Control of Light Intensity of LEDs for Outdoor Lighting

Ainee Ansaari[1], Damitha Weerakoon[2]

Abstract—**This paper aims to present an effective approach to design a system for outdoor LED lighting in which user can control the light intensity of the LEDs. Since the light intensity of LEDs is directly proportional through the current passing through them, the proposed system can be implemented using constant current regulators to limit the flow of current through the LEDs based on the single PWM produced by an MCU. The circuit is a constant current source, which implies that the LED brightness would be constant regardless of the power supply used. It's more consistent, flexible and efficient.**

Index Terms—**Constant Current Regulator, LED, Light Intensity, PWM.**

I. Introduction

The LED market is flourishing quickly around the globe. LEDs have taken over incandescent light sources and are used in environmental and task lighting. As a part of the advanced technology, LEDs are now used for high-power illumination maintaining efficiency and reliability. These are quite useful for when subjected to frequent ON-OFF cycling conditions.

LEDs can very simply be dimmed either by pulse-width modulation or lowering the forward current. This pulse-width modulation is why LED lights viewed on camera, headlights on cars, seem to be flashing or flickering. This advantage of LEDs has led researchers develop various systems where the light intensity of LEDs can be controlled. In this paper, a novel technique is deployed to control their dimming with the help of a buck converter and a current sensing and intensity control unit.

A DC-DC boost converter is a step up converter. It is a DC-to-DC power converter where output voltage is more than its input voltage. It consists of simple components like capacitor, diode, inductor, switch and load connected at the output. Battery is used to give the input supply. Inductor behaves like an energy storage element and capacitor connected at the output of the converter helps in lowering output voltage ripple. The SMPS (switched-mode power supply) switch must be turned ON and OFF quickly and have low losses in order to attain high efficiency. The boost converters are efficient, lightweight, simple and hence can be implemented in small inexpensive circuits. They have a wide range of applications. They are used in battery power systems to increase the voltage and reduce the number of cells in the battery. They are of great use in hybrid electric vehicles and lighting systems. They are used in portable lighting system like LEDs and they can yield higher voltages to operate cold cathode fluorescent tubes in LCD backlights and some flashlights.

There are basically two reasons to drive LEDs used for display backlighting and other illumination purposes with constant current; to avoid the violation of absolute maximum current rating and compromising the reliability, and to achieve expected and matched luminous intensity and chromaticity from each LED.

PWM, Pulse Width Modulation, is a modulation technique, which is used to encode the amplitude of a signal into the width of the pulse of another signal for transmission. Even though it is used to transform information, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. The average value of current and voltage fed to the load is limited by turning the switch between supply and load ON and OFF at a fast rate. Higher will be the total power supplied to the load if the switch is in ON state for a longer time than in the OFF state. The PWM switching frequency has to be much higher than the power used by the device, which implies that the resultant waveform present at the load side must be as smooth as possible.

The operation of the proposed circuit and related calculations are given in Section II. The experimental section is given in Section III. The simulation results are presented in Section IV and the conclusion is put forward in Section V.

II. Operation of the Proposed Circuit

Upon turning ON a light-emitting diode, energy is released by it in the form of photons. Since LEDs have lower power consumption and longer lifetime, they have been widely adopted in the signage and lighting industries. LEDs exhibit a unique exponential relationship between the applied forward biased voltage and the resulting current flowing through its body. Although a higher forward current can force the LED to emit brighter light, it also tends to over-drive the LED [1]-[6]. The major benefits of using the constant current topology are:

1. Avoids violating the absolute maximum forward current specified for the LEDs and compromising the reliability.
2. Achieves more consistent brightness between different LED strips.

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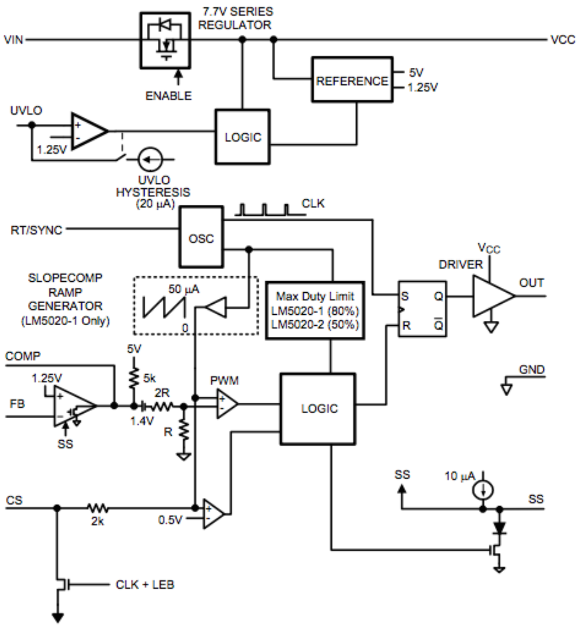

