HIGH EFFICIENCY DC-DC BOOST CONVERTER DESIGN FOR LED DRIVES

S. Aparnajha[1], P. Kowsalya[2], B. Mahalakshmi[3] , P.Sridevi ponmalar[4]

Student, Department of Electrical and Electronics, New Prince Shri Bhavani College of Engineering and Technology, Chennai, India[1,2,3]

Assistant Professor, Department of Electrical and Electronics, New Prince Shri Bhavani College of Engineering and Technology, Chennai, India[4]

ABSTRACT

A conventional boost converter has a high power efficient CMOS adaptive controlled boost step-up LED drive implemented in BCD technology [1]. A novel adaptive minimum frequency control provides up to 52v from a single battery 4.5v input supply to ten series connected LEDs at the output. The proposed control scheme provides an accurate load current while achieving high power efficiency than conventional fixed on time schemes. TPS40211 and TPS40210are able to switch between PWM (pulse width modulation) automatically by calculating the feed backs from the inductor and LEDs current. This controller is functional from light to heavy loading situations which critical in improvement of power efficiency and battery life-time for high boost ratio applications in order as provide accurate LED current [10].

KEY WORDS: *CMOS(complementary metal oxide-semiconductor), BCD technology, PWM(pulse width modulation control), TPS40211 and TPS40210, LED(light emitting diode).*

I.INTRODUCTION:

In Recent Years, wide use of electrical equipment has forced strict demands for electrical utilizing energy and this development is constantly growing. Accordingly, researchers and governments worldwide have prepared on renewable energy applications for explanatory natural energy consumption and environmental location. Among different renewable energy sources, the photovoltaic cell and fuel cell have been considering attractive choice. However, without additional arrangements, the output voltages generated from both sources. Thus, a high step-up dc-dc converter is desired in the power conversion systems corresponding to these two energy sources. In addition to the mentioned applications, a high step-up dc-dc converter is also required by many industrial applications, such as high-intensity discharge lamp ballasts for automobile headlamps and battery backup systems for uninterruptible power supplies. The conventional boost converter can be advantageous for Step-up applications that do not demand very high voltage gain, mainly due to the resulting low conduction loss and design simplicity. Theoretically, the boost converter static gain tends to be infinite when duty cycle also tends to unity. However, in practical terms, such gain is limited by the I^2R loss in the boost inductor due to its intrinsic resistance, leading to the necessity of accurate and high-cost drive circuitry for the active switch, mainly because great variations in the duty cycle will affect the output voltage directly.

To overcome this disadvantages the TPS40210 and TPS40211 are used. They are the wide-input voltage (4.5V to 52V), non-synchronous boost controllers. They are suitable for topologies which require a grounded source N-channel FET including boost, fly back, SEPIC and various LED driver applications. The device features include programmable soft start, over current protection with automatic retry and programmable oscillator frequency. Current mode control provides improved transient response and simplified loop compensation. The main difference between the two parts is the reference voltage to which the error amplifier regulates the FB pin [10].

II.METHODOLOGY

To achieve more efficiency when compare to the existing system nearer to 95%. To reduce switching loses and power dissipations. To reduce the complex design of the circuit for the external processing units like error amplifier, current and voltage sensing unit, PWM controller unit, current and voltage regulator, oscillator unit and soft switching unit. To produce the high voltage gain with low input voltage. To maintain the proper duty cycle. To reduce the power losses in the circuit [2].

The boost converter system consist of one inductor, capacitor, resistor, controller IC and switch for its operation. The one side of the inductor is connected to the input terminal and the another side is connected between switch and diode meting point. The other side of the diode is connected to the capacitor. The resistor is connected across the output terminal [3]. The controller IC unit is connected with the MOSFET switch for PWM operation and also connected with the another ends of the capacitor, resistor and positive region of the output terminal to perform the current and voltage limiting, controlling, regulating operations. The over all control of the circuit is carried out by the TPS40211 OR TPS40210 ICs. The control of the input and output over voltages and over current, error amplification, voltage regulation, fault clearance and duty cycle maintenance all are can be done using a single IC. So that the design complexity is reduced. The heat losses due to the single IC is low when compare to the conventional method. So that we can able to achieve the 95% efficiency.

