

ADDRESSABLE LED ARCHITECTURE

Field of the Invention

[0001] The present invention generally relates to light emitting diodes (LED), and more particularly to a LED architecture that enables serially connected LEDs to be controlled individually.

Background of the Invention

[0002] Light emitting diodes (LEDs) are gaining popularity in the past several years because they offer several advantages over conventional light sources. For example, LEDs are small in size, able to produce more colors and provide versatility in a broad range of applications. Some of these applications include traffic indicators, automotive lightings and light display devices.

[0003] A typical LED light system or architecture comprises an array of LEDs coupled to a plurality of LED drivers. The LED driver is one of the important components of a LED lighting system because it serves as the power supply for the LED lighting system. In particular, the LED driver converts a higher input AC power to the proper low-voltage DC power required by the LEDs. Also, voltage fluctuations may cause the LEDs to change their light output. The LED driver prevents the voltage fluctuations by regulating the current flowing through the LEDs.

[0004] The LED light system can be designed in a variety of configurations. One basic configuration comprises a LED driver coupled to a chain of serially connected LEDs. In particular, the LED driver generates a pulse-modulated current to control the brightness of the serially connected LEDs. However, this configuration does not enable the LED driver to control the brightness of each individual LED. In order to control the brightness of each LED individually, a multiple channel LED driver is typically used in the system. For example, FIG 1 shows a system that comprises a master controller **110** coupled to a plurality of multiple channel LED drivers **120**. Each multiple channel LED driver **120** is coupled to a plurality of LEDs **140**. Specifically, each channel **122** of the multiple channel LED driver **120** is coupled to one LED **140**. Although the multiple channel LED driver **120** is able to control the brightness of each LED **140** individually, it has certain

limitations. For example, each channel **122** is only able to drive one LED **140**. Also, every LED **140** is coupled to the multiple channel LED driver **120**, resulting in a complicated PCB layout. Furthermore, the number of LEDs **140** is limited by the number of channels **122** available on the multiple channel LED driver **120**.

[0005] Therefore, there is an imperative need to have an improved and simple way to control a large number of LEDs individually. Among other things, this disclosure satisfies this need by teaching a LED light system that comprises single channel drivers that drive a plurality of serially connected LEDs, wherein the brightness of each LED is individually controllable.

Brief Description of the Drawings

[0006] Preferred embodiments according to the present invention will now be described with reference to the Figures, in which like reference numerals denote like elements.

[0007] FIG 1 illustrates a block diagram of a prior art LED system comprising multiple channel LED drivers.

[0008] FIG 2 illustrates a block diagram of the addressable LED architecture in accordance with one embodiment of the present invention.

[0009] FIG 3 illustrates a block diagram of a LED device in accordance with one embodiment of the present invention.

[0010] FIG 4 illustrates the drive current output from a chain controller in accordance with one embodiment of the present invention.

Detailed Description of the Invention

[0011] The present invention may be understood more readily by reference to the following detailed description of certain embodiments of the invention.

[0012] This disclosure teaches an addressable LED architecture that is able to control a plurality of LEDs individually. The LED architecture can be implemented in applications such as large display screens, or display features in personal digital assistants, cell phones, digital still cameras, and camcorders. It is contemplated that the LED

architecture is not limited to the above examples but also includes other applications such as lighting systems.

[0013] Accordingly, in one aspect, the LED architecture comprises a plurality of single channel drivers (referred hereinafter as chain controllers) configured to generate predetermined drive currents, wherein the predetermined drive currents include switching signals; a plurality of LED devices, wherein the plurality of LED devices are serially connected to form a plurality of chains of LED devices, wherein each chain of LED devices is coupled to one of the plurality of chain controllers, wherein each LED device comprises: at least one LED; and a LED controller coupled to the LED, wherein the LED controller is configured to receive the switching signals for controlling the operation of the LED; and wherein the plurality of chain controllers generate predetermined drive currents to control the operation of each LED controller in each chain of LED devices, thereby controlling the operation of each LED individually in the each chain of LED devices.

[0014] In another aspect, this disclosure teaches a method of controlling the operation of chains of serially connected LEDs. The method comprises generating predetermined drive currents by a chain controller, wherein the chain controller is coupled to the at least one chain of serially connected LEDs, wherein the predetermined drive currents include switching signals; receiving switching signals by a plurality of LED controllers, wherein each of the plurality of LED controllers is coupled to one of the serially connected LEDs, and wherein the plurality of LED controllers control the operation of the serially connected LEDs in response to the switching signals, thereby controlling the operation of the serially connected LEDs individually.

