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Motion Integrated Sensor for Energy Efficient LED Lighting

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Abstract: *The growing popularity of Light Emitting Diode (LED) lighting is rooted in energy savings, longer life, and new fixture options that enable them to be used in almost any application. An LED driver plays a leading role to LED lighting. Basically LED driver is a device that can manage the power and control the current flow in any LED lighting product for effective illumination. The LED driver can work in constant current or constant voltage mode. Constant current mode is preferable mode to get constant lumens\watts and also improves life time of LED lighting as a product. Controller and topology selection plays very significant role in the entire working of the driver to operate in constant current mode. Integrating a motion sensor along with LED lighting product would lead to a further saving in power/energy consumption. Motion sensor detects the infrared radiation around the sensor radiated by human. Human presence and absence in the range of motion sensor the light will automatically turn on/off, hence results in additional power/energy saving without any human intervention.*

Index Terms: *LED, LED Driver, Motion sensor*

I. Introduction

The rapid improvement in Light Emitting Diode (LED) Technology with relatively reduced power consumption and longer life time provides greater potential for general lighting application ranging from corridor lighting, streetlights, traffic signals and others. An LED driver plays a leading role to LED lighting. The LED driver can work in constant current or constant voltage mode. Constant current mode is preferable mode to get constant lumens\watts and also improves life time of LED lighting as a product. Controller and topology selection plays very significant role in the entire working of the driver to operate in constant current mode. Buck topology is suitable one for this application because of its advantages like less complexity and low cost. Discontinuous Conduction mode (DCM) operated buck topology is used to reduce conduction losses.

II. BUCK CONVERTER

A buck converter is a voltage step down and current step up converter. The Buck Converter is used in SMPS circuits where the DC output voltage needs to be lower than the DC input voltage.

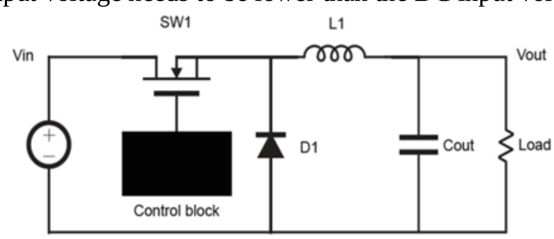


Figure 1: Buck converter circuit diagram

The switching transistor between the input and output of the Buck Converter continually switches ON and OFF at high frequency. To maintain a continuous output, the circuit uses the energy stored in the inductor L, during the on periods of the switching transistor, to continue supplying the load during the off periods.

Buck converter operation

The buck Converter circuit consists of the switching transistor, together with the flywheel circuit (Dl, L1 and C1). While the transistor is on, current is flowing through the load via the inductor L1. The action of any inductor opposes changes in current flow and also acts as a store of energy. In this case the switching transistor output is prevented from increasing immediately to its peak value as the inductor stores energy taken from the increasing output; This stored energy is later released back into the circuit as a back e.m.f. as current from the switching transistor is rapidly switched off .

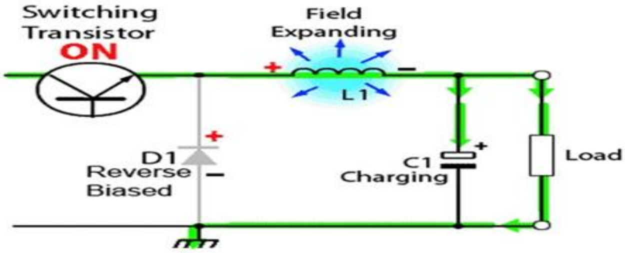


Figure 2: Transistor Switch 'on' Period

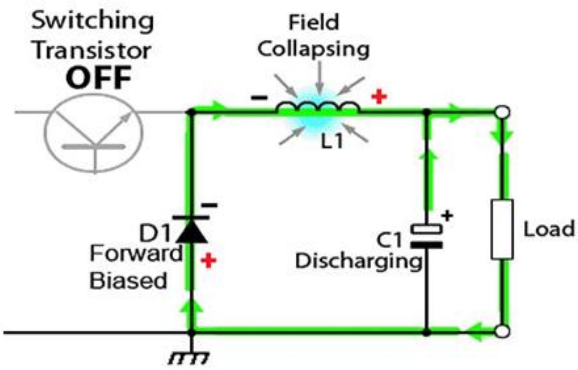


Figure 3: Transistor Switch 'OFF' Period

III. Design Requirements for Buck Converter

PARAMETR	MIN NOM	MAX	UNIT
V in Input voltage	12	30	V
ILEDOutput current	0.5		A
ISCP Short circuit current trip point	3.3		A
Switching frequency	300		KHZ