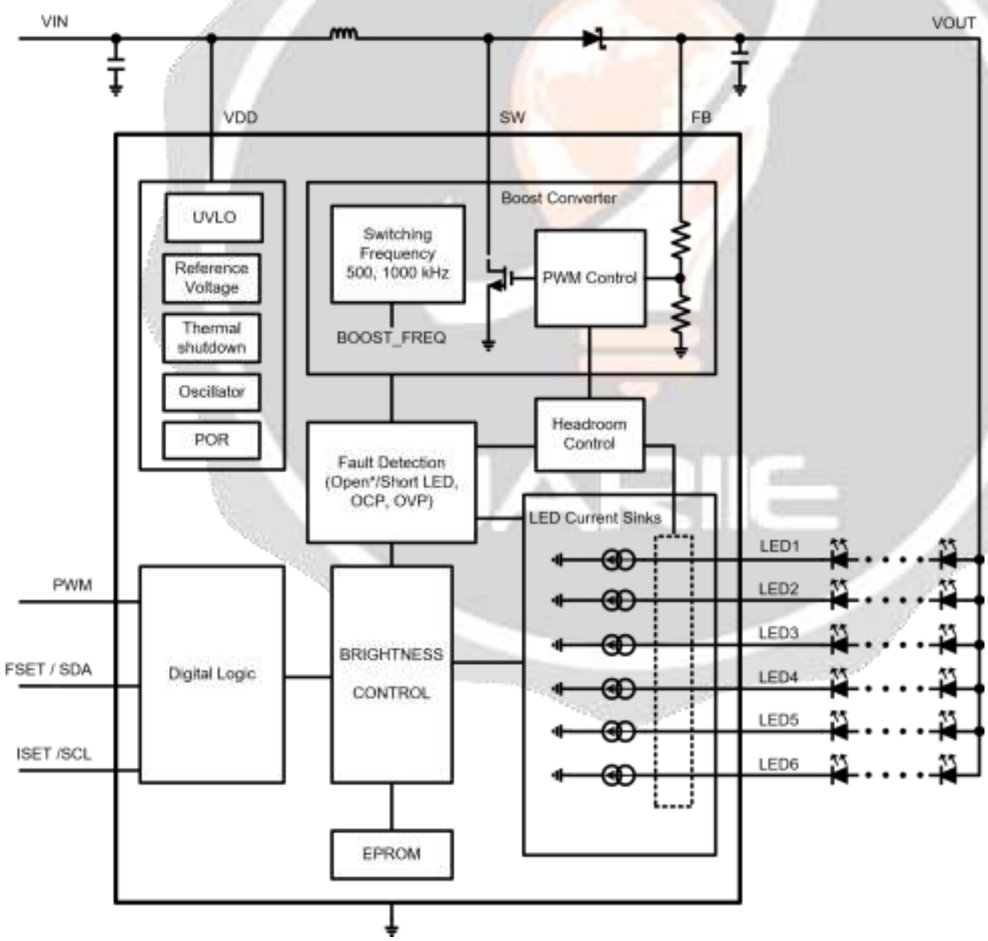


Fig 1 functional block diagram of boost converter

DETAILED DESCRIPTION OF FUNCTIONAL BLOCK DIAGRAM

The TPS40210 and TPS40211 are high-efficiency LED drivers each featuring an integrated DC-DC inductive boost converter and six high-precision current sinks. TPS40210 is intended for applications that exclusively use a pulse width modulated (PWM) signal for controlling the brightness while TPS40211 is intended for applications that can utilize an I^2C master as well.

The boost converter has adaptive output voltage control. This feature minimizes the power consumption by adjusting the voltage to the lowest sufficient level under all conditions. The adaptive current sink headroom voltage control scales the headroom voltage with the LED current for optimal system efficiency. The LED string auto-detect function enables use of the same device in systems with 1 to 10 LED strings for the maximum design flexibility. Proprietary hybrid PWM plus current mode dimming enables additional system power savings. Phase shift PWM allows reduced audible noise and smaller boost output capacitors. Flexible CABC support combines brightness level selections based on the PWM input and I^2C commands. The TPS40210 and TPS40211 feature a full set of features that ensure robust operation of the device and external components. The set consists of input under voltage lockout, thermal shutdown, overcurrent protection, overvoltage protection, and LED open and short detection.

A. BOOST CONVERTER: The boost converter is defined as the output voltage is always greater than the input voltage. Switched mode supplies can be used for many purposes including DC to DC converters. Often, although a DC supply, such as a battery may be available, its available voltage is not suitable for the system being supplied. For example, the motors used in driving electric automobiles require much higher voltages, in the region of 500V, than could be supplied by a battery alone. Even if banks of batteries were used, the extra weight and space taken up would be too great to be practical. The answer to this problem is to use fewer batteries and to boost the available DC voltage to the required level by using a boost converter. Another problem with batteries, large or small, is that 1their output voltage varies as the available charge is used up, and at some point the battery voltage becomes too low to power the circuit being supplied. However, if this low output level can be boosted back up to a useful level again, by using a boost converter, the life of the battery can be extended. The DC input to a boost converter can be from many sources as well as batteries, such as rectified AC from the mains supply, or DC from solar panels, fuel cells, dynamos and DC generators. The boost converter is different to the Buck Converter in that it’s output voltage is equal to, or greater than its input voltage. However it is important to remember that, as power (P) = voltage (V) x current (I), if the output voltage is increased, the available output current must decrease. MOSFET, both Bipolar power transistors and MOSFETs are used in power switching, the choice being determined by the current, voltage, switching speed and cost considerations. The rest of the components are the same as those used in the buck converter

B. TPS40211 AND TPS40210: The TPS40210 and TPS40211 are used. They are the wide-input voltage (4.5V to 52V), non-synchronous boost controllers. They are suitable for topologies which require a grounded source N-channel FET including boost, fly back, SEPIC and various LED driver applications. The device features include programmable soft start, over current protection with automatic retry and programmable oscillator frequency. Current mode control provides improved transient response and simplified loop compensation. The main difference between the two parts is the reference voltage to which the error amplifier regulates the FB pin.

