connectable to the comparator **234** for receiving the *maximal energy exceeded* switching signal therefrom. The switch is adapted for operating a switching function to disconnect/connect power to the output **PWR_OUT** based on the *maximal energy exceeded* switching signal. For example in case a *maximal energy exceeded* switching signal exists/is over a certain value, the switch **210** disconnects the power/electric-current to the load. Accordingly the driver system provides for limiting the energy supplied to the load. As a result, when utilizing driver **200** with a laser system connected thereto as the load **20**, the laser can safely operated when the level of the *maximal energy exceeded* switching signal is set to the proper level allowed by the required safety class of the laser.

In certain embodiments of the present invention the current integrator includes or is associated with a separate current measurement circuit **220** that is adapted to

- 44 -

measure or obtain data signals indicative of the current through the output **PWR_OUT**. The measurement circuit **220** may be configured to provide, at its output, a voltage signal indicative of the measured current. The current integrator integrates that voltage signal to obtain a value indicating the total current (e.g. the energy) through the output **PWR_OUT** during a certain time period (e.g. which may be between resets of the current integrator).

As will be clarified in more details below the integrator may reset automatically, after the current through the output **PWR_OUT** is diminished (after the load's pulse is over). This may be achieved by configuring the time constant τ of the current integrator circuit to be shorter than the time period between operations/pulses of the load (e.g. the time constant of the integrator is about 10% of the total D_{cycle} time of the loads operation). This gives enough time for the integrator to reset itself, once the load is inoperative, namely when the measured current (and accordingly the voltage of the measurement circuit **220**) is zero. For example at D_{cycle} of 10% and with pulses Frequency of 10Hz, the time for reset the integration signal is 90mSec which about 5time more than needed – since the integrator time τ is 10mSec.

In certain embodiments of the present invention the current integrator module **132** includes a suitably configured *integrator circuit* (also referred to in the following as exponential response circuit or *exponential behaving circuit*) connectable to the output of the measurement circuit **220**. The voltage response and/or current response of the *exponential behaving circuit* generally behaves exponentially in time, and in good approximation behaves linearly for certain limited time scales (e.g. for times shorter than a time constant τ of the circuit, and more preferably shorter than 0.5τ). To this end the current integrator module **132** may include such an *exponential behaving circuit* formed for example as an RC circuit, an RL circuit, and/or as a so called *charge amplifier* circuit (the later typically includes operational amplifier and a capacitor). According to the technique of the present invention, a measure of an exponential behaving voltage/current measured/sensed certain one or more elements of such *exponential behaving circuit*, may be used as an indication to the integral current supplied to the load, at a given time and thus as indication of the total energy supplied to the load **20**. Although in the following the use of an RC circuit as an *exponential behaving circuit* is described in more details, it will be appreciated by those versed in the art that other types of exponential behaving circuits, such as RL and charge

- 45 -

amplifier circuits, may be used to integrate the current flow to the load without departing from the scope of the present invention. This is discussed in more details below with reference to **Fig. 4C**.

To this end, in certain embodiments of the present invention an RC circuit
5 connected to the output of the measurement circuit **220** and serves as an exponential behaving circuit when, such that when current flows through the output **PWR_OUT** a voltage signal generated at the measurement circuit **220** is applied to the RC circuit thus charging the capacitor of the RC circuit. Accordingly, the value of the voltage on the capacitor of the RC circuit is used as an indication to the value of the current through
10 output **PWR_OUT** integrated over time. To this end the capacitor of the RC circuit may be connected to the comparator **234** such that the voltage on the capacitor of the RC circuit serves as the integration signal, which is compared against the reference signal by the comparator **234** to determine the whether the energy provided to the load exceeded the maximal level associated with the reference signal.

15 In this regards it should be understood that the value of the integration signal is not necessarily equal to the integrated value of the current over time, but it may be considered to be indicative thereof in the sense that under certain consequences (e.g. when load with suitable parameters is used and the of the properties of the RC circuit are selected in accordance thereto and according to the voltages and currents used in the
20 driver **200**) that a one to one monotonic correspondence (function) exists, relating the voltage on the capacitor of the RC circuit and the energy supplied through the output **PWR_OUT** (as long as the RC circuit is not reset (e.g. as long as the capacitor is not discharged). Accordingly the value of the voltage on the capacitor may serve as indication of the energy supply through **PWR_OUT**. The value of the reference signal
25 that is provided to comparator **234**, is also selected in accordance with the one to one correspondence between the integration signal and the actual amount of energy supplied through the output **PWR_OUT** such that the *maximal energy exceeded* switching signal is issued by the comparator **234** when the actual amount of energy supplied through the output **PWR_OUT** exceeds the permitted level.

30 It should be noted that in certain embodiments where an RC circuit is used for integrating the current through the output **PWR_OUT**, the capacitor and resistor used are selected in accordance with the properties of the load (its voltage and current consumption and the maximal energy allowed to be provided to the load). In some cases

- 46 -

the capacitance C and resistance R values of the RC circuit are selected such that the time constant $\tau = R \cdot C$ of the RC circuit is equal or shorter than the max time it takes the maximum allowed pulse (energy) to generate a voltage on the capacitor, which reaches the threshold level of the comparator. This provides that current integrator is
 5 suitable configured for integrating the output current. In certain embodiments of the present invention the capacitance C and resistance R values are selected so as to fulfill three prominent conditions:

- (i) the resistor value R should be sufficiently large so as not to affect the accuracy of the current measurement by measurement circuit/sensor **220**;
- 10 (ii) $\tau = R \cdot C$ is set to about half the maximal pulse width; and
- (iii) The capacitor and resistor can withstand the current and voltage needed to be measured/applied thereto.

In particular in some embodiments the capacitance C and a resistance R of the RC circuit are selected based on the operational parameters and particularly the pulse
 15 width of the load, as follows. Considering the value $MVO_{\max}$ denoting the value of the voltage signal **CurrentVsig** provided by the measurement circuit **220** for the max allowed current output to the load **20**, then RC are selected such that after (e.g. $MVO_{\max}$ measured voltage output for max allowed current) this will determine the type of capacitor, the capacitor should be no more than 10% accurate, for max energy pulse
 20 with max power we can calculate the pulse width energy/power = pulse width the ,
 $0.8 \cdot V_{\text{threshold}} = V_{\text{capacitor}}$, $(t) = MVO_{\max} \cdot (1 - \exp(-t/RC))$ @ $t = 0.5RC$.

It should be noted that in certain embodiments of the present invention an LC circuit can be used as a current integrator for cases where the load is to be operated in very short pulses (e.g. in the order of up to microsecond pulses. However, using such an
 25 LC circuit as current integrator for loads operation in longer pulses (e.g. in the order of milliseconds to second pulses) might be cumbersome and require a relatively large real-estate, because in such cases a very large inductor and capacitor will be required. Thus, use of an RC circuit as described above might be preferable for the purpose of integrating the current to laser light sources, such as those used in laser projection
 30 systems, (which pulse durations are in the order of milliseconds).

Optionally, in certain embodiments of the present invention the driver system **200** also includes a power limiter **240** adapted for limiting the peak power supplied to the load. The power limiter may be associated with the current measurement circuit **220**

- 47 -

(or with another current measurement circuit measuring the current through output **PWR_OUT**). The power limiter **240** includes a second comparator **244** connectable to the current measurement circuit **220**. The current measurement circuit **220** is adapted to provide the second comparator **244** with a voltage signal indicative of the measured
5 current. In turn the second comparator is configured and operable for comparing the voltage signal from the measurement circuit **220** with a second reference voltage/signal indicative a maximal allowed value of the measured current. Based on the comparison, the comparator generates a *maximal power exceeded* switching signal, in case the current exceeded the maximal value of the allowed current through the output
10 **PWR_OUT**. The switch module **210**, is connected to the second comparator **244** and upon receiving the *maximal power exceeded* switching signals, it is adapted for switching of the power to the output **PWR_OUT**.

To this end, the switch may be configured and operable for operating a switching function based on the *maximal energy exceeded* and the *maximal power exceeded* switching signals to accordingly enable or disable electric current to the load.
15 In some embodiments of the present invention the load includes one or more laser diodes. The *maximal energy exceeded* and the *maximal power exceeded* switching signals are associated with maximal radiant power and maximal integrated radiance laser safety measures, and their values correspond to the laser safety class which needs to be met. For laser type loads, the switch module **210** may be configured to disable the operation of the load/laser when at least one of a maximal power or maximal energy provision to load is exceeded. This enables safely operation a laser type loads by limiting both their instantaneous power and the total energy of their output pulses to not exceed the maximal values allowed by the safety class associated with the laser's
20 operation. It should be noted that one of the advantages of the present invention lies in the fact that the total energy supplied to the laser at a given period, and the instantaneous power supplied to the laser are independently and accurately measured and determined by analogue means. In particular, the energy provided to the laser is accurately determined by analogically integrating the current (i.e. which generally
25 corresponds to the instantaneous power) supplied to the laser over time. These features of the present invention provides much needed flexibility, in operation the laser **20** with variable power over time while not exceeding the power and energy limitations of the laser.

- 48 -

In certain embodiments of the present invention the driver system **200** also includes a control system **250** which is adapted for monitoring and/or controlling the operation of the load. For example the control system **250** may be connectable to the switch module **210** and configured and operable triggering the operation of the load on and off. Thus, in certain embodiments of the present invention the switch may be adapted for receiving a control signal from the control system, indicating whether power should be supplied to the load as well as the *maximal energy exceeded* and possibly also the *maximal power exceeded* signals indicating whether operation of the load is within prescribed energy and power limits. The control system **250** may also be adapted for monitoring if the *maximal energy exceeded* and/or if the *maximal power exceeded* in order to provide feedback to a control module (not specifically shown in the figure) operation the laser/load regarding the operation of the laser/load (e.g. whether it is operation or not).

Also, in some embodiments of the present invention the control system **250** may be configured and operable to serve as supplementary/secondary laser safety measure. In such embodiments the control system **250** may be connectable to the current measurement circuit **220**, and adapted for receiving therefrom data/signals indicative of the current provided to the load/laser **20**. The control system **250** may, in this case, limit the power of the laser by digitally comparing the value of the measured current with a certain maximal current limit associated with the maximal allowed power and in case the measured current exceeds that value, operate the switch **210** to disconnect the load/laser **20**. Alternatively or additionally, the control system **250** may limit the energy to the laser by digitally integrating the value of the measured current over time and comparing the result of the integration with a certain maximal integrated current value associated with the maximal allowed energy of the laser. In case the digitally integrated value of the current exceeds the maximal allowed integrated current limit associated with the maximal allowed energy limit, the control system **250** operates the switch **210** to disconnect the load/laser **20**. It should be noted that the above digital calculations may be performed based on a certain a priori known voltage value of that is provided to the laser **20**. In such cases, the maximal allowed current limit and the maximal allowed integrated current limit, are respectively proportional to the maximal allowed power and the maximal allowed energy, with the voltage V provided to the load being the proportion constant. In cases the voltage is not a priori known to the required accuracy,

- 49 -

the system **200** may include a voltage measurement module/circuit (not specifically shown in the figure), which may be configured provide the control system **250** with data/signals indicating the voltage provided to the load/laser **20**. In turn, the power to the laser may be determined by the control system **250** by digitally multiplying the measured voltage with the current measured by **220**. The control system may compare the measured power, which was calculated based on the current and voltage measurements, and compare it with the actual maximal power limit, to stop the laser when the power exceeds the limit. Similarly, the energy provided to the laser may be accurately determined by integrating the measured power over time, and the laser may be stopped once the energy exceeds the maximally allowed energy limit.