Table .1 Design parameters

Criteria for Selection of Components:
The Key components for selection
i. Inductor
ii..Output capacitor
iii. Output diode
iv. MOSFET
v. Switching frequency

i. Inductor Selection Criteria:

Ferrite core will be selected because of its good high frequency properties, is the material choice. The device must deliver a maximum current of 2.5A this requires the output inductors saturation current be above

2.5A +1/2 (ripple current) caused during inductor switching. The min inductance value can be calculated by using this formula

$$L_{MIN} = \frac{V_{IN} - V_{OUT}}{I_{PEAK}} \times T_{ON}$$

The inductor used in this circuit is close to standard value 33uH. This is maximum inductance that can be used in the converter to deliver the minimum current

ii. Selection of Output Capacitor :

In order to satisfy the output voltage and undershoot specifications there must be enough output capacitance to keep the output voltage with in specified voltage / its ripple limits during load current steps. The capacitance value can be calculated by using this formula.

$$\frac{1}{2} \times L_O I_O{}^2 \leq \frac{1}{2}\left[C_o\left(V_{OS}{}^2 - V_O{}^2\right)\right]$$

Where

VOS=Overshoot voltage above the output voltage
VO =output voltage
CO=output capacitance
LO=inductance
IO=output current.

When the load increases from minimum to full load the output capacitor must deliver current to the load

iii. FET Selection Criteria:

The maximum input voltage for this application is 30 V. switching the inductor causes overshoot voltages that can equal the input voltage. Since the RDS(on) of the FET rises with breakdown voltage, select a FET with as low a breakdown voltage as possible.

iv. Switching Frequency

The frequency is set by using the design formula given in the FET Selection Criteria

$$F_{SW} = \frac{1}{R_{RC} \times C_{RC} \times 0.105}$$

IV Controller selection for Buck Topology

Controller selection plays very significant role in the entire working of the driver to operate in constant current/voltage mode of operation. Controller is a very important block for the operation of converter. Entire switching operation in a converter depends upon the controller. Controllers give gate pulses to the switch as per its internal operation and also provide several inbuilt features like Voltage Feed Forward Compensation, under voltage Lockout, Programmable Short-circuit Protection, Hiccup Over current fault recovery voltage change, closed- loop soft start, and external synchronization.

Texas Instruments TPS40200 is a non synchronous controller with a built in 200-mA driver designed to drive high speed P-Channel FETs up to 500 kHz. The controller uses a low value current sensing resistor in series with the input voltage and the power FETs source connection to detect switching current. When the voltage drop across this resistor exceeds 100 mV, the part enters a hiccup fault mode at about 2% of the operating frequency The device uses voltage feedback to an error amplifier that is biased by a precision 700-mV reference. Feed forward compensation from the input keeps the PWM gain constant over the full input voltage range, eliminating the need to change frequency compensation for different input voltages. The TPS40200 also incorporates a soft start feature where the output follows a slowly rising soft start voltage, preventing output voltage overshoot.

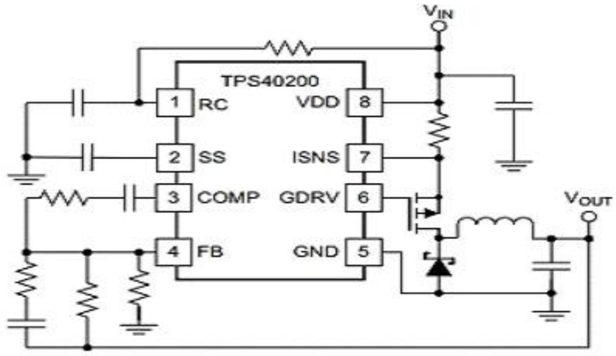


Figure4: Simplified schematic of TPS40200D controller

PIN		Input/output	Description
Pin Name	Pin No		
RC	1	I	Switching frequency setting RC network. The device may be synchronized to an external clock frequency(optional)
SS	2	I	Soft- starts programming pin. Connect an external capacitor SS pin to GND. Pulling this pin SS below 150 mV causes the output switching to stop, placing the device in a shutdown state.
COMP	3	O	Error amplifier output
FB	4	I	Error amplifier inverting input. Connect feedback resistor network midpoint tap to this pin.
GND	5	-	Device ground pin
GDRV	6	O	Driver output for external P-channel MOSFET
ISNS	7	I	Current sense comparator input. Connect a current sense resistor in series with switch in order to set over current threshold
VDD	8	I	Input voltage. Connect local bypass capacitor from VDD to GND

Table. 2: Pin Functions & Description

IV. VOLTAGE AND CURRENT-MODE CONTROL FOR PWM SIGNAL GENERATION IN DC-TO-DC SWITCHING REGULATORS

Switching DC-to-DC voltage converters ("regulators") comprise two elements:

i. Controller
ii. Power stage.