C.CAPACITOR

BOOST INPUT AND VDD CAPACITOR SELECTION

The VDD pin is typically tied to the same supply as the input of the boost power stage (V_{IN} node). A 10µF input capacitor is recommended on that node. The voltage rating of the capacitor must be at least 10 V. If a supply powering the VDD pin is different from a supply powering the boost power stage, then 10-µF input capacitors are required on both VDD and VIN nodes.

BOOST OUTPUT CAPACITOR SELECTION

The inductive boost converter typically requires two 4.7-µF output capacitors. The voltage rating of the capacitor must be 35 V or higher as the OVP threshold is at 29.6 V (typ). Pay careful attention to the capacitor tolerance and DC bias response. For proper operation of the degradation in capacitance due to tolerance, DC bias, and temperature should stay above 2 µF. This might require placing more than two devices in parallel in order to maintain the required output capacitance over the device operating temperature and output voltage range.

D.INDUCTOR

INDUCTOR SELECTION

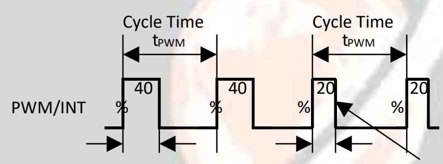
The chosen inductor must be from 10 to 22 µH (for 500-kHz operation) or 4.7 to 10 µH (for 1-MHz operation) and must have a saturation rating equal to, or greater than, the circuit's peak operating current.

E. SCHOTTKY DIODE SELECTION

The Schottky diode must have a reverse breakdown voltage greater than the TPS40211's maximum output voltage. Additionally, the diode must have an average current rating high enough to handle the TPS40211 maximum output current; at the same time the diode's peak current rating must be high enough to handle the peak inductor current. Schottky diodes are required due to their lower forward voltage drop (0.3V to 0.5V) and their fast recovery time.

F. PWM INPUT DUTY MEASUREMENT

When using PWM input for brightness control the input PWM duty cycle is measured as described in following diagram and the brightness is controlled based on the result. When changing the brightness it must be noted that the measurement cycle is from rising edge to next rising edge and brightness change must be done accordingly (time from rising to rising edge is constant (=cycle time) and falling edge defines the brightness) [4].



$$Duty = \frac{t_{ON}}{t_{PWM}}$$

On-time On-time Change in Duty t_{ON1} t_{ON2} on this Edge

Fig 2 PWM Input Duty Cycle Measurement

BRTMODE = 00b

With BRTMODE = 00b, the LED output current is controlled by the PWM input duty cycle. The PWM detector block measures the duty cycle at the PWM pin and uses it to generate a PWM-based brightness code. Before the output is generated, the code goes through the curve shaper block. Then the code goes into the hybrid PWM & I Dimming block which determines the range of the PWM and Current control. The outcome of the hybrid PWM & I dimming block is current and/or up to 6 PWM output signals.

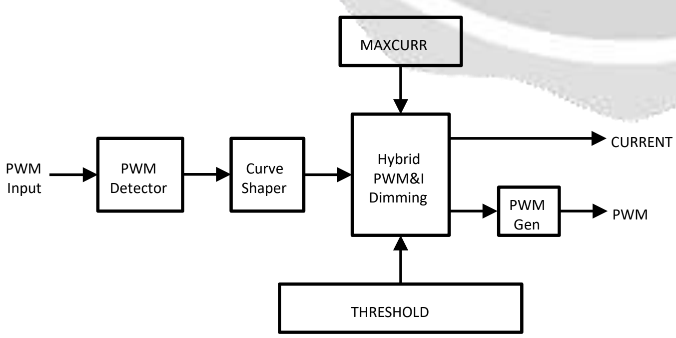


Fig 3 brightness data path for BRTMODE = 00b

BRTMODE = 01b

With BRTMODE = 01b, the LED output current is controlled by the BRTHI/BRTLO registers. Before the output is generated the BRTHI/BRTLO registers-based brightness code goes through the Curve Shaper block. Then the code goes into the hybrid PWM & I dimming block which determines the range of the PWM and current control. The outcome of the Hybrid PWM&I Dimming block is Current and/or up to 6 PWM output signals.