[0015] Now referring to FIG 2, the LED architecture **1** comprises a master controller **20**, a plurality of chain controllers **40**, and a plurality of LED devices generally represented by the numeral **60**. The master controller **20** can be any type of micro-controller unit, and is electrically coupled to the plurality of chain controllers **40**. The electrical connections between the master controller **20** and the plurality of chain controllers **40** can be I2C, SPI or CAN. Furthermore, the master controller **20** and the plurality of chain controllers **40** receive electrical power from a power input terminal (not shown) for energizing their operations. The master controller **20** controls the operation of the plurality of chain controllers **40** in order to control the overall display and brightness of

the LED architecture 1. The chain controller 40 can be a dedicated integrated chip (IC) with 6 to 8 pins.

[0016] The plurality of chain controllers 40 are coupled to a plurality of LED devices 60. In particular, each chain controller 40 is coupled to a chain of serially connected LED devices 60, also known as a daisy chain configuration. The advantage of implementing a daisy chain configuration is that there is no direct connection from each LED device 60 to the respective chain controller 40, and thus the daisy chain configuration provides simple connections and allows easy PCB layouts. Furthermore, the chain of LED devices 60 can be cascaded in the LED architecture 1, thus enabling a large number of LED devices 60 to be controlled by a single master controller 20. Each chain controller 40 is electrically coupled to a chain of LED devices 60 via a power line (not shown). Furthermore, the plurality of chain controllers 40 also control the operation of corresponding LED devices 60 via the power line. Depending on the type of signals received from the master controller 20, each of the chain controllers 40 would generate drive currents to control their corresponding chain of LED devices 60. The method of generating drive currents to control the chains of LED devices 60 will be discussed in detail below.

[0017] Referring to FIG 3, the LED device 60 comprises a LED 70 coupled to a LED controller 80, wherein the LED controller 80 can be an integrated component of the LED device 60. Alternatively, the LED device 60 and the LED controller 80 can be separate components, wherein the LED controller 80 can be a dedicated 2 or 6 pins IC that is electrically coupled to the LED device 60, particularly to the LED 70. The LED controller 80 is configured to receive the drive currents generated from the corresponding chain controller 40, and the LED controller 80 controls the operation of the LED 70 in response to the drive current.

[0018] The anode terminal of the LED 70 is coupled to a V+ node, and the cathode terminal coupled to a V- node. Furthermore, the LEDs 70 in a single chain of LED devices 60 can be of the same color, for example red, green, yellow or white. Alternatively, a single chain of LED devices 60 may comprise a combination of different colors of LEDs 70. Different colors or types of LEDs have different operating characteristics, which is difficult to control if they are combined in a single chain. However this embodiment controls the operation of each LED 70 via the LED controller 80, thus different colors or

types of LED can be serially connected in a single chain of LED devices **60**, thereby enhancing the versatility of the LED architecture **1**.

[0019] The LED controller **80** comprises a switch **82**, a switch controller **84**, and a charge pump **86**. The switch **82** is coupled to the LED **70**, wherein the switch **82** is preferably a normally-off NMOS transistor. However, it is contemplated that other types of transistors may be used. The switch **82** is referred hereinafter as the NMOS. The gate terminal of the NMOS **82** is coupled to the switch controller **84**, the drain terminal coupled to the V+ node, and the source terminal coupled to the V- node. The switch controller **84** has a plurality of address terminals generally referenced by the numeral **85**, wherein the plurality of address terminals **85** are coupled to the V+ node or V- node. The address terminals **85** of switch controller **84** are uniquely coupled to the V+ and V- nodes for each of the plurality of LED devices **60**, which will be discussed in detail below. The charge pump **86** is coupled to the V+ node and V- node. Furthermore, the charge pump **86** is coupled to the switch controller **84** for the purpose of maintaining the voltage supply to the switch controller **84**.

[0020] In the daisy chain configuration, the chain controller **40** is coupled to the V+ node of a first LED device **60a**. The V- node of the first LED device **60a** is then coupled to the V+ node of a second LED device **60b**. Similarly, the V- node of the second LED device **60b** is coupled to the V+ node of a third LED device **60c**. The V- node of the last LED device **60p** in the chain is then coupled to a ground terminal.