The power stage incorporates the switching elements and converts the input voltage to the desired output. The controller can do the switching operation to control the output voltage. These two are connected by a feedback loop that compares the actual output voltage with the desired output to develop the error voltage. The controller is key to the stability and precision of the power supply, and practically every design uses a pulse-width modulation (PWM) technique for regulation. There are two main methods of generating the PWM signal.

- 1. Voltage-mode control and
- 2. Current-mode control

Voltage-mode control switching regulators are recommended when wide-input line or output-load variations are possible, under light loads (when a current-mode control-ramp slope would be too shallow for stable PWM operation), in noisy applications (when noise from the power stage would find its way into the current-mode control feedback loop), and when multiple-output voltages are needed with good cross regulation.

Current-mode control devices are recommended for applications where the supply output is high current or very-high voltage; the fastest dynamic response is required at a particular frequency, input-voltage variations are constrained, and in applications where cost and number of components must be minimized.

a. VI. Simulation & Hardware results

I.Simulation of Closed Loop Buck Converter for Constant Voltage Mode Control

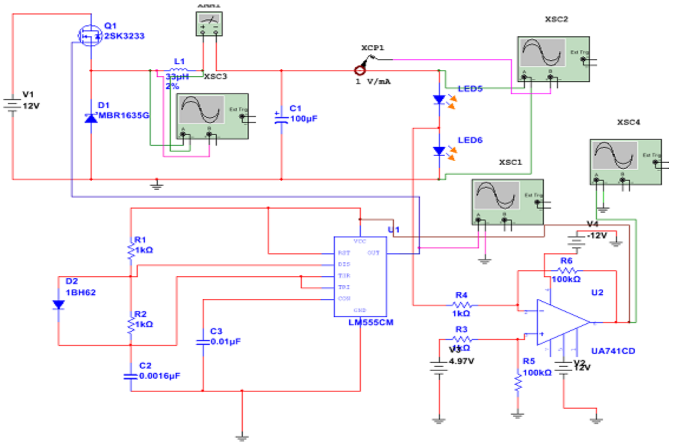
- 

Figure 5 Simulation Closed Loop Buck Converter for Constant Voltage Mode Control

ii. Design of Differential Amplifier:

A differential amplifier is designed by using µA741 with a gain of 100. Input to the non-inverting terminal is fixed equal and inverting terminal input other is taken from the potential divider of buck converter. The difference between these two is amplified with a gain of 100 and giving to 555 timers.

iii. Design of PWM Generator:

The output of differential amplifier is fed to 555 Timer which in turn generates PWM signal. The PWM signal required for switching action is with a frequency of 219 KHz and duty ratio of 50 percent. To generate a 50 percent duty cycle, the 555 timer has to work in astable mode.

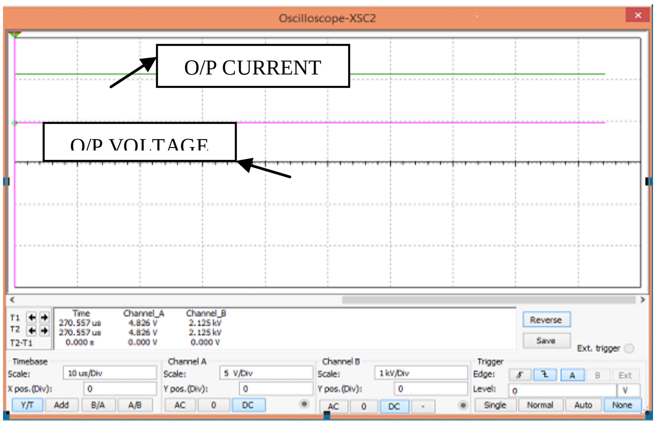


Figure 6: Output voltage and current waveforms

Input Voltage	Output Voltage
12 V	4.826V
18V	4.826V
24V	4.826V
30V	4.826V

Table 3: Voltage controlled OUTPUT

From the above table as the input voltage varied the output voltage will be constant.