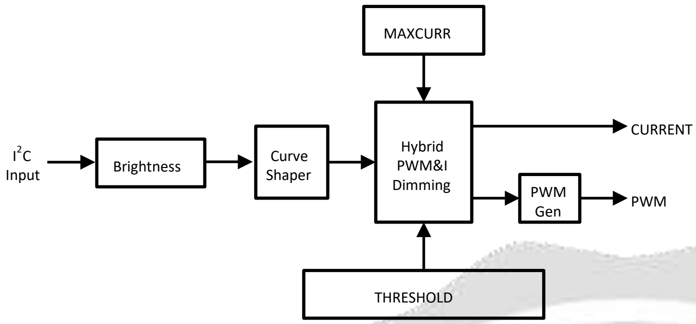


Fig 4 Brightness Data Path for BRTMODE = 01b

BRTMODE = 10b

With BRTMODE = 10b, the LED output current is controlled by the PWM input duty cycle and the BRTHI/BRTLO registers. The PWM detector block measures the duty cycle at the PWM pin and uses it to generate PWM-based brightness code. Before the code is multiplied with the BRTHI/BRTLO registers-based brightness code, it goes through the curve shaper block. After the multiplication, the resulting code goes into the hybrid PWM & I dimming block which determines the range of the PWM and Current control. The outcome of the hybrid PWM & I dimming block is current or up to 6 PWM output signals.

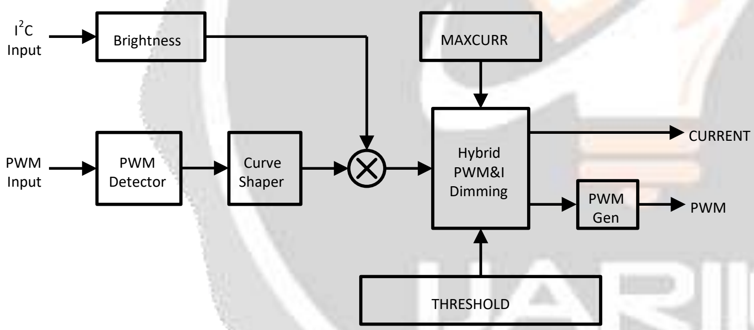


Fig 5 Brightness Data Path for BRTMODE = 10b

BRTMODE = 11b

With BRTMODE = 11b, the LED output current is controlled by the PWM input duty cycle and the BRTHI/BRTLO registers. The PWM detector block measures the duty cycle at the PWM pin and uses it to generate PWM-based brightness code. In this mode, the BRTHI/BRTLO registers-based brightness code goes through the curve shaper block before it is multiplied with the PWM input duty cycle-based brightness code. After the multiplication, the resulting code goes into the hybrid PWM & I dimming block which determines the range of the PWM and Current control. The outcome of the hybrid PWM & I dimming block is current and/or up to 6 PWM output signals.

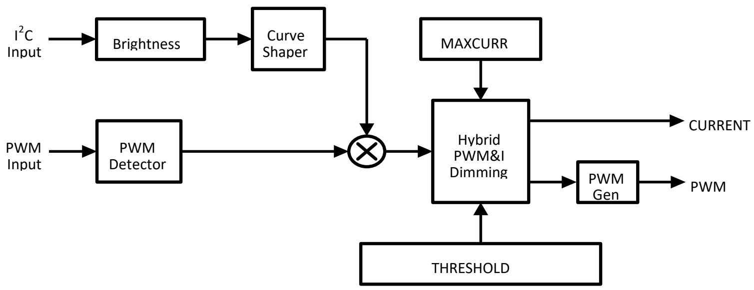


Fig 6 Brightness Data Path for BRTMODE = 11b

III.PERFORMANCE ANALYSIS

The main intension of this paper is to design a high efficient boost converter. Hardware consists of three main constituent which are the input, adaptive boost converter and the output. The input voltage is from the solar panel, the adaptive boost converter function is to get high output voltage and to increase the efficiency these can be achieved by using TPS40211, TPS40210, LP8557, LP85571 type ICs. These types of ICs are multitasking devices so that they can act like a regulator for the output voltages and currents, error amplifier, disable and enable operator, soft switcher, switching frequency manager, current and voltage sensor, high output gain producer and duty cycle maintenance operator. These all controlling processes can be done in a single IC. So that the circuit complex can be reduced, losses also reduced, efficiency can be obtained is high and the out put voltage is used to glow the LEDs [5]. The boost DC-DC converter generates a 50V to 52V boost output voltage from a 4.2V to 4.5-V boost input voltage. The converter is a magnetic switching PWM mode DC-DC inductive boost converter with a current limit. It uses current programmed mode control, where the inductor current is measured and controlled with the feedback. During start-up, the soft-start function reduces the peak inductor current. Figure shows the boost block diagram [9].