[0021] The operation of the LED architecture **1** will now be discussed. Basically, a LED has a forward voltage drop of up to 4.5 V in normal operating conditions. At a low current for example less than 5 mA, the brightness of the LED is insignificant. Thus, a small change in the current drive results in a significant change in the forward voltage drop of the LED. Typically, the change in the forward voltage drop is from 200 mV to 500 mV. This embodiment uses the range of forward voltage drop (200-500 mV) as a transmission medium for controlling the individual LEDs.

[0022] In operation, the master controller **20** transmits digital signals to the plurality of chain controllers **40**, wherein each of the plurality of chain controllers **40** is pre-assigned with a unique identity. In response to the digital signals, the plurality of controllers **40** generate drive currents to control the chains of LED devices **60**. Specifically, a particular chain controller **40** generates drive currents to control each

individual LED 70 in the chain of LED devices 60. The chain controller 40 transmits a high drive current pulse to generate a high voltage drop across a LED 70, and transmit a low drive current pulse to generate a low voltage drop across the LED 70. For illustration purposes, the high drive current pulse is assigned at 5 mA and the low drive current pulse is assigned at 3 mA. It is contemplated that the high drive current pulse and low drive current pulse can be assigned with different current values and are not restricted to the above example.

[0023] FIG 4 illustrates the drive current generated by the chain controller 40. The drive current is driven in a plurality of frames. For example, each frame has a period of 10 ms, wherein the first 1 ms of the frame is assigned as the control header, and the remaining 9 ms of the frame is assigned as the bulk drive. It is known to one skilled in the art that the frame, control header and bulk drive are not limited to the above example, and may be assigned with other values.

[0024] During the control header of the frame, the chain controller 40 generates a series of high drive current pulses (5 mA) and low drive current pulses (3 mA) to produce a series of voltage swings between 200 mV to 500 mV. The series of voltage swings serve as switching signals that control the operation of the chain of LED devices 60. Specifically, the switching signals comprise data bytes or a string of binary numbers (e.g. 10110010...) for controlling the operation of the switch controllers 84 in the chain of LED devices 60. During the bulk drive, the chain controller 40 provides a constant drive current and no data is transmitted during this period.

[0025] In this embodiment, the switch controller 84 drives the NMOS 82 in response to the switching signals, thereby controlling the operation of the LED 70. For illustration purposes, the NMOS 82 can be driven in three operating modes:

[0026] (i) Data State ($V_{ds} = V_{data}$),

[0027] (ii) Drive-Hi State ($V_{ds} = V_{bright}$), and

[0028] (iii) Drive-Low State ($V_{ds} = V_{dark}$), wherein V_{ds} represents the drain-source voltage of the NMOS 82.

[0029] Furthermore, the voltage levels are predetermined as:

[0030] (i) $V_{bright} = 3.5V - 4.5V$

[0031] (ii) $V_{dark}, V_{data_hi} = 2.5V$

[0032] (iii) $V_{data}, V_{data_low} = 2.0V$

[0033] During the Data State, the switch controller **84** drives the NMOS **82** to Vdata. However, due to the slow response of the NMOS **82** at the Data State, the Vds swings between Vdata_low and Vdata_hi.

[0034] As discussed above, each switch controller **84** has a plurality of address terminals **85**. The address terminals **85** are uniquely coupled to the V+ and V- nodes for every switch controller **84** in a particular chain of LED devices **60**. For example, in the first LED device **60a**, address terminal **85a** can be coupled to the V+ node, and address terminals **85b**, **85c**, **85d** can be coupled to the V- node. In the second LED device **60b**, address terminals **85a**, **85b** can be coupled to the V+ node, and address terminals **85c**, **85d** can be coupled to the V- node. By varying the switching signals of the drive current, the chain controller **40** is able to control the switch controllers **84** in the chain of LED devices **60**, and thus allowing each LED **70** to be controlled individually. Specifically, the switch controller **84** controls the NMOS **82** in response to the switching signals. Suppose NMOS **82** is open, it permits electrical current to flow through the LED **70**, wherein the LED **70** is turned on. When NMOS **82** is close, it becomes a short circuit and thereby shunts current around the LED **70**, wherein the LED **70** is now turned off.