Fig. 1. Block Diagram

A. Operating Description

This is a high voltage PWM controller. It includes a high-voltage startup regulator that operates over a wide input range. It is designed to achieve high speed including an oscillator frequency range to 1MHz and total propagation delays less than 100ns. Other qualities contain high start up voltage regulator, over voltage protection, precision reference cycle-by-cycle current limit, loop controller, power drive, line under-voltage lockout, soft start, thermal shut-down and auto power down. This circuit is designed for current-mode control power converters, which require a single drive output such as Flyback and Forward topologies [7].

B. High Start Up Voltage Regulator

The internal high voltage startup regulator allows the input pin (Vin) to be connected directly to line voltages as high as 100V. The regulator output current is limited to 15mA. On applying power, the regulator gets enabled and sources current into an external capacitor connected to the V_{CC} pin. The capacitance range for the V_{CC} regulator should be between 0.1μF and 100μF. When the voltage on the V_{CC} pin reaches the regulation level of 7.7V, the controller output is enabled. The controller will remain enabled until V_{CC} falls below 6V. The external V_{CC} capacitor must be selected such that the capacitor keeps the V_{CC} voltage greater than the 6V during the initial start-up. An external start-up can be used by connecting the V_{CC} and the V_{IN} pins together and feeding the external bias voltage (8-15V) to the two pins to limit the external current during fault conditions [7].

C. Over Voltage Protection

If an over voltage is detected on the LED side due to control system malfunction, D102 will conduct and cause the PWM controller to turn OFF. Maximum allowed output voltage for this is determined by D102.

D. Current Sense and Current Limit

U102 acts as a current sense amplifier. R115 and R116 are connected in series with the LED string. The voltage across these two resistors is proportional to the current in the LED string. Since this voltage is very small, non-inverting amplifier is used as a current sense amplifier to increase this voltage to reference voltage of the PWM Controller. Changing R115 and R116 can control maximum current flowing in the LED string. Also, the design allows a preset maximum current in the LED string by setting gain of the current sense amplifier with the help of R113 preset resistor. This can be used to set the intensity during installation as needed by the user. R109, R106, R108 and C110 are used to detect and limit the max inductor current. This prevents the inductor from saturating.

E. Loop Controller

The signals from both, the over voltage protection and current sense amplifier are fed to the loop controller that produces the feedback signal (V_{FB}) to the PWM Controller. External PWM signal can be given to the PWM_DIM, which controls the light intensity. This can be connected to 12V PWM dimmer and user can vary the light intensity form 0 to the preset maximum value by varying the duty of the PWM signal.

F. Power Drive

Power drive is a standard boost converter. With the help of the control system, the output current is kept constant and the voltage is boosted till this current flows through the LED string. Input and output filter capacitors are used to reduce noise on either side of the converter. Filter capacitors should be mounted close to the power drive and it's recommended to use a few capacitors in parallel instead of one big capacitor as this technique reduces the ESR of the capacitors and gives better performance. C101 is used as power supply decoupling capacitor so that the controller gets noise-less supply voltage and hence, it should be mounted closed to the controller pin [3].

G. Line Under-Voltage Detector

An external set-point voltage divider from V_{IN} to GND sets the operational range of the converter. The resistor divider must be created such that the voltage at the Under Voltage Lock Out (UVLO) pin is greater than 1.25V when V_{IN} is in the desired operating range. When the UVLO threshold is exceeded, the current source is activated causing a voltage rise at the UVLO pin. When the UVLO pin voltage falls below the threshold value, the current source is turned OFF, making voltage at the UVLO pin to fall. The UVLO pin can also be used to apply a remote enable / disable task. If an external transistor pulls the UVLO pin below the 1.25V threshold, the converter is disabled. Under voltage cutoff is used to turn the system OFF if the input voltage drops below a threshold voltage. R103 and R102 voltage divider set the voltage on UVLO pin. By using external voltage on the gate of Q101, we can force voltage on UVLO to 0V forcing the controller to shut down [7].