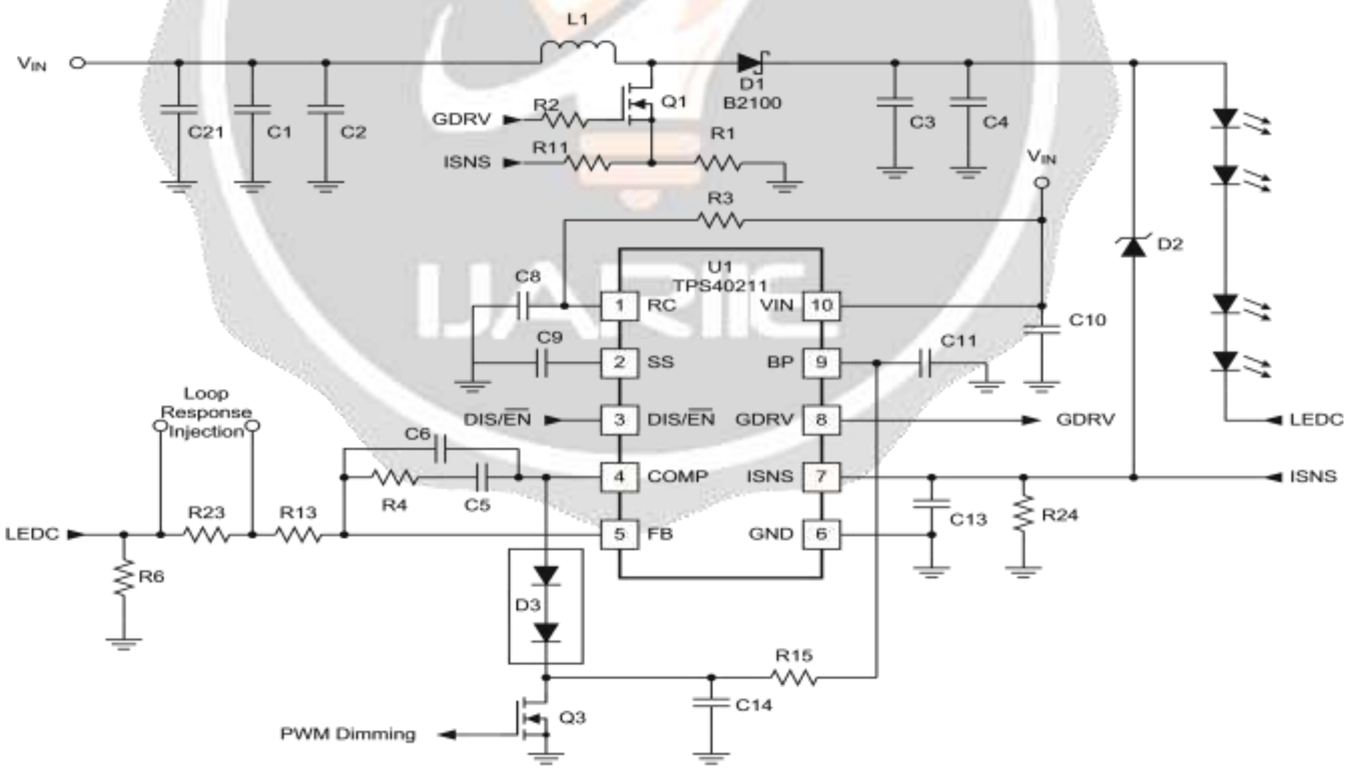


Fig 7 12-V Input, 700-mA LED Driver, Up to 35-V LED String

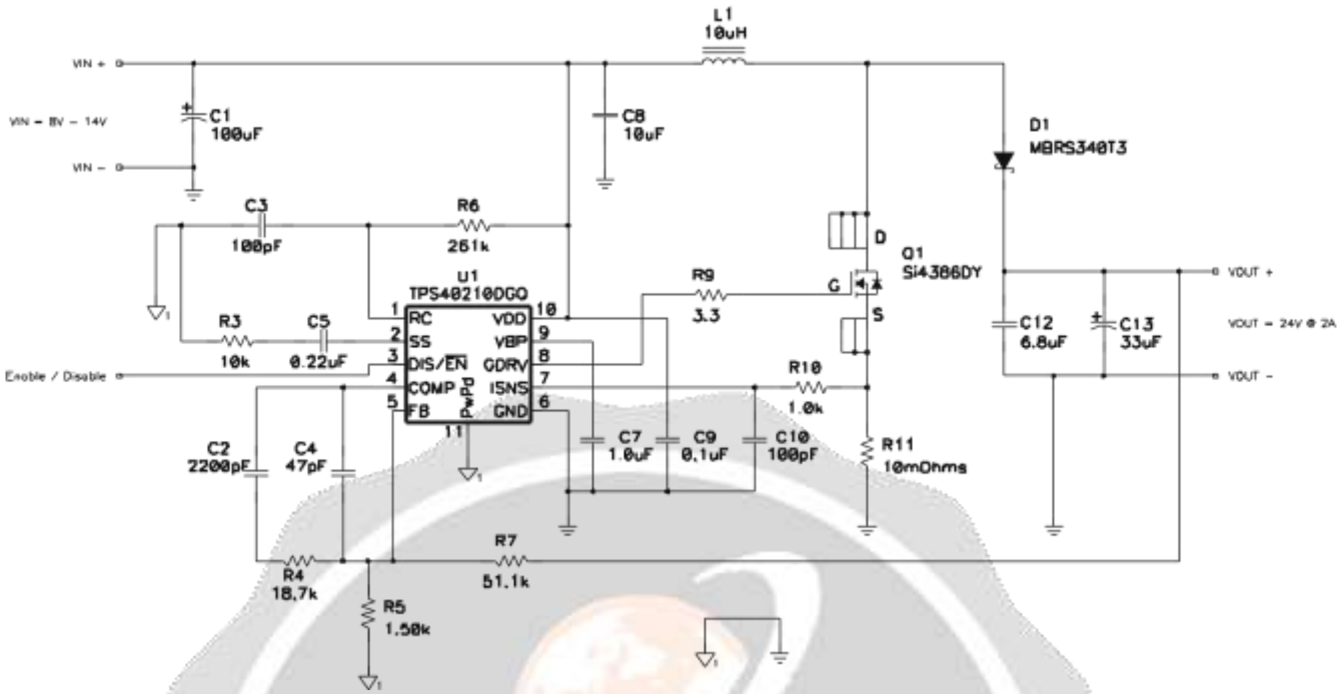


Fig 8 TPS40210 Design Example 12V to 52V at 3.5A

SIMULATION RESULTS

The fully integrated LED driver circuit is functional for LED currents up to 50 mA at low input supply voltages (3.0 V to 5.5 V). The LED driver with PWM & PFM