It should be understood that the above digital power and energy limitations which may be digitally imposed by the control system, may typically only serve as secondary/supplementary laser safety precautions, as in many jurisdictions, such digital safety measures are not considered as reliable as the analogically implemented measures.

Alternatively or additionally, control system **250** may use the data indicative of the energy and power provided to the laser in order to provide feedback to a control module (not specifically shown in the figure) that controls/adjust to laser's operation, so as to enable such control module to consider the amount of energy and the power provided to the laser, and determine the remaining amount of energy and power it has at its disposal for further operation of the laser before the energy and/or power limits are exceeded. It should be understood that such a control module may be implemented as a software/hardcoded module part of controller **250** and/or by a separate processing module. For example, as described above, such a control module may be a processing module of a projection system which utilizes/operates the laser to project light (e.g. light patterns on the scenery. The feedback, which is provided from control system **250**, may be used by such control module to adjust the projection properties, and optimize the power and the energy of the projected light, without exceeding the safety limits associated with the laser's safety class.

Reference is made to **Fig. 4B**, is a schematic illustration of an electric circuit implementing a driver system **200** according to an embodiment of the present invention. The circuit is shown schematically in a way that would be readily understood by those versed in the art. Also references are made in the figure to portions of the circuit which

- 50 -

are associated with the modules described above with reference to **Fig. 4A**. Nevertheless certain elements/modules of the driver system **200** in the illustrated circuit are discussed in more details below.

The driver system **200** includes a switch module **210**, connected to an input
5 power source **10** (via legs **12** to **17**), and to load **20** formed as a laser system (via legs **6** to **11**). Multiple input and output legs, of the switch are used in this case due to the relatively high currents/power consumption of the load **20**. In the present example the switch module **210** is implemented as a power stage by utilizing two properly wired MOSFET transistors, as will readily be appreciated by those versed in the art. A current
10 measurement module **220** is electrically connected between the switch and the load and configured for measuring the current provided to the load, and generating a voltage signal indicative thereof. In the present non limiting example the current measurement module **220** is implemented by utilizing an operational amplifier **U4** connectable via legs 4 and 5 thereof in parallel to resistor **R8** which is further electrically connected
15 (directly/or indirectly) to the load **20**. The current to the load is measured by the operational amplifier(*shunt resistor Amplifier*) **U4** and a corresponding voltage signal **CurrentVsig** indicative thereof is generated and provided through leg **1** of the operational amplifier **U4**. As will be appreciated by those skilled in the art, in various embodiments of the present invention the switch **210** and the current measurement
20 module **220**, can be implemented in various techniques without departing from the scope of the present invention. For example the switch **210** can be implemented for example by the use of a MOSFET or some sort of solid-state switch, and the current measurement module **220** can be implemented utilizing any suitable sensor type such as *eSense* sensor and/or Hall effect sensor or other suitable sensors for measuring currents.

25 Voltage signal, which is outputted at leg **1** of the current measurement module **220**, is provided to the energy limiter module **230** and the power limiter module **240** via proper electrical connections.

In the present example the energy limiter module includes an RC circuit connecting the output of leg **1** to the ground potential via a large resistor **R5** of 330 k Ω
30 and a capacitor **C6** of 47nF/4V that are connected in series and a comparator **234** with the designator **U1B** is connected to the capacitor **C6** and to a reference voltage **Vref_2** (set to 0.3V). In this embodiment of the present invention, the RC circuit formed by the resistor **R5** and the capacitor **C6** is configured as a current integrator **232** integrating the

- 51 -

value of the current measurement signal **CurrentVsig**, which value is a measure indicative of the current flow to the load (e.g. being an analogue measure indicative of the power provided to the load/laser). The voltage **CurrentIntegralSig** on the capacitor **C6** of the current integrator **232** thus provides a measure to the integrated current flow to the load over time (e.g. being an analogue measure indicative of the energy provided to the load/laser). This is because as long as current flows to the load, the **CurrentVsig** generated by the current measurement module **220**, charges the capacitor **C6** thus increasing its voltage which is actually the **CurrentIntegralSig** voltage indicating the integration of the current over time.

It should be noted that according to the invention the laser/load, when operates, is configured to consume a current that is above a certain minimal value $I_{\text{threshold}}$ current consumption. Accordingly, under this assumption, when operation the load in this way the current integrator module **230** operates properly for integrating the current to the load. To this end the current integrator module **230** may be designed (e.g. by proper selection of the time constant τ of the circuit and the measurement circuit **220**, such that the when the load is operated at currents above $I_{\text{threshold}}$, the current integration performed by current integrator module **230** is performed accurately.

Comparator **234** received the integrated current voltage signal **CurrentIntegralSig** at leg **6** thereof and the reference signal **Vref_2** at leg **5** thereof, compares them, and incases the **CurrentIntegralSig** is greater than the reference signal, the comparator issues a max energy exceeded signal **DISBLE** via leg **7** of the comparator, which is electrically connectable to the switch **210** and possibly also to the controller **250**. To this end the value of the reference voltage signal **Vref_2** is set such that the max energy exceeded signal **DISBLE** is issued only when the integrated current (indicated by the **CurrentIntegralSig** signal) is greater than a certain value associated with the maximal energy that is allowed to be provided to the load **20**. This is achieved via the **3V3_LP** circuit that is illustrated in the figure, if the controller **250** did not enabled the signal **3V3_LP** then all thresholds as set to 0V there for the switch **210** is disconnected. This will be readily understood by a person of ordinary skill in the art

Turning now to **Fig. 4C**, the operation of an *exponential behaving circuit* of integration the current to the load is exemplified graphically in graphs **G1** and **G2** wherein **G1** illustrates the charge response to a step function and the **G2** illustrates the discharge response (e.g. the RC integrator reset Function). More specifically graph **G1**

- 52 -

shows how the RC circuit (C6 & R5) of the current integrator module **230** exemplified in of **Fig. 4B** behave as a function of the time the load is operated. **G1** represents the voltage V_C on the capacitor **C6** as a function of time (V_C is the **CurrentIntegralSig** indicating the integration of the current to the load over time). The step response of the

5 RC circuit as shown in **G1** generally corresponds to the general RC equation:

$$\text{CurrentIntegralSig} \equiv V_C = \text{CurrentVsig} * (1 - \text{Exp}(-t/\tau_E));$$

where **CurrentVsig** is the measured current signal applied to the RC circuit by the current measurement module **220**, **CurrentIntegralSig** is the voltage on the capacitor **C6** as measured by the comparator **234**, τ_E is the time constant of the RC circuit

10 calculated as $\tau_E = C6 * R5$, and t is the time lapse since the measured current signal **CurrentVsig** is applied to the RC circuit.

The capacitance and resistance values (C6 & R5) of capacitor **C6** and resistor **R5** are selected such that the time constant τ_E ($\tau_E = C6 * R5$) of the RC circuit of the energy limiter is equal or greater than the time duration of at least one pulse/one

15 operation period of the load such that the current integrator **132** is not saturated in the maximal time duration T_P of the operation/pulse of the load (e.g. the duration of one or more one operation interval of the load) and therefore can serves for integrating the current to the load during these operation intervals. $\tau_E > \sim T_P$. Even more preferably, in some embodiments of the present invention the time constant τ_E of the exponential

20 behaving circuit (e.g. of the RC / RL circuit) of the current integrator **230** RC is selected to be substantially greater (e.g. two, three or more times greater than T_P such that the RC circuit operates in substantially the linear regime of the exponential graph **G1**. It should be noted that according to certain embodiments of the present invention the accuracy of the RC circuit as a current integrator, is further improved by when selecting

25 the resistance and capacitance values R and C such that time constant $\tau = R * C$ is about twice or more the width/time period of the pulse of the load. Accordingly the threshold voltage **Vref_2** is typically set to be less (e.g. at about 80% of) the laser threshold current (the current below which there is no laser emission), such that when operating the laser with current above the laser threshold, the integrated voltage signal

30 **CurrentIntegralSig** raises above **Vref_2** when the ,maximal energy limit is exceeded.. Accordingly, in this case the response of the RC circuit is in the linear (about linear) regime of the exponent (it can be estimated by as a linear equation) and accordingly,

- 53 -

the value of the voltage V_c (being the **CurrentIntegralSig**) provides good and accurate measure to the integrated current that was provided to the load.

As indicated above, in some embodiments of the present invention the current integrator **132** may be implemented by utilizing a serial RL circuit.

5 Thus, in various embodiments of the present invention RC circuits and/or RL circuits and/or charge amplifier circuits, and/or other exponentially behaving circuits are used in the current integration module due to their exponential time response to input voltage applied thereon. A signal being either a voltage signal and/or a current measurement signal, sensed/measured on at least one component of such circuit (e.g. the
10 resistor or capacitor of the RC circuit, and/or the resistor or inductor of the RL circuit) may provide indication to the integral volume of current that had being provided to the load **20**.

Turning back to **Fig. 4B**, In some embodiments of the present invention the energy limiter **230** includes a reset feature adapted to reset the state of the Current
15 integrator **232** and accordingly to reset the value of the current integration signal **CurrentIntegralSig** that is provided to the comparator **234**. In this connection the load **20**, which may be a pulsed laser system, may be operated by the control system **150** in pulses, wherein the energy of each pulse or each predetermined number of pulses should, for safety reasons, not exceed the maximal allowed energy limit. Accordingly,
20 the control system may be adapted to operated the laser **20** in pulses, by issuing an operation signal **PWM_LASER** to the switch module **210**, and after every pulse, , of the laser **20**, resetting the value of the current integrator

As indicated above, the driver system **200** may also include a power limiter module/circuit **240** that is adapted to limit the instantaneous power provided to the laser
25 so that it does not exceed a certain maximal allowed power limit. In the present example the power limiter module/circuit **240** includes a comparator **244** including a comparator with open drain output **U1A** that is connected via leg **2** thereof of sensing a voltage signal **I_LASER** associated with the signal outputted at leg **1** of the current measurement module **220**. At leg **3** the comparators **U1A** is connected to a reference
30 signal **Vref_1** which value is selected and generated in accordance with the maximal allowed power limit to be imposed by the power limiter. In the present example the reference signal **Vref_1** with the suitable value is generated by the via the **3V3_LP**

- 54 -

circuit that is illustrated in the figure and which will be readily understood by a person of ordinary skill in the art

In the present example the power limiter module **240** also includes an RC circuit which is aimed at smoothing the current measurement over short time scales, which is with time constant of $1\mu\text{Sec}$, is at least 100 times shorter than the time scale of one operation pulse/time-interval of the load **20**. In other words the RC circuit is optionally used in the power limiter module **240** in order to shootout fluctuations of the current measurement signal from module **220**, and prevent such fluctuations from being falsely interpreted as a maximal current exceeded indication. To this end the RC circuit which is used herein has a different porous than that of the power limiter **240** and accordingly it is associated with an RC circuit time scale $\tau_p = R_{11} * C_{10}$ that is much shorter than that of the timescale τ_E of the energy limiter **240**. For instance in the present example a resistor **R11** of $1\text{ k}\Omega$ and a capacitor **C10** of $1\text{ nF}/10\text{ V}$ are used in the power limiter. These have much lower resistance and much lower capacitance than those of the energy limiter and accordingly their associated time scale $\tau_p = R_{11} * C_{10}$ is much shorter than of the duration of a pulse of the laser, so that this RC circuit of the power limiter operates to smooth the current measurement signal before it reaches the comparator **244** but does not integrate the current, as the case is in the energy limiter module. It should be noted that in general, according to the present invention the power limiter could also be implemented without using the RC circuit formed by **R11** and **C10**, although in such a case fluctuations in the current measurement signal **CurrentVsig** might cause false alarm issuance of max power exceeded signal, unless such fluctuations are handled by a different way. It should be understood that other techniques/methods for smoothing such fluctuations may also be used according to the present invention. For example a suitably amplifier with lower bandwidth circuit may be sued instead, or in addition to the above described RC circuit of the power limiter.