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H. Soft Start

The soft start characteristic permits the power converter to progressively reach the initial steady state operating point, thereby reducing start-up stresses and current surges. At power ON, after the V_{CC} and the line UVLO thresholds are satisfied, an internal 10μA current source charges an external capacitor connected to the SS pin. The capacitor voltage will ramp up slowly and will limit the COMP pin voltage and the duty cycle of the output pulses [7].

I. Thermal Shut Down

Internal circuitry for thermal shutdown is given to protect the integrated circuit if the maximum junction temperature exceeds. This attribute prevents catastrophic failures from accidental device overheating. When enabled at 165 degrees Celsius, the controller is forced into a low power standby state disabling the output driver and the bias regulator. After the temperature is reduced (typical hysteresis = 25° C) the V_{CC} regulator is enabled and a soft-start sequence is initiated [7].

J. Auto Power Down

Auto Power down circuit is a schmitt trigger. An LDR and resistor voltage divider detects the outside light and the schmitt trigger switches states based on the voltage of the divider. This can be used to auto turn OFF the LEDs during the daytime. Varying the R126 preset resistor can change the threshold light condition. The user cannot change upper and lower thresholds. It will turn OFF at one light intensity and turn ON at the other (electrical hysteresis). Schmitt trigger is used instead of a simple comparator to get the electrical hysteresis; otherwise the system will oscillate (turn OFF and ON rapidly) due to minor light variations. LDR should be mounted such that the light from the LED string does not land on it.