controllers is fully functional in the 40 V process of 0.25 µm BCD technology, as shown by the simulated gate-drive, inductor current, LED current and output voltage waveforms presented in Fig. 9 and Fig. 10.

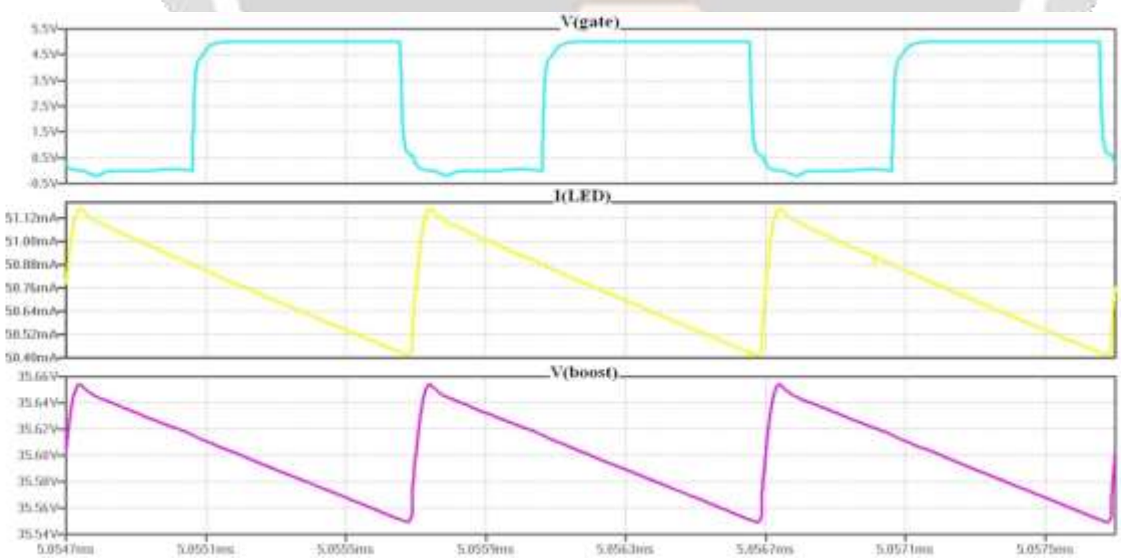


Fig 9 Simulated gate-drive, inductor current, led current (50 mA) and output voltage waveforms of the proposed PWM mode