Comparator **244** receives, at leg **2** thereof, the voltage signal **I_LASER** associated with the signal **CurrentVsig** outputted at leg **1** (being smoothed in time by the RC circuit of **R11** & **C10**), receives the second reference signal **Vref_1** at leg **1**, compares the voltage signal **I_LASER** and the reference signal **Vref_1**, and incases the **I_LASER** is greater than the reference signal, the comparator issues a max power exceeded signal **DISBLE** via leg **1** of the comparator, which is electrically connectable to the switch **210** and possibly also to the controller **250**. In the present example the

- 55 -

same electrical connection are used to carry the max power exceeded and max energy exceeded signals to the switch and to the controller **250**, and therefore the same reference **DISBLE** is used to denote these signals. It should be understood that in some implementations the controller **250**, and possibly also the switch **210**, may be wired to
5 receive those signals separate such that the max power exceeded signal may be distinguished from the max energy exceeded signal (e.g. by the controller **250**).

Reference is made to **Fig. 4D** which is a flow chart **700** of a method according to an embodiment of the present invention for determining and possibly limiting the energy supply and possibly also the power supply to a load **20** connectable to a power
10 source **10**. In the following description of the method **700** reference numerals same as those of **Figs 4A to 4C** are used to describe the operation of similar elements/modules having similar of same functionality.

In operation **710**, measurement is applied (e.g. by measurement module **220**) to determine/sense a value of an electric current provided to the load. The measurement
15 yields a first voltage signal **CurrentVsig** indicative of the measured current. A current integration module **230** is provided in operation **720**. The current integration module **230** may be similar to that described above and generally includes an integrator circuit. For example the electric circuit may include a serial RC circuit, a serial RL circuit, and/or a charge amplifier circuit (e.g. including an operational amplifier and a
20 capacitor) may be used for current integration. The electric circuit of current integration module **230** has an exponential time response with a time constant τ selected in accordance with the time scale T_P during which for integration of the electric current to the load may be required. To this end, as indicated above, the values of R and C and/or the values of R and L in the RC/RL circuits respectively, may be properly configured to
25 satisfy this requirement.

Moreover, preferably, electric circuit of current integration module **230** may be configured such that its time constant τ is much lower (e.g. about third or below) the time scale T_P so that the time response of the current integration module **230** is in the linear regime of the exponential response. In this way better accuracy may be achieved
30 in determining the integrated current over a time up to T_P . Also, the capacitance C or inductance L of the electric circuit of current integration module **230**, as the case may be, may be selected in accordance with the magnitude/range of values which can be acquired by the first voltage signal.

- 56 -

In operation **730** the first voltage signal from the current measurement is applied to the electric circuit of the current integration module **230**. A second signal **CurrentIntegralSig**, being a voltage/or a current signal, associated with the time response of the electric circuit of the current integration module **230** is obtained in **240**.

5 As indicated above, the second signal may be for example the voltage on the capacitor C of the RC circuit, and/or the voltage on the resistor R or inductor L of the RL circuit, and/or the current through any of the resistor R, and the capacitor C or inductor L, of the RC or RL circuit of the current integration module **230** (e.g. the current may be measured via a second current measurement module). As the second signal has an

10 exponential time behavior/response, and since it is preferably measured within a time frame that is a fraction (e.g. 1/2 and more preferably 1/3 or below) the time constant τ of the circuit, it thus corresponds to the integral value of the current that is provided to the load over time.

In general, in various applications the second signal **CurrentIntegralSig** may be

15 used for various purposes where the integral current (which is proportional to the total energy – e.g. given the voltage on the load is constant that is provided to a certain device/load, needs to be determined by analogue means/circuits (as opposed to digital ones).

According to certain embodiments of the present invention the value of the

20 integral current provided to the load **20** (e.g. the energy to the load), which is a laser source, needs to be limited, so as not to exceed a certain value associated with faults during the operation of the laser. To this end, method **700** optionally includes the operation **750** in which the second signal **CurrentIntegralSig** is compared (e.g. via comparator **234**) with a reference signal to determine whether the integration of the

25 current provided to the load over time exceeds a predetermined limit (e.g. a maximal energy exceeded limit). In case it does (or alternatively as long as it doesn't) a third signal **DISABL** signal is issued indicating that the energy provided to the load exceeded a predetermined energy limit (or alternatively indicating the limit was not exceeded). The third signal **DISABL** may be provided directly or indirectly to a switch

30 module/controller controlling the operation of the load/laser, for stopping its operation in case it was operated beyond its maximal energy limit.

In optional operation **760**, the integrator is reset to zero after each laser pulse.

- 57 -

Method **700** optionally also includes operation **780** in which a power limit is imposed on the load. Here the first voltage signal **CurrentVsig** (being optionally slightly smoothed in time in operation **770** to remove/flatten short time fluctuations), is compared (e.g. by comparator **244**), with a second reference signal. The comparison is aimed at determining whether the current provided to the load (which is proportional to the power that is provided to the load) exceeds a predetermined power limit and if so (or alternatively as long as it doesn't) a forth signal (e.g. also referenced above **DISBLE**) indicating that the power provided to the load exceeded a predetermined power is issued. The forth signal may be provided directly or indirectly to a switch module/controller controlling the operation of the load/laser, for stopping its operation in case it was operated beyond its maximal power limit.

As indicated above, method **700** may also optionally include time smoothing operation **770** which precedes operation **780**, and by which first voltage signal which is used for comparing with the reference signal of the power limit is slightly smoothed in time to flatten fluctuations in the first voltage signal, and generate a smooth signal thus reducing false alarms which may be associated with such fluctuations.

Turning back to **Fig. 1**, according to some embodiments, the present invention provides a light-source/laser system/apparatus **500** including a buffering circuit **100** (similar to that described above in details with reference to **Fig. 1 and Figs. 2A-3G**), a driver system **200** (similar to that described above in details with reference to **Fig. 1 and Figs. 4A-4D**), and a laser emitter (e.g. including one or more laser diodes being the load **20**). The buffering circuit **100** is connectable to a power source **10** at its input and, at its output it is connected to the power input of the driver system **200** for providing power to the driver system **200**. In turn the driver system **200** is connected to the laser emitter **20** at its output. The laser system **500** may include a control system **300** configured and operable for receiving operational instructions for operating the laser emitter emitted and generating corresponding control signals to accordingly control/adjust the operation the laser emitter **20** (e.g. by activate a respective switch associated with the laser **20**). As indicated above, the buffering circuit **100** and the driver system **200** may also include respective controllers **150** and **250**. These may be implemented as separate modules and/or they may be integral with the control system **300**. The control system **300** and controllers **150** and **250** may include one or more digital processing units (e.g. DSPs) capable of processing signals required for operating

- 58 -

the laser emitter, controlling the power consumption consumed from the power source 10 by the buffering circuit 100 and optionally also monitoring the driver system's operation 200 and the safe operation of the laser 20. In this regards the control system 300 and/or the controllers 150 and 250 may be configured and operable for
5 implementing the respective methods 400 and 700 described above, and may include one or more memory module storing computer readable/executable instructions for executing these methods.

The control system 300 may include the controller 250 of the driver system 200, or it may be connected thereto. The later may be adapted to monitor the amount of
10 energy and optionally the power provided to the laser 20. Also the controller 250 may receive the analogue *maximal energy exceeded* signals/indications and possibly also the analogue *maximal power exceeded*, and may verify whether the energy and/or power to the laser exceeded the permitted safe values. The control system 300 may also include and/or may be connected to the controller 150 of the buffering electric circuit 100. The
15 control system 300 may use data indicative of the energy/power consumption of the laser 20 (as may be provided by the controller 250 of the driver system 200), and may record/use and provide this data to the controller 150 of the buffering electric circuit 100 to facilitate adjusting the current of the controllable current source 110 of the buffering electric circuit based on the required operation of the laser emitter 20 and the
20 energy and/or power consumed thereby in preceding operations of the laser 20 (in preceding pulses/operation intervals).

In certain embodiments of the present invention, the buffering electric circuit 100 is used as an additional eye safety measure. To this end, the controllable input power of the buffering electric circuit is used to apply a limit on the average output
25 power that can be consumed by the load. Accordingly, the control system 300 utilize data indicative of the max allowed output average power to the load/laser and operate the controllable current source of the buffering circuit so as to cap/limit the average input power consumed from the power source accordingly. In this manner, the energy limiter and the power limiter of the driver system may provide safety measures for
30 limiting the peak power and the total energy of each operation of the load, while the buffering circuit, in addition to its normal operation, may also be used for limiting the average power that can be provided to the load.

- 59 -

It is to be understood that the presently disclosed subject matter is not limited in its application to the details set forth in the description contained herein or illustrated in the drawings. The presently disclosed subject matter is capable of other embodiments and of being practiced and carried out in various ways. Hence, it is to be understood that
5 the phraseology and terminology employed herein are for the purpose of description and should not be regarded as limiting. As such, those skilled in the art will appreciate that the conception upon which this disclosure is based may readily be utilized as a basis for designing other structures, methods, and systems for carrying out the several purposes of the present presently disclosed subject matter.

10 It will also be understood that the system according to the presently disclosed subject matter can be implemented, at least partly, as a suitably programmed computer. Likewise, the presently disclosed subject matter contemplates a computer program being readable by a computer for executing the disclosed method. The presently disclosed subject matter further contemplates a machine-readable memory tangibly
15 embodying a program of instructions executable by the machine for executing the disclosed method.

While certain features of the invention have been illustrated and described herein, many modifications, substitutions, changes, and equivalents will now occur to those of ordinary skill in the art. It is, therefore, to be understood that the appended claims are
20 intended to cover all such modifications and changes as fall within the true spirit of the invention.

It will be appreciated that the embodiments described above are cited by way of example, and various features thereof and combinations of these features can be varied and modified.

25 While various embodiments have been shown and described, it will be understood that there is no intent to limit the invention by such disclosure, but rather, it is intended to cover all modifications and alternate constructions falling within the scope of the invention, as defined in the appended claims.