III. EXPERIMENTAL SET UP

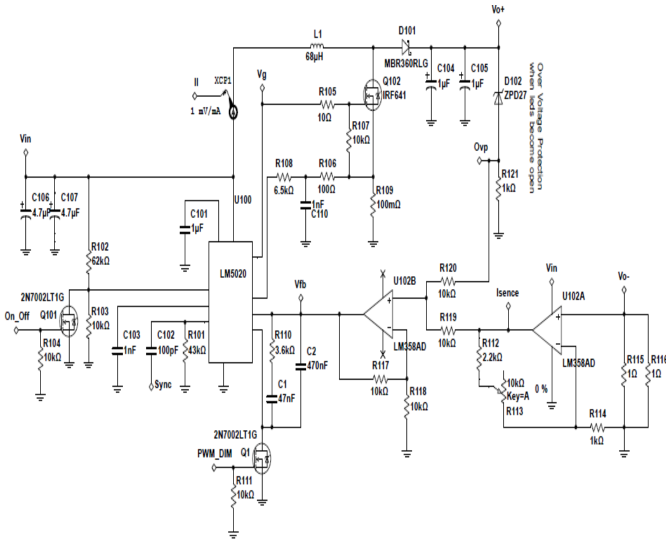

Fig. 2.a. Experimental Set Up

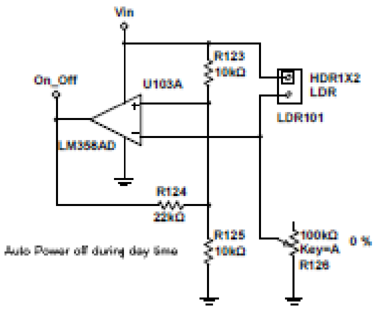

Fig. 2.b. Auto Power OFF

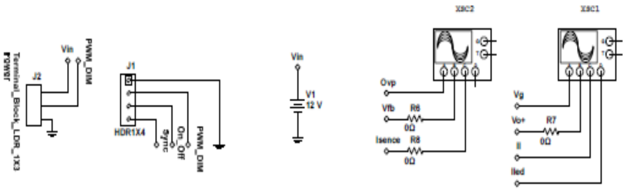

Fig. 2.c. Connections

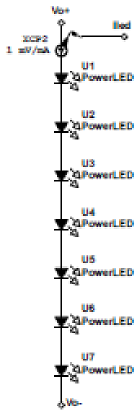

Fig. 2.d. LED String

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IV. SIMULATION RESULTS

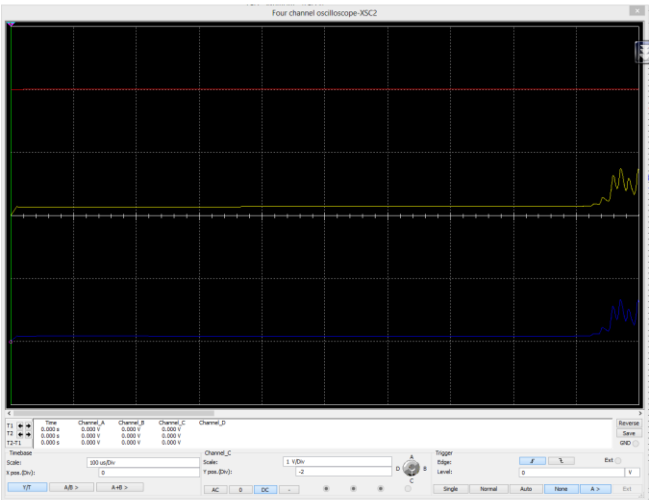

Fig. 3.a. Starting Operation 1

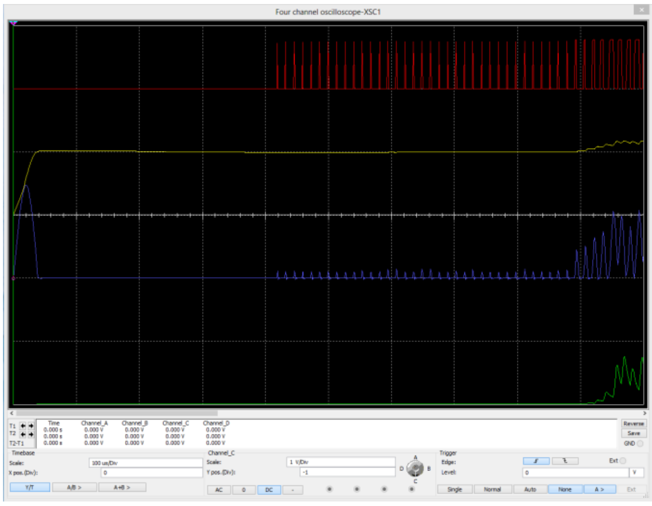

Fig. 3.b. Starting Operation 2

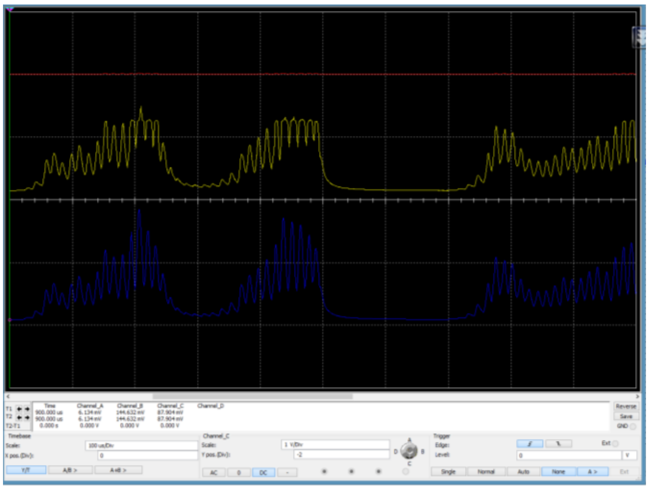

Fig. 4.a. Normal Operation 1

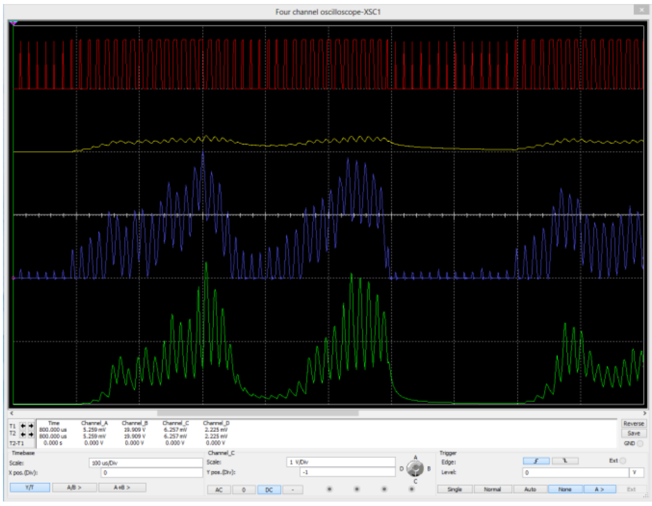

Fig. 4.b. Normal Operation 2

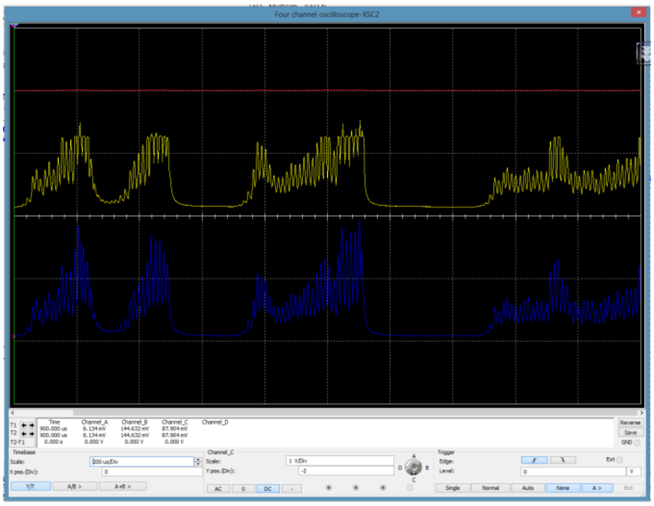

Fig. 4.c. Normal Operation 3

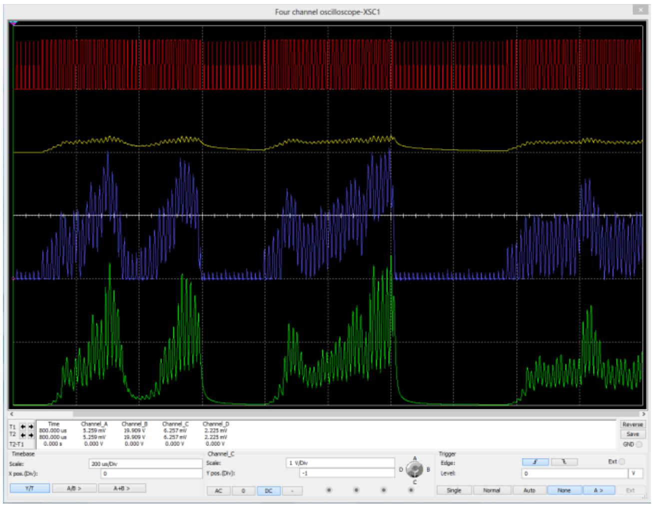