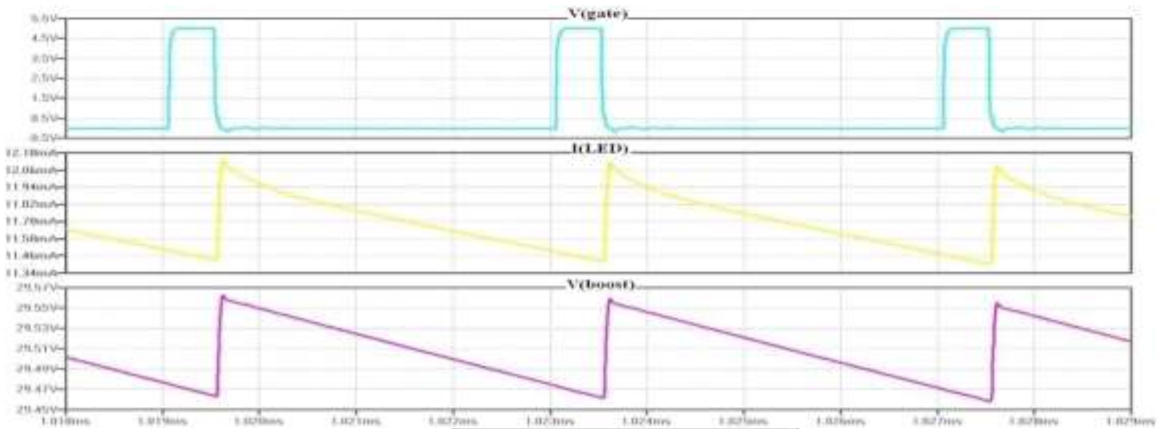
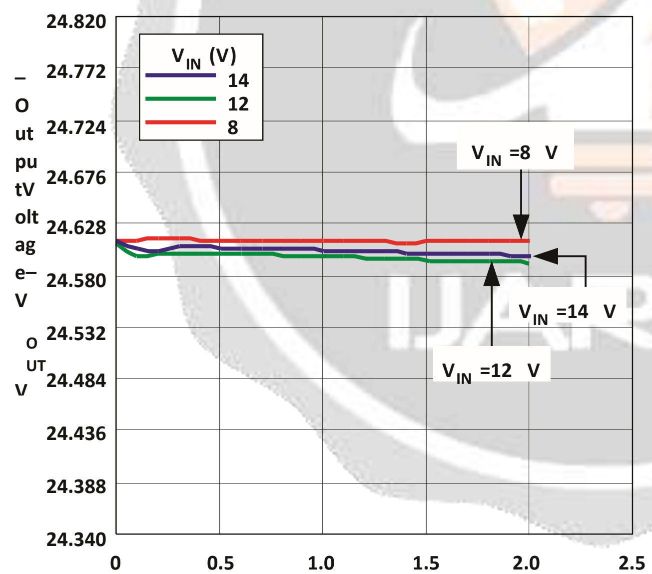


Fig 10 Simulated gate-drive, inductor current, led current (16 mA)and output voltage waveforms of the proposed PFM mode

V(gate) is the gate drive signal of power MOSFET M1. I(L) and I(LED) are the inductor current and the LED current, respectively. V(boost) is the boost converter output voltage. In Fig. 6, the converter is operating at constant 1 MHz PWM mode. Ripplepk-pk of the output LED current is 1.34%. In Fig. 7, the controller operating frequency is not constant and is around 250 kHz. Ripplepk-pk of the output LED current in PFM mode is 2.75% [6].