CLAIMS:

1. A buffering electric circuit, the circuit comprising: an energy storage module connectable to a load to which electric energy is to be supplied from said energy storage module; a controllable current source connectable to an electric power source and to
5 said energy storage module; and a controller adapted for controlling a current of the controllable current source so as to maintain an energy stored in said energy storage device within a predetermined range of energy values while restricting said current from exceeding a predetermined maximal current value.
2. The buffering electric circuit of claim 1 wherein said controller is adapted to
10 average said current such that a standard deviation of said current does not exceed a predetermined standard deviation threshold.
3. The buffering electric circuit of claim 1 or 2 wherein said controller is adapted to obtain data indicative of an operational parameters of said load and of the energy stored in said energy storage module, process said data to determine a value of the
15 current to be provided by said current source, and operate said current source to provide said current with said current value.
4. The buffering electric circuit of claim 3 wherein one or more of the operational parameters of said load are predetermined parameters associated with at least one of: (i) properties of said load and (ii) operational scheme used for operating said load.
- 20 5. The buffering electric circuit of claim 3 or 4 wherein one or more of the operational parameters of said load are determined in real time during the operation of said load.
6. The buffering electric circuit of any one of claims 3 to 5 comprising one or more measurement circuits associated with said load and connectable to said controller; said
25 one or more measurement circuits are adapted to directly or indirectly measure data indicative of one or more of the following operational parameters of the load: voltage provided to said load; current provided to said load; and power consumed by said load; and provide said data indicative of said one or more operational parameters to said controller; said controller processes said data to determine said current value based on
30 an estimated average power consumption of the load.
7. The buffering electric circuit of any one of the claims 3 to 6 wherein power consumption of said load varies in time.

- 61 -

8. The buffering electric circuit of claim 7 wherein said load is operated in pulse mode, and said operational parameters of the load include parameters indicative of the power consumption of the load during a pulse and a pulse duty cycle.
9. The buffering electric circuit of any one of the preceding claims wherein said
5 load is a high power load having instantaneous power consumption in the order of the maximal output power of the power source or above.
10. The buffering electric circuit of any one of claims 2 to 9 wherein said predetermined standard deviation threshold is selected so as to reduce interference effects between multiple power consumers connected to said power source.
- 10 11. The buffering electric circuit of any one of the preceding claims, wherein said predetermined maximal current value is selected so as to reduce the magnitude of voltage fluctuations in said power source to below a certain value.
12. The buffering electric circuit of any one of the preceding claims wherein said power source is a power source of a mobile system and includes one or more of the
15 following: a battery, USB port and direct current (DC) Power supply.
13. The buffering electric circuit according to any one of the preceding claims, wherein said energy storage module includes one or more energy reservoirs including at least one of a capacitor and inductor modules.
14. The buffering electric circuit according to any one of claims 3 to 13, wherein
20 said controller is adapted to determine the energy stored in said energy storage module based on the following: (i) energy stored in said energy storage module at certain time prior to one or more recent operational periods of the load; (ii) energy consumed by said load during said one or more recent operational periods; and (iii) energy provided to said by said controllable current source in the time duration from said certain time.
- 25 15. The buffering electric circuit according claim 14, wherein said controller is adapted to determine (ii) and (iii) utilizing data indicative of the following: (iv) the current provided by said controllable current source during operation of said load; (v) a duration of the operation of the load; (vi) the current provided by said controllable current source to said energy storage during non operation period of said load; (vii) a
30 duration of the non operation period of the load ; (viii) power consumption of the load.
16. The buffering electric circuit according claim 15, wherein said controller is connectable to a driver associated with said load for obtaining data indicative of one or more of (v) and (vii).

- 62 -

17. The buffering electric circuit according claim 15 or 16, wherein data indicative of (viii) is obtained by at least one of the following: a driver associated with said load, a measurement circuit adapted for measuring at least one of a current and a voltage provided to said load, and a predetermined data indicative of a power or current
5 consumption of the load.

18. The buffering electric circuit according and one of claims 15 to 17, wherein data indicative of (iv) and (vi) is obtained by at least one of the following: a measurement circuit adapted for measuring at least one of a voltage and a current at said energy storage module; and pre-stored data indicative of value of current previously provided
10 by said current source to said energy storage module.

19. A method for operating an electric load by an electric power source, the method comprising: determining a magnitude of a substantially constant current that should be consumed from the power source for one or more next operation intervals of the electric load; and operating a controllable current source for charging an energy storage module
15 that is connectable to said power source, with electric current of said magnitude from the power source to thereby store energy for operating said electric load in said energy storage; and wherein said determining comprising: obtaining data indicative of power consumption of the electric load during operation and, and estimating, based on said data, an expected energy consumption of the load in said one or more next operation
20 intervals; obtaining data indicative of a value of stored energy that is stored in said energy storage module; and estimating a magnitude of said electric current based on the estimated energy consumption of the load, the value of said stored energy, and a time duration to said one or more next operations of the load.

20. A driver system associated with an input for receiving electrical input power and an output connectable to a load to be activated by said driver; and comprising an
25 energy limiter adapted for limiting the energy supplied to said load; wherein said energy limiter comprises: a current integrator adapted to measure a current supply to said load, integrate a value of said current over time, and generate an integration signal indicative of said integrated value of said current over time; a
30 comparator connectable to said current integrator for receiving said integration signal, comparing said integration signal with a reference value, and, based on said comparing, generating a *maximal energy exceeded* switching signal; and a switch module associated with said output port and adapted for operating a switching function based on said

- 63 -

maximal energy exceeded switching signal to accordingly enable or disable electric current to said load;

21. The driver system of claim 20 wherein said current integrator comprises: a current measurement circuit adapted to measure current associated with said output port and provide, at an output of said measurement circuit, a voltage signal indicative of the measured current; and an RC circuit connectable to said output of said measurement circuit such that a voltage of a capacitor of said RC circuit associated with said integration signal is indicative of the measured current integrated over time.

22. The driver system of claim 21 wherein said comparator is connected to said capacitor of the RC circuit and configured for comparing said voltage of the capacitor of the RC circuit with a reference voltage associated with said reference value.

23. The driver system of claim 21 or 22 wherein a value of a capacitance and resistance of said RC circuit are selected such that a time constant τ of said RC circuit is longer than a maximal pulse width of an operation of the load thereby providing that said current integrator operates for integrating said measured current during the operation of the load.

24. The driver system of any one of claims 20 to 23 comprising a power limiter adapted for limiting the peak power supplied to said load.

25. The driver system of claims 24 wherein said power limiter is associated with a current measurement circuit adapted to measure current associated with said output port and provide a voltage signal indicative of the measured current; and a second comparator connectable to said current measurement circuit and adapted for comparing said voltage signal with a reference voltage indicative a maximal allowed value of the measured current, and based on said comparing, generating a *maximal power exceeded* switching signal; said switch module is adapted for operating said switching function based on said *maximal energy exceeded* and said *maximal power exceeded* switching signals to accordingly enable or disable electric current to said load.

26. The driver system of claim 25 wherein said switch module is configured such as to disable the operation of said load when at least one of a maximal power or maximal energy provision to said load is exceeded.

27. The driver system of any one of claims 24 to 26 wherein said power limiter includes an RC circuit interconnected in between said current measurement circuit and said second comparator.

- 64 -

28. The driver system of claim 27 wherein the RC circuit of the power limiter is configured and operable as a low pass filter and wherein capacitance C2 and resistance R2 of said RC are selected based on an allowed bandwidth of the load's operation.
- 5 29. The driver system of any one of claims 24 to 28 wherein said power limiter and said energy limiter are connectable to the same current measurement circuit.
30. The driver system of any one of claims 20 to 29 wherein said load includes one or more laser diodes, and wherein said *maximal energy exceeded* and said *maximal power exceeded* switching signals are associated with maximal radiant power and
10 maximal integrated radiance laser safety measures.
31. The driver system of any one of claims 20 to 30 wherein said load is operable in pulses and said energy limiter is adapted to reset value of said integration signal during a time between pulses of the load operation.
32. A light source system comprising a driver system according to any one of claims
15 20 to 31, and a light emitter connectable at the output port of said driver system and including one or more laser diodes.
33. The light source system of claim 32, comprising a control system configured for receiving operational instructions for operating said light emitter and generating corresponding control signals for controlling the operation of said light emitter; and
20 wherein said switching module is adapted for operating said light emitter based on at least said control signals *maximal energy exceeded* signals and said *maximal power exceeded* signals to thereby ensure safe operation of said light emitter in accordance with a laser safety class associated with said laser system.
34. The light source system of claim 32 or 33, comprising a buffering electric circuit
25 according to any one of claims 1 to 18, connectable to said input port of the driver system for providing electrical input power thereto.
35. The light source system of claim 34, comprising a control system configured for receiving operational instructions for operating said laser emitter and generating corresponding control signals for controlling the operation of said laser emitter; and
30 wherein data indicative the operation of said laser emitter is provided by said control system to said controller of the buffering electric circuit to facilitate adjusting the current of the controllable current source of the buffering electric circuit based on the operation of said light emitter.

- 65 -

- 36.** A method for determining an amount of electric energy supply to a load, the method comprising:
measuring an electric current provided to a load to obtain a first voltage signal indicative of a value of said electric current;
- 5 applying said first voltage signal to an analogue current integration circuit comprising at least one of electric element comprising at least one of a capacitor and an inductor; and obtaining a second signal associated with a voltage on said at least one of electric element; wherein said second signal is indicative of an amount of electric energy supply to said load.
- 10 **37.** An apparatus configured to obtain distance data from a two-dimensional image of a scene, said apparatus comprises a projector comprising: a laser system according to any one of claims 32 to 35; said projector is configured operate said laser system for projecting a coded light pattern on a scene, to thereby enable an image processing module to capture a two-dimensional image of the scene with the coded light pattern
- 15 projected thereupon, and to process said two-dimensional image to obtain distance data from said two-dimensional image.
- 38.** The apparatus of claim 37, wherein said projector comprises a control system adapted to operate said laser system for projecting said coded light pattern in the form of bi-dimensional coded light pattern;
- 20 **39.** The apparatus of claim 38, wherein said bi-dimensional coded light pattern comprises multiple appearances of a finite set of feature types, each feature type being distinguishable according to a unique bi-dimensional formation; and wherein said bi-dimensional coded light pattern is projected such that a distance between adjacent epipolar lines associated with substantially identical appearances of any given feature
- 25 type in said pattern is minimized according to a limiting epipolar separation factor, thereby giving rise to a plurality of distinguishable epipolar lines separated by approximately a minimum safe distance for epipolar line distinction.
- 40.** The apparatus of any one of claims 37 to 39, wherein said projector comprises a control system adapted to operate said laser system for projecting at least a first bi-
- 30 dimensional coded light pattern and a second bi dimensional light pattern;
wherein said first bi-dimensional coded light pattern includes a plurality of feature types, each feature type being distinguishable according to a unique bi-dimensional formation, and wherein and feature type comprises a plurality of elements

- 66 -

having varying light intensity, wherein said plurality of elements comprises: (i) at least one maximum element; (ii) at least one minimum element; and (iii) at least one saddle element; and

wherein said second bi dimensional light pattern is similar to said first bi-
5 dimensional coded pattern except that the one or more maximum elements and/or the one or more minimum elements are inverted to minimum elements and maximum elements respectively and said saddle elements remains unchanged;

thereby enabling to obtain locations of said projected elements in the scene by processing an image of the scene formed by subtraction of a first and second images of
10 the scene associated with projection of said first and second bi-dimensional coded light patterns.

41. The apparatus of any one of claims 37 to 40 comprising an imaging module configured to capture one or more 2D image of a scene with at least one coded light pattern and image processing module configured to process said two dimensional
15 images to determine data indicative of three dimensional parameters of the scene.