Fig. 4.d. Normal Operation 4

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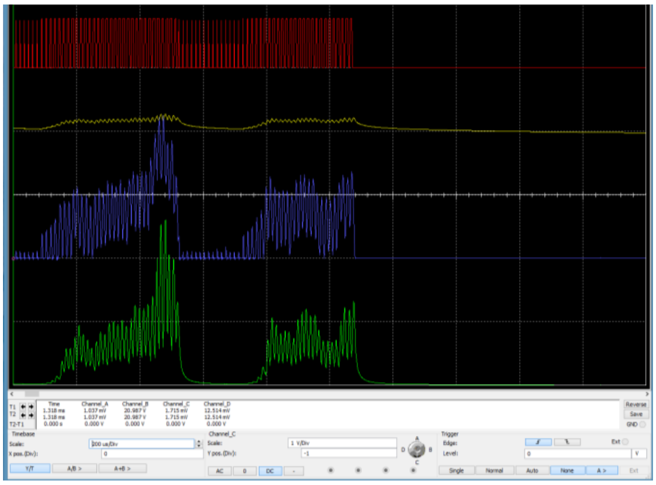

Fig. 5.a. Power Down 1

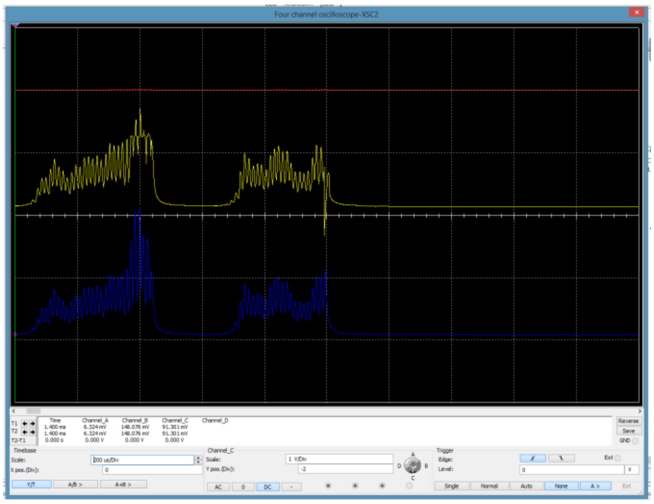

Fig. 5.b. Power Down 2

V. CONCLUSION

This paper proposes a system in which the user can control the light intensity of the LEDs. The circuit is simulated to verify the feasibility of the proposed LED driver and the circuit shows good robustness. It provides all of the advantages of current mode control including line feed forward, cycle-by-cycle current limiting and simplified loop compensation. It is designed for current-mode control power converters, which require a single drive output, such as Flyback and Forward topologies.

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