OUTPUT VOLTAGE vs LOAD CURRENT



I_{LOAD} – Load Current – A

Fig11 the graph between Vout and Iload

EFFICIENCY

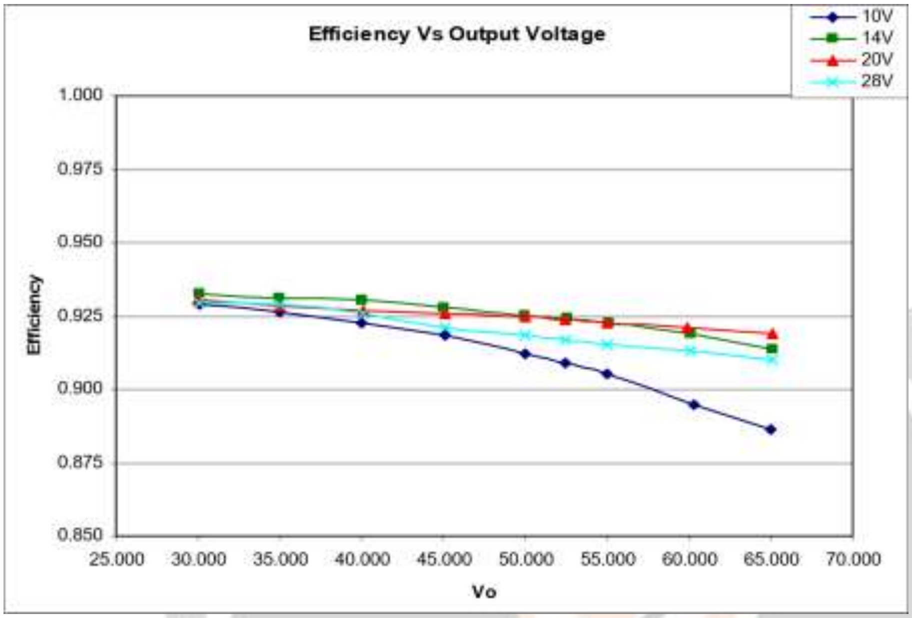


Fig 12 Efficiency with output voltage

REGULATION

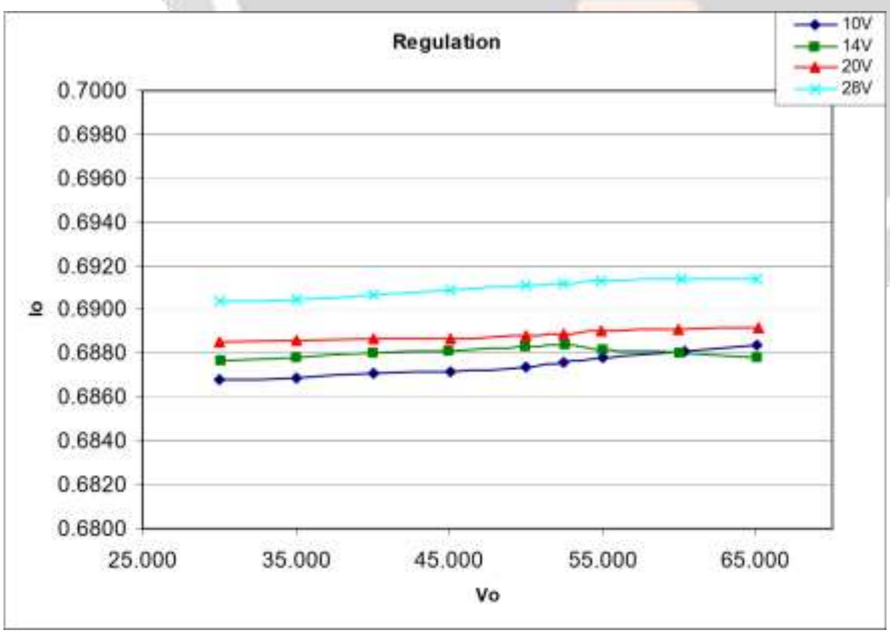


Fig 13 Output Current Regulation with output voltage

The efficiency of the proposed PWM/PFM controller has been measured when the LED current is changing from 3mA to 50 mA [7]. The controller switches between PWM and PFM modes automatically with the changes of the LED current. The averaged efficiency of the converter is 86%. This boost LED driver provides up to 32 V from a single battery (3.6 V to 5.5 V) input supply to 10 series-connected LEDs at the output, 30mA is the switchover point between PFM mode and PWM mode. PFM acquires high efficiency when the LED current is less than 30mA [8]. PWM acquires high efficiency when the LED current is larger than 30mA. The combination modulation of PWM and PFM realizes constant high power efficiency in a wide range of LED currents.

5.8 CONCLUSIONS

A novel combination of PWM and PFM controlled boost converter is proposed, designed, and simulated in 0.25 μm BCD technology. The converter provides up to 32 V from a 3.6 V to 5.5 V input supply for 10 serial LEDs at the output. To obtain the best power management efficiency, the controller switches between PWM mode and PFM mode automatically as the LED current changes. The averaged efficiency of the converter is 86% when the LED current is on the range of 3

REFERENCES

[1] C. Richardson, Driving high-power LEDs in series-parallel arrays, National Semiconductor, Santa Clara, CA, 2008 [Online]. Available: http://www.edn.com/contents/images/6615611.pdf

[2] W. Ly, Circuit delivers dimming control for white-LED driver, National Semiconductor, Santa Clara, CA, 2004 [Online]. Available: http://www.edn.com/article/CA472839.html

[3] R. Erickson and D. Maksimovic, High efficiency, dc-dc converters for battery operated systems with energy management, Department of Electrical, Computer, and Energy Engineering, University of Colorado, Boulder [Online]. Available: http://ecee.colorado.edu/~rwe/papers/EnergyMangmt.pdf

[4] L. Zhu and F. Quanyuan, "Design of PWM controller for monolithic boost converter," 7th International Conference on ASIC, pp. 660-663, 2007

[5] B. Sahu and G.A. Rincon-Mora, "An Accurate, Low-Voltage, CMOS Switching Power Supply with Adaptive On-Time Pulse-Frequency Modulation (PFM) Control," IEEE Transactions on Circuits and Systems, Volμme 54, Issue 2, Feb. 2007 pp: 312 – 321

[6] C.H. Chang, H. M. Chen, and R.C. Chang, "A 2.3 V CMOS Monolithic, 84% Efficiency PFM Control DC-DC Boost Converter for White LEDs Driver IC," PEDS 2005, pp. 833 – 837

[7] Y. Fang, Siu-Hong Wong and L. Hok-Sun Ling, "A Power converter with pulse-level-modulation control for driving high brightness LEDs", Proc. Twenty-Fourth Annual IEEE Applied Power Electronics Conference and Exposition APEC, 2009, pp. 577-581

[8] H.V.D. Broeck, G. Sauerlander, and M. Wendt, "Power driver topologies and control schemes for LEDs", Applied Power Electronics Conf. (APEC2007), Mar. 2007, pp. 1319-1325

[9] S. M. Baddela, D. S. Zinger, "Parallel connected LEDs operated at high frequency to improve current sharing" IAS Conference, 2004. 39th IAS Annual Meeting. Conf. Rec. of the 2004 IEEE Vol. 3, 3-7 Oct. 2004 Pages: 1677-1681

[10] Texas Instrument data sheet.