1/11

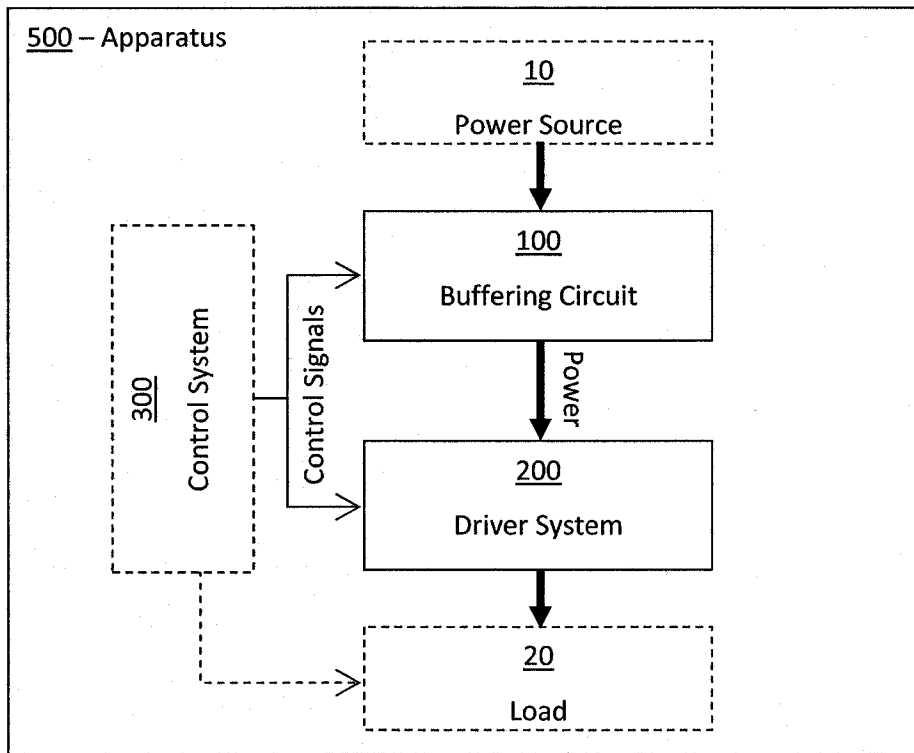


Fig. 1A

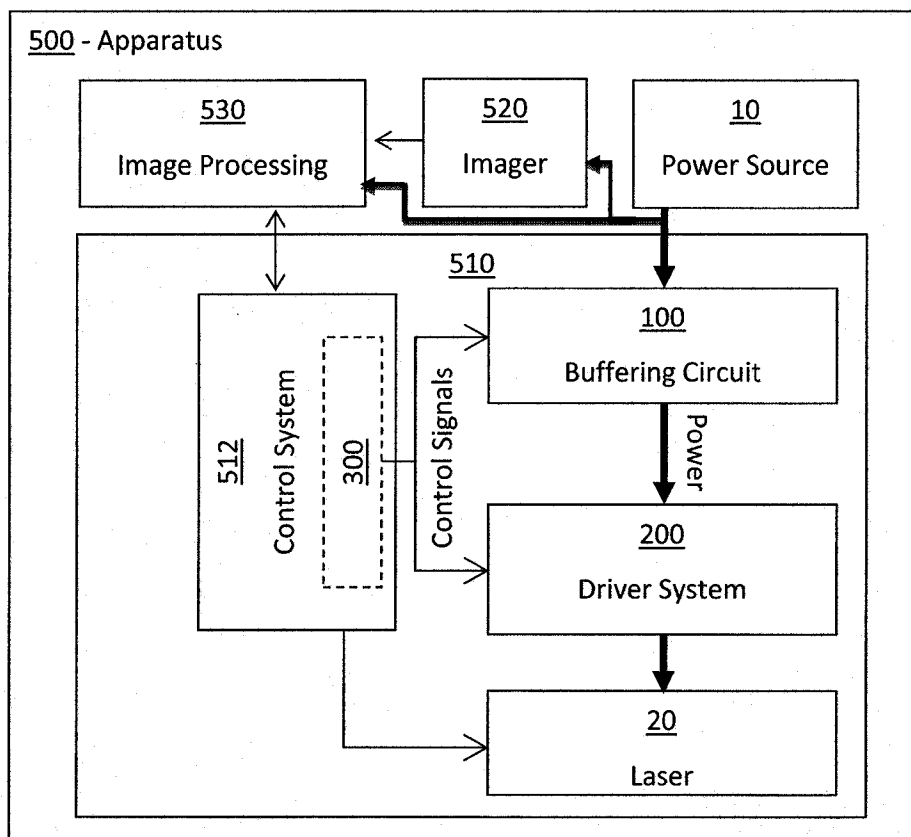


Fig. 1B

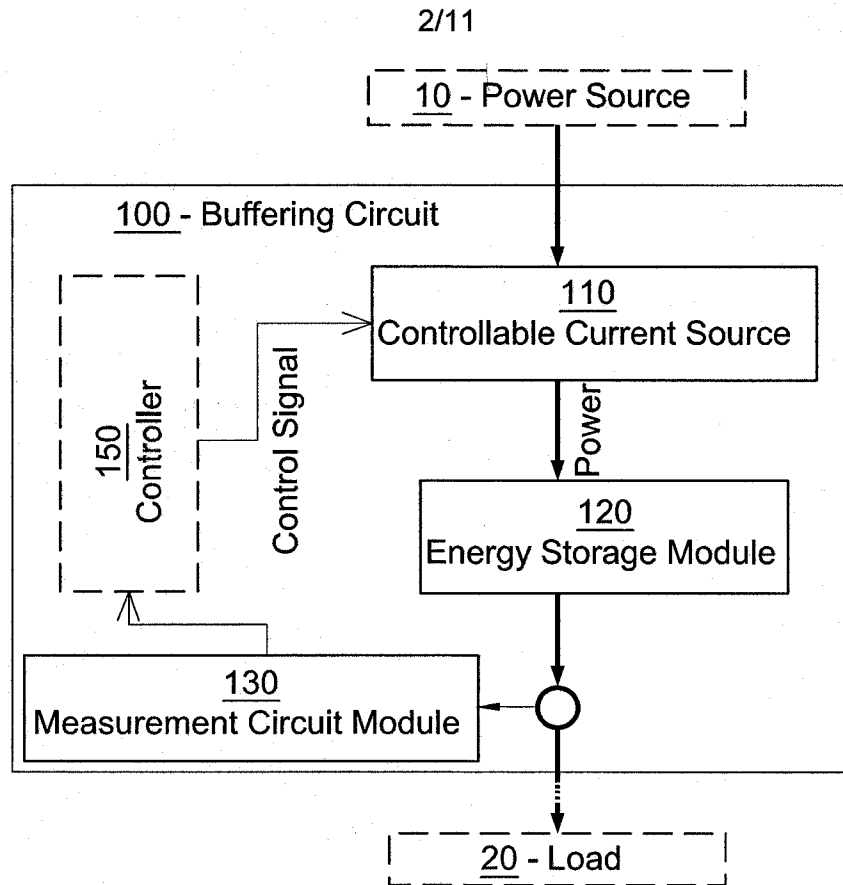


Fig. 2A

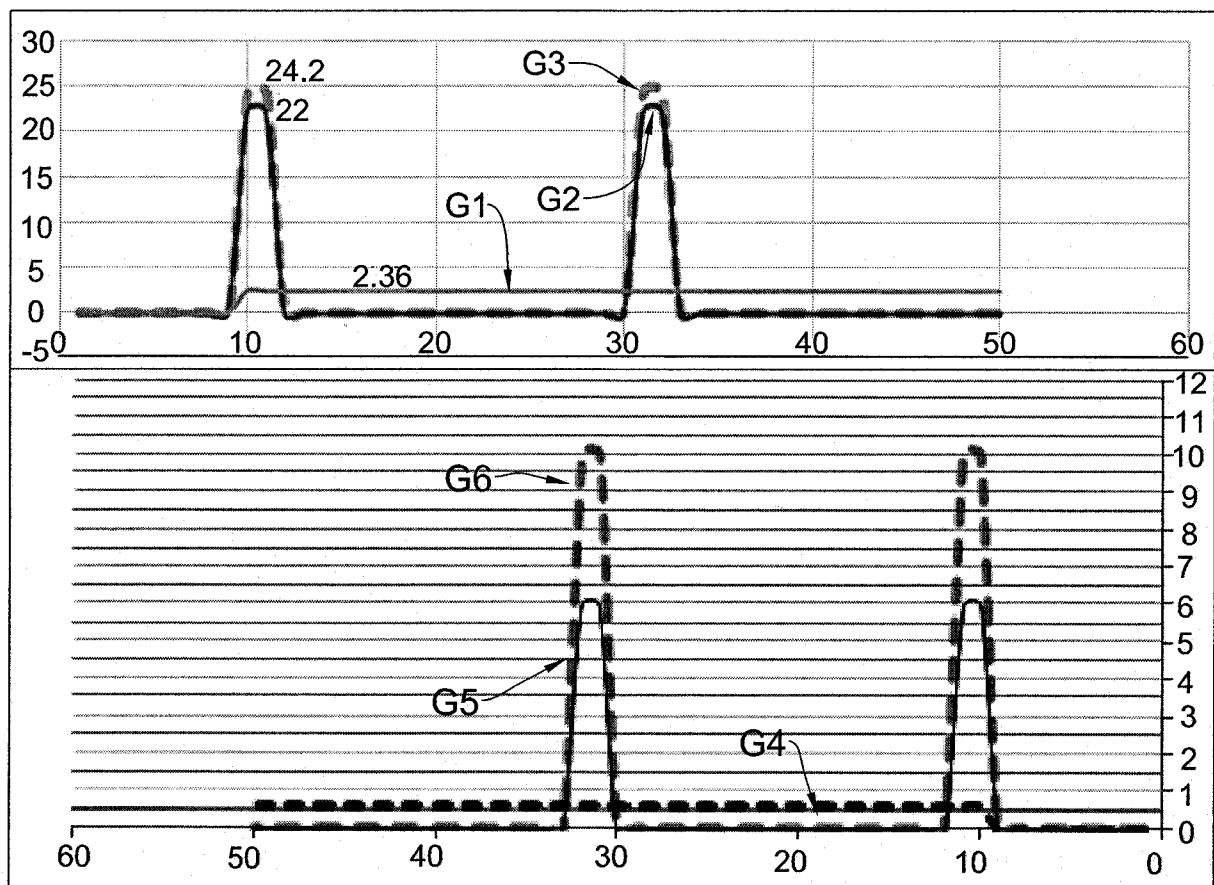


Fig. 2B

3/11

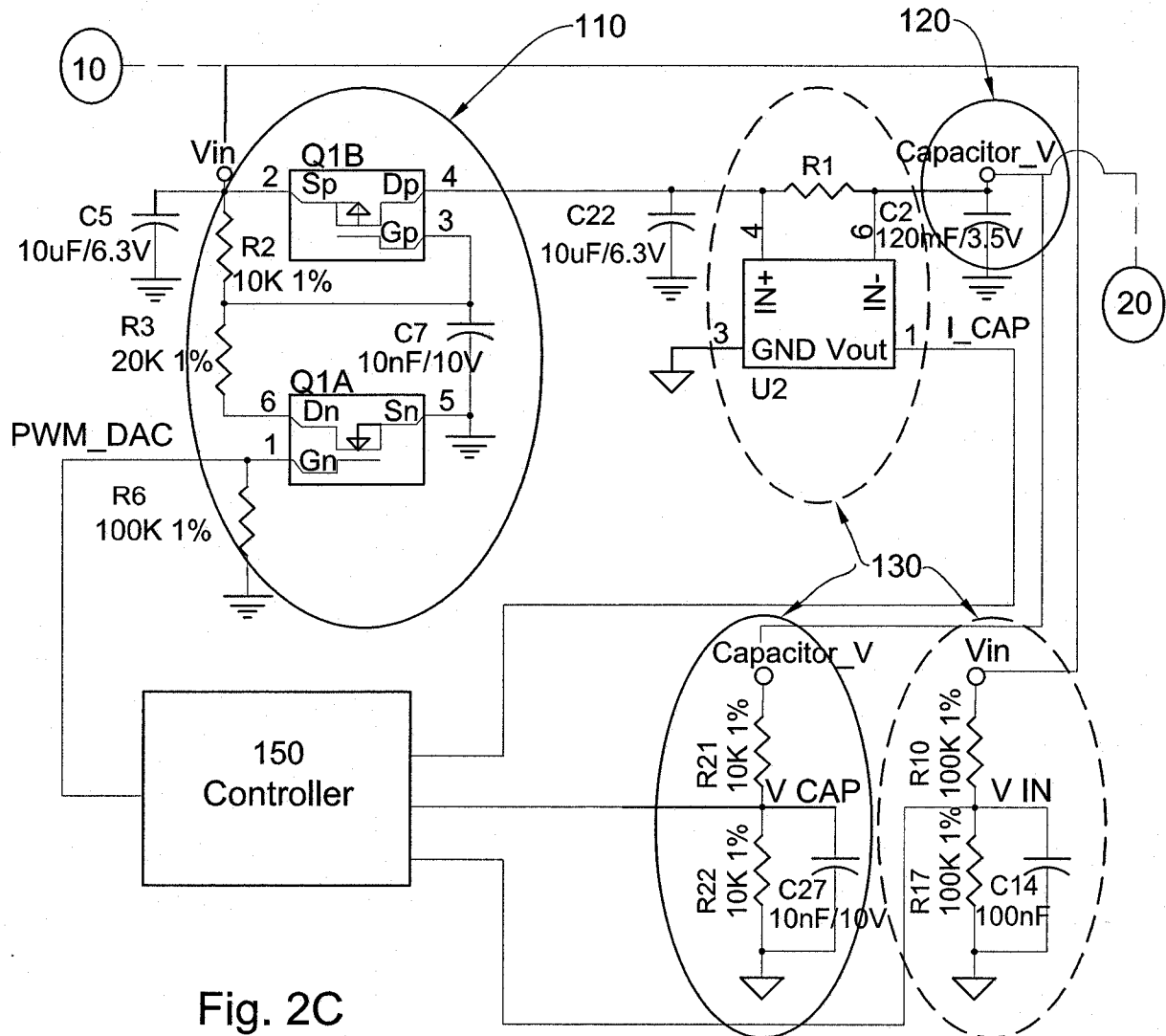


Fig. 2C

400

410 - Obtain data indicative of the operation of the load

420 - Estimate expected energy consumption of the load in the next operation(s)