[0035] As discussed above, the chain controller **40** generates drive currents to control the LEDs **70** individually. For example in a first 10 ms frame, the chain controller **40** generates drive current pulses comprising switching signals to turn on or turn off the desired LEDs **70** in the chain of LED devices **60**. In the second 10 ms frame, the desired LEDs **70** are either turned on or off. Also, the drive current pulses generated in the second 10 ms frame will determine whether the LEDs **70** remain on or off in the following third frame. Hence, each of the LEDs **70** is either turned on or off for each particular frame. Due to the fact that the 10 ms frames are occurring very fast, the human naked eye does not visualize the actual turning on/off of the LEDs **70** but sees the variation in brightness of the LEDs **70**.

[0036] While this detailed description has set forth some embodiments of the present invention, the appended claims are sufficiently supported to cover and will cover other embodiments of the present invention which differ from the described embodiments according to various modifications and improvements. For example, a single chain of LED devices **60** may comprise a combination of different colors of LEDs **70** instead of a single color. Furthermore, other types of transistors such as bipolar junction transistors

(BJT) or complementary MOSFETS (CMOS) can be used as the switch **82**. Also, each frame of the drive current may comprise more than one control header. For example, one frame can be equally divided into two periods, wherein each period comprises the control header and the bulk drive.

CLAIMS

What is claimed is:

1. A light emitting diode (LED) architecture comprising:
 - a plurality of chain controllers configured to generate predetermined drive currents, wherein the predetermined drive currents include switching signals;
 - a plurality of LED devices, wherein the plurality of LED devices are serially connected to form a plurality of chains of LED devices, wherein each chain of LED devices is coupled to one of the plurality of chain controllers, wherein each LED device comprises:
 - at least one LED; and
 - a LED controller coupled to the LED, wherein the LED controller is configured to receive the switching signals for controlling the operation of the LED; and
 - wherein the plurality of chain controllers generate predetermined drive currents to control the operation of each LED controller in each chain of LED devices, thereby controlling the operation of each LED individually in the each chain of LED devices.
2. The LED architecture of claim 1, wherein the LED controller comprises:
 - a switch coupled to the LED; and
 - a switch controller coupled to the switch, wherein the switch controller opens or closes the switch in response to the switching signals, and wherein the switch when opened allows electrical current to flow through the LED, wherein the switch when closed shunts electrical current around the LED.
3. The LED architecture of claim 2, wherein each LED device further comprises a charge pump for maintaining the voltage supply to the switch controller.
4. The LED architecture of claim 2, wherein the switch is a NMOS transistor.

5. The LED architecture of claim 1, wherein the plurality of chain controllers can be dedicated integrated chips.
6. The LED architecture of claim 1, wherein the LED controller can be a dedicated integrated chip.
7. The LED architecture of claim 1, further comprising a master controller coupled to the plurality of chain controllers, wherein the master controller controls the operation of the plurality of chain controllers.
8. The LED architecture of claim 7, wherein the master controller can be coupled to the plurality of chain controllers via I2C, SPI or CAN connections.
9. The LED architecture of claim 7, wherein the master controller can be a micro-controller unit.
10. The LED architecture of claim 1, wherein each chain of LED devices may comprise different colors or types of LEDs.
11. The LED architecture of claim 1, wherein the electronic device is selected from the group consisting of large display screens, or display means in personal digital assistants, cell phones, digital still cameras, and camcorders.
12. A method of controlling the operation of at least one chain of serially connected light emitting diodes (LEDs), comprising:
 - generating predetermined drive currents by a chain controller, wherein the chain controller is coupled to the at least one chain of serially connected LEDs, wherein the predetermined drive currents include switching signals;
 - receiving switching signals by a plurality of LED controllers, wherein each of the plurality of LED controllers is coupled to one of the serially connected LEDs, and

wherein the plurality of LED controllers control the operation of the serially connected LEDs in response to the switching signals, thereby controlling the operation of the serially connected LEDs individually.

13. The method of claim 12, further comprising:

transmitting digital signals by a master controller, wherein the master controller is coupled to the chain controller, wherein the master controller controls the predetermined drive currents generated by the chain controller.

14. The method of claim 13, wherein the master controller can be coupled to each chain controller via I2C, SPI or CAN connections.

15. The method of claim 12, wherein each of the plurality of LED controllers comprises:

a switch coupled to the LED; and

a switch controller coupled to the switch, wherein the switch controller opens or closes the switch in response to the switching signals, wherein the switch when opened allows electrical current to flow through the LED, wherein the switch when closed shunts electrical current around the LED.

16. The method of claim 12, wherein the at least one chain of serially connected LEDs may comprise different colors or types of LEDs.