430 - Determine/estimate the time to the next operation(s) of the load

440 - Obtain data indicative of the energy stored in the storage module

450 - Determine a current command to the controllable current source

Fig. 2D

4/11

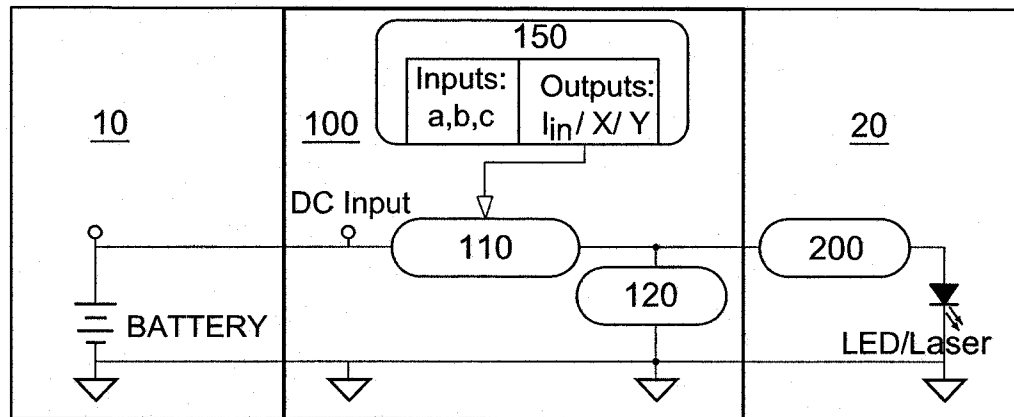


Fig. 3A

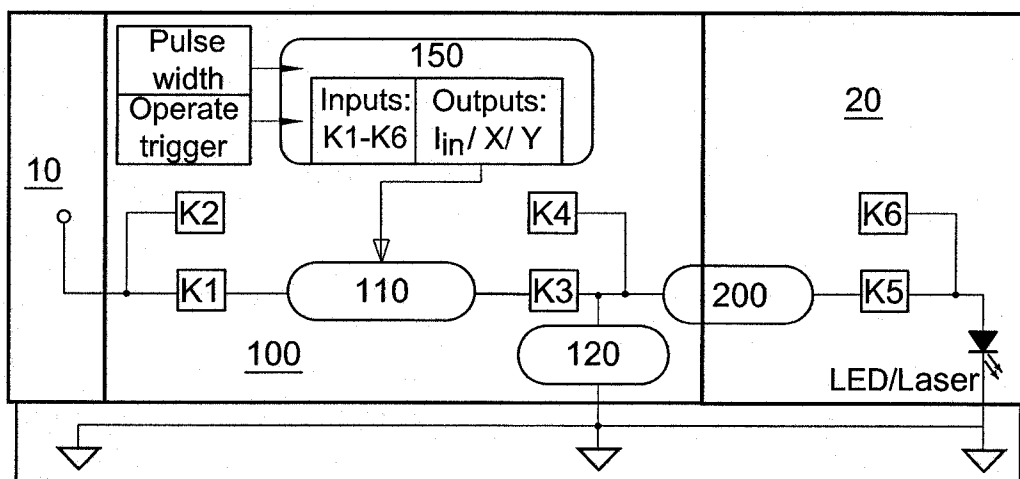


Fig. 3B

5/11

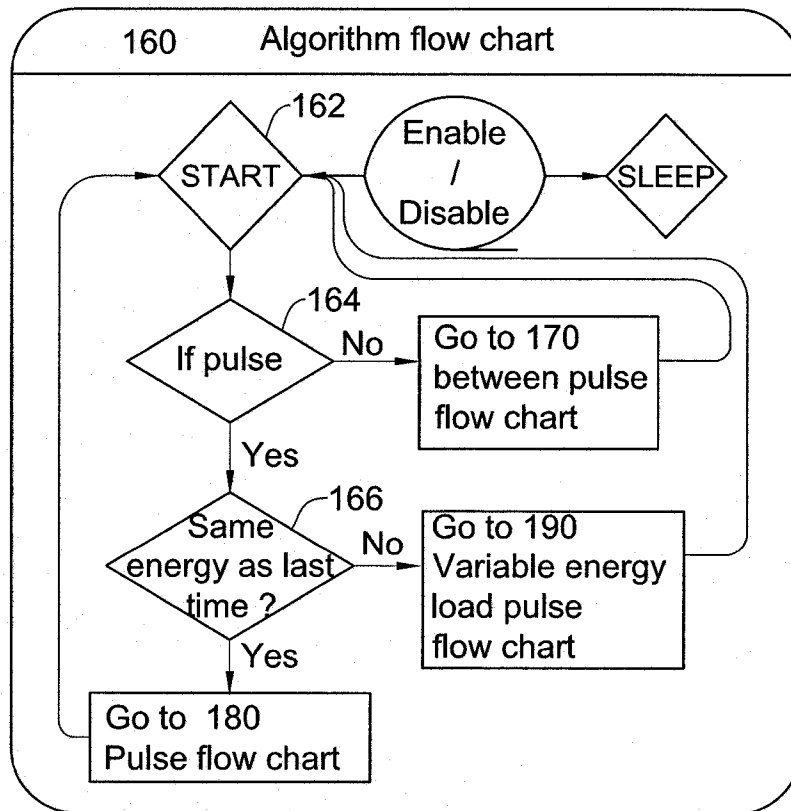


Fig. 3C

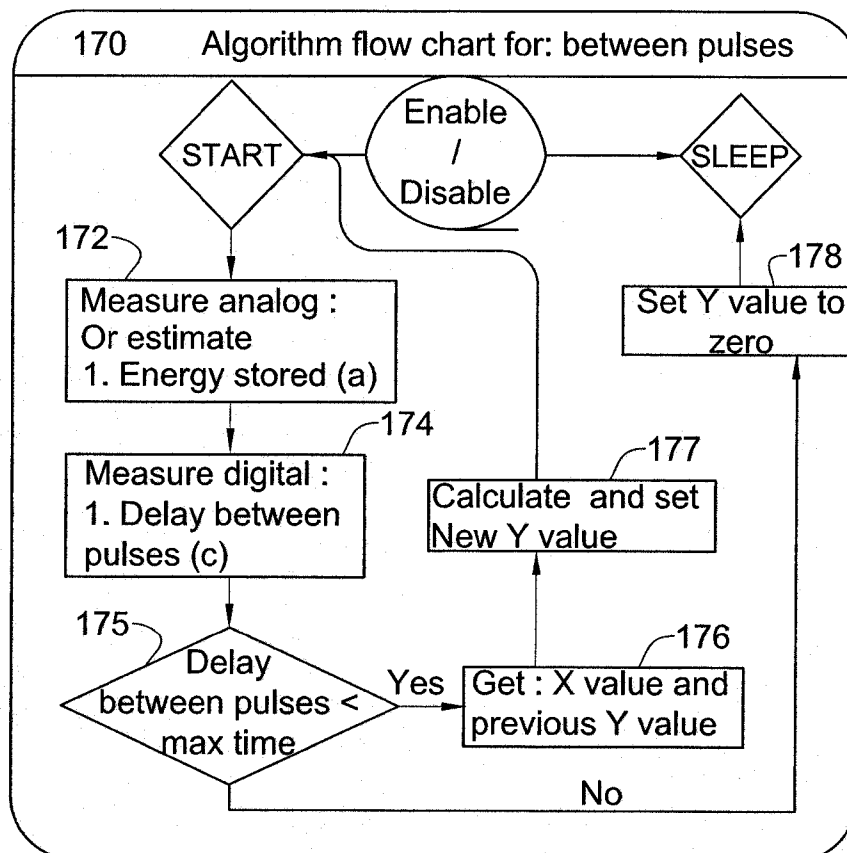


Fig. 3D

6/11

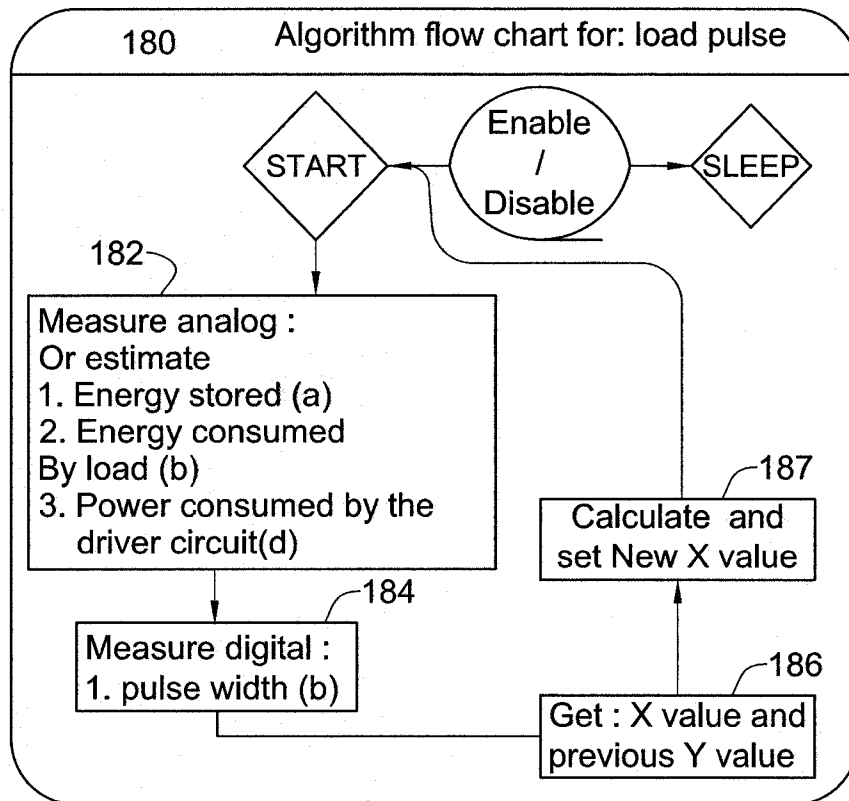


Fig. 3E

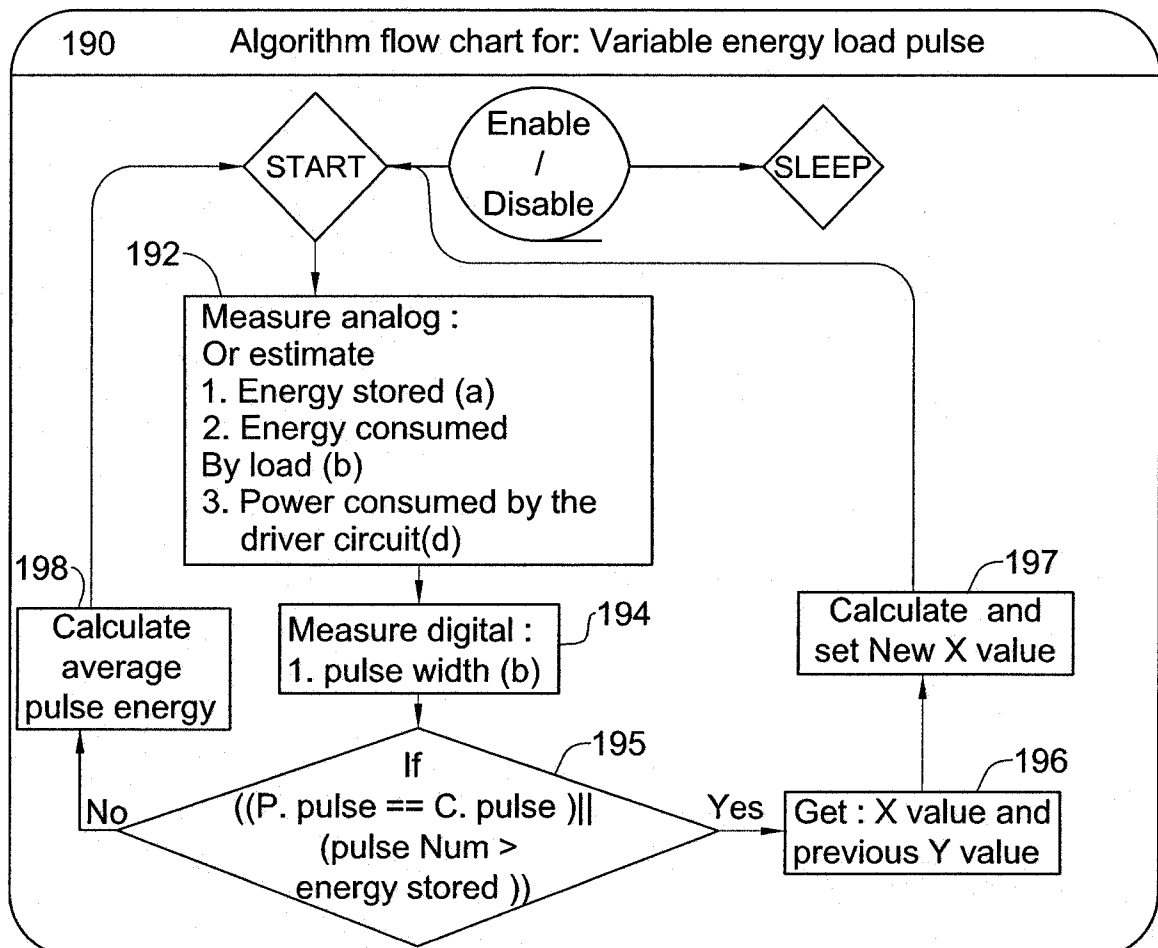


Fig. 3F

7/11

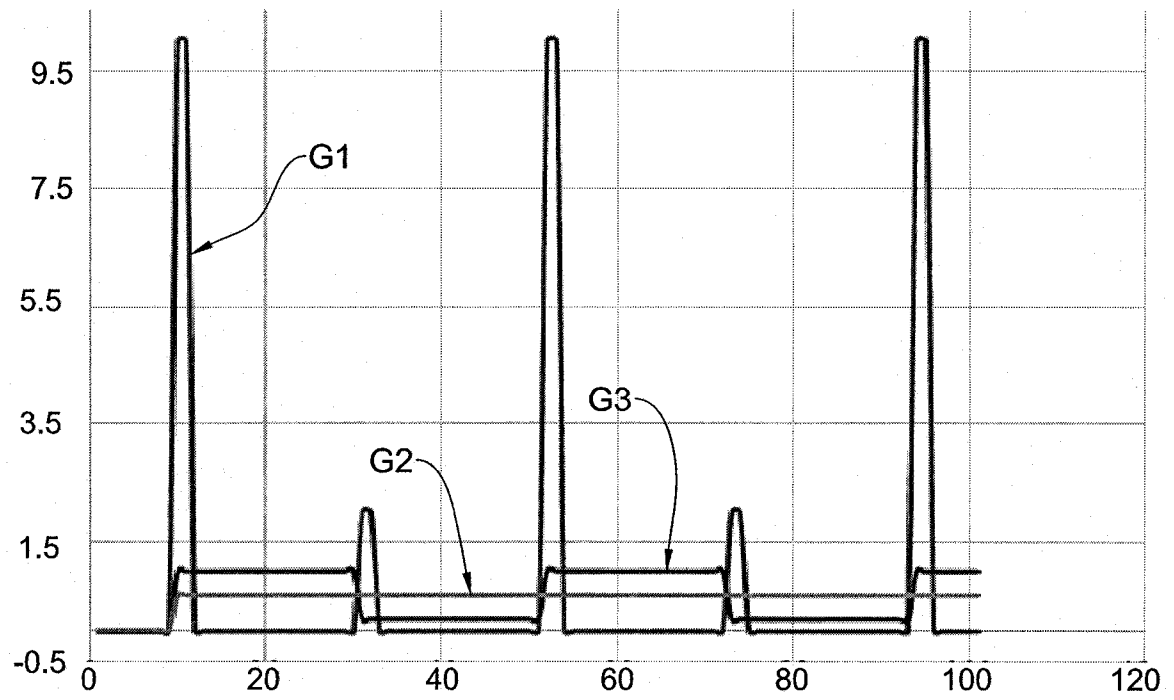


Fig. 3G

8/11

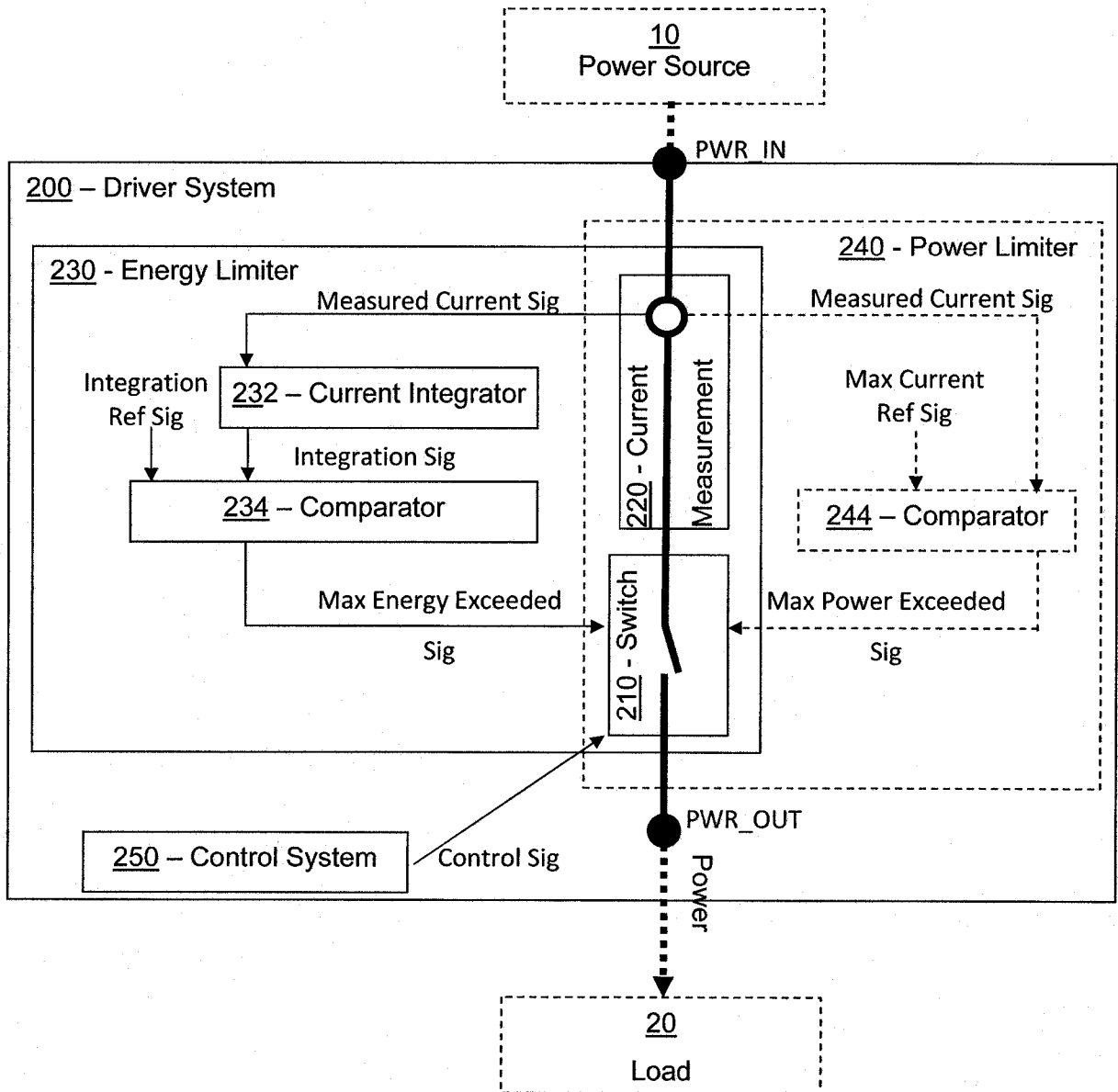


Fig. 4A

9/11

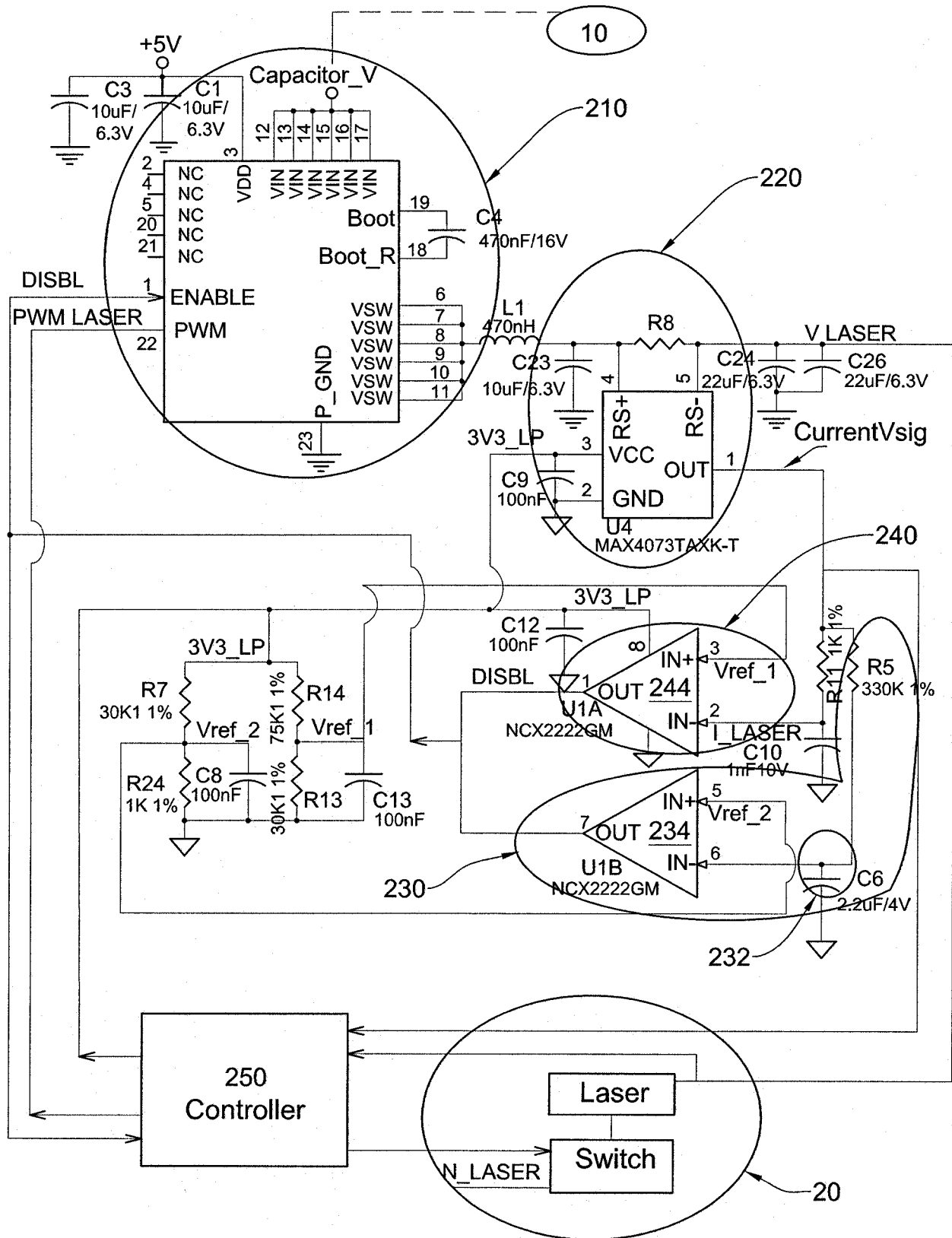


Fig. 4B

10/11

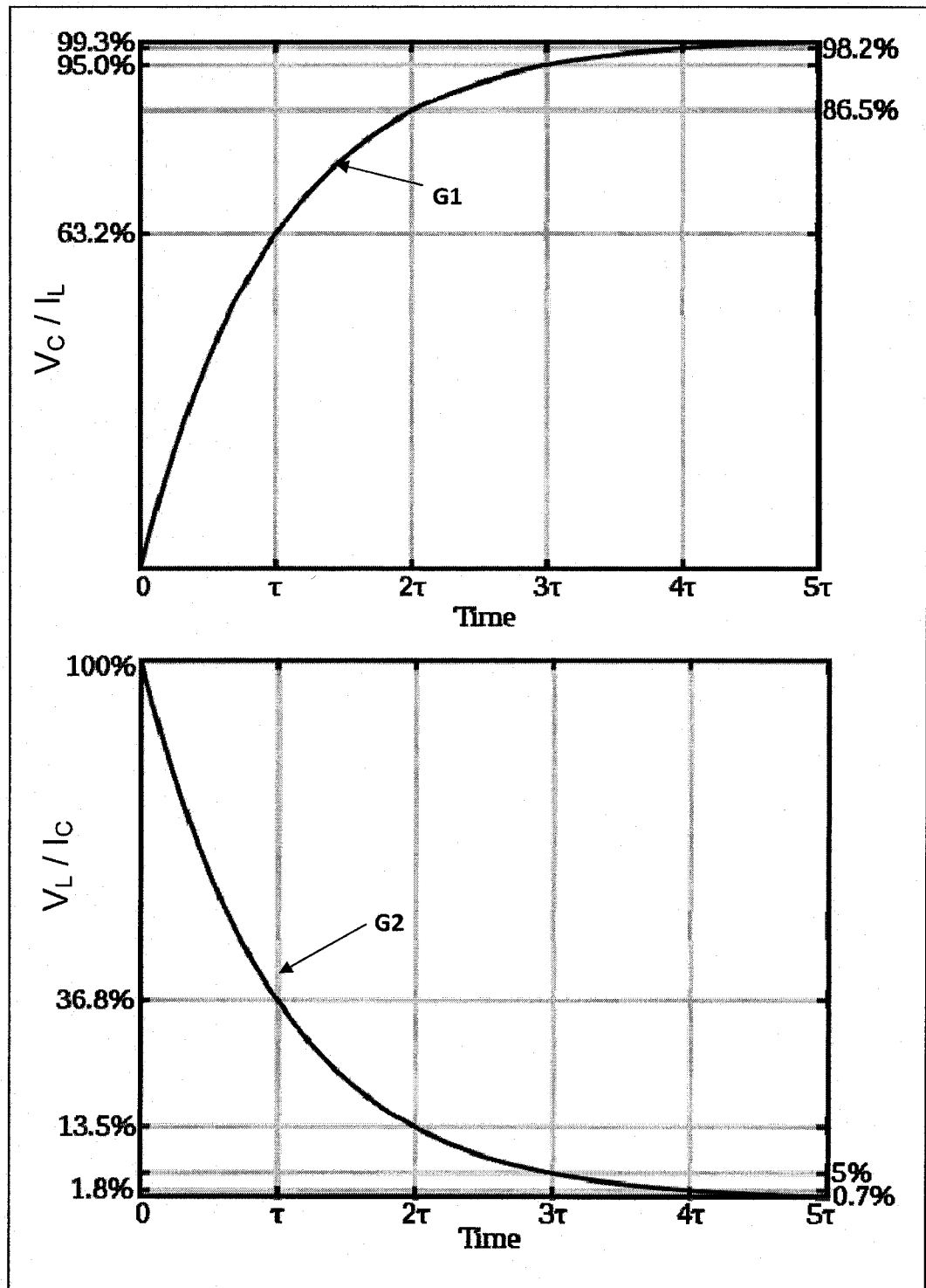


Fig. 4C

11/11

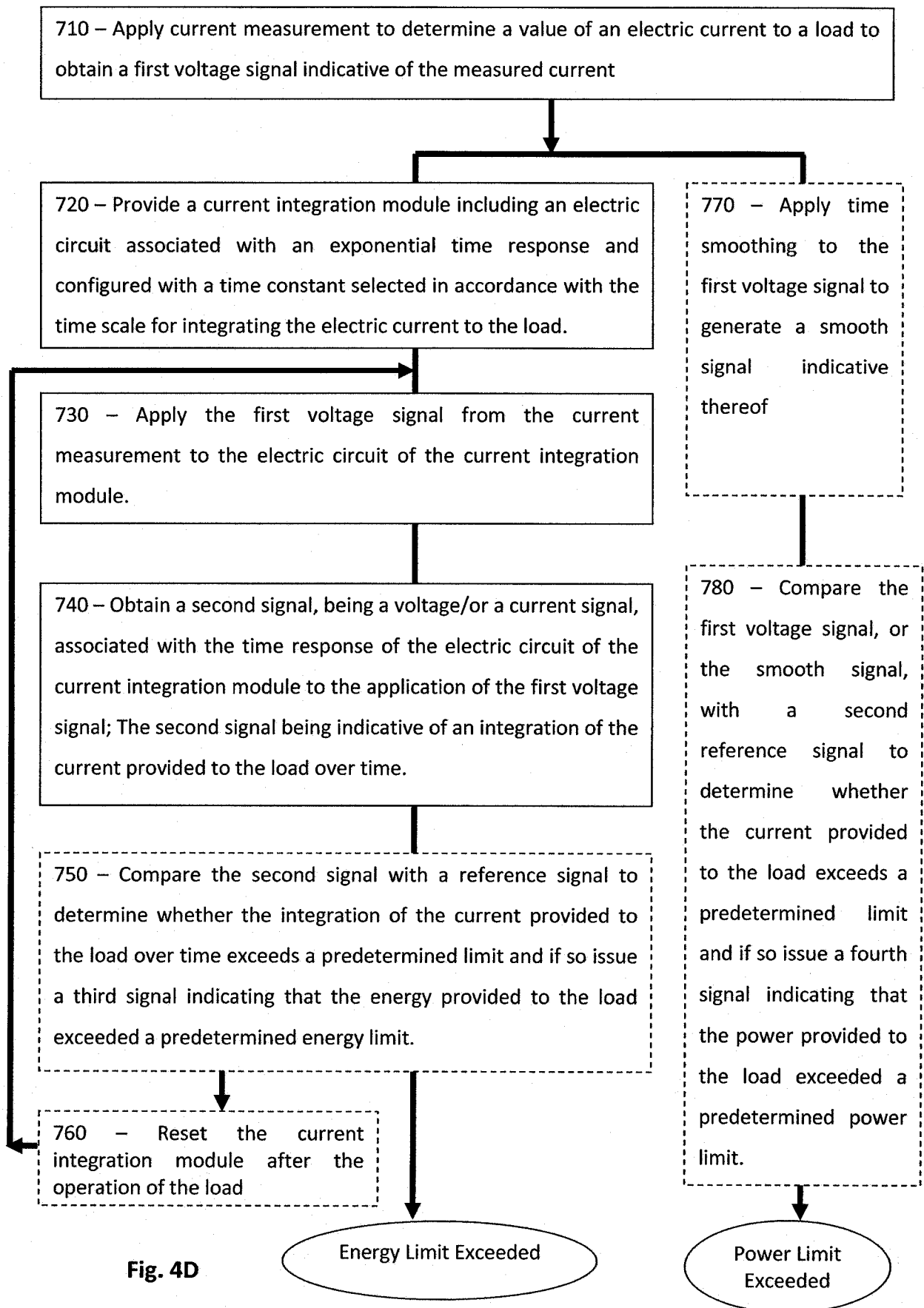
700

Fig. 4D