II. Hardware implementation of Wide Input Voltage Led Constant Current Driver:

This application uses the TPS40200 as a buck controller that drives a string of LED diodes. The feedback point for this circuit is a sense resistor in series with this string. The low 0.7 V reference minimizes power wasted in this resistor, and maintains the LED current at a value given by 0.7/RSENSE. As the input voltage is varied, the duty cycle changes to maintain the LED current at a constant value so that the light intensity does not change with large input voltage variations.

i. Circuit diagram for buck converter

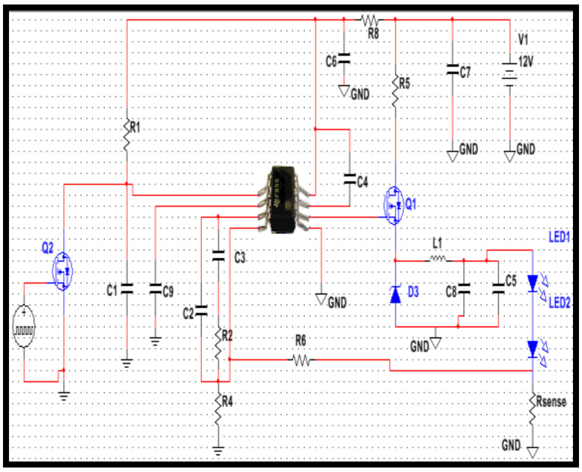


Figure 7:Circuit diagram for buck converter

Specifications

- 8-V to 16-V input range
- Output voltage 3.3V to 7V
- output current 0.5A
- 300 KHz Switching frequency

.ii.Evaluation Module of Buck converter

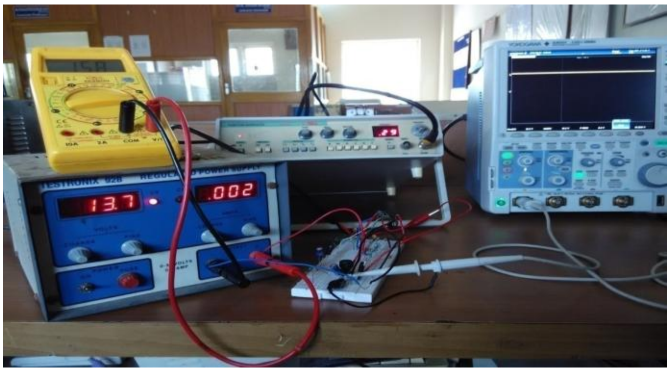


Figure8: Evaluation Module of Buck converter

iii.Hardware Implementation of Constant Current Mode Buck Converter

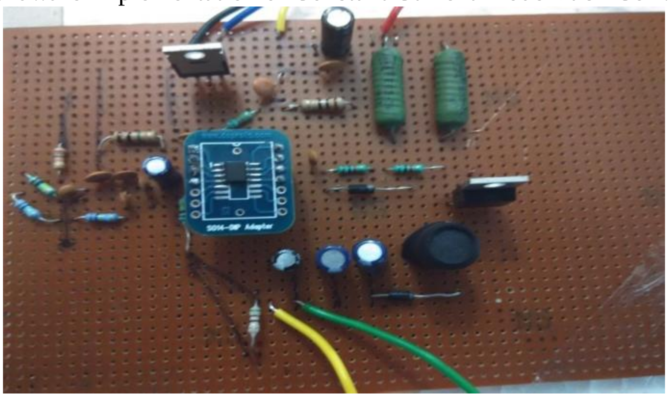


Figure9: Hardware prototype for constant current Buck converter

iv. Hardware Results:

Saw tooth Observation across Switching Frequency Network

- Observed switching frequency at 300 kHz(R=68k & c=470pf) in Digital oscilloscope

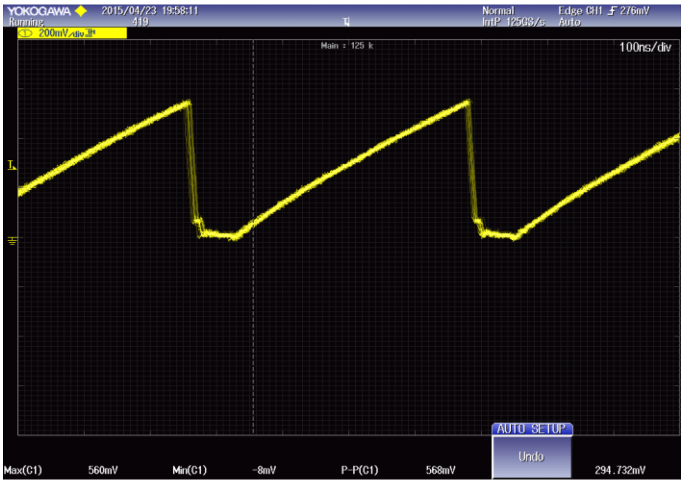


Figure 10: Saw tooth Observation across Switching Frequency Network

Gate drive voltage without external frequency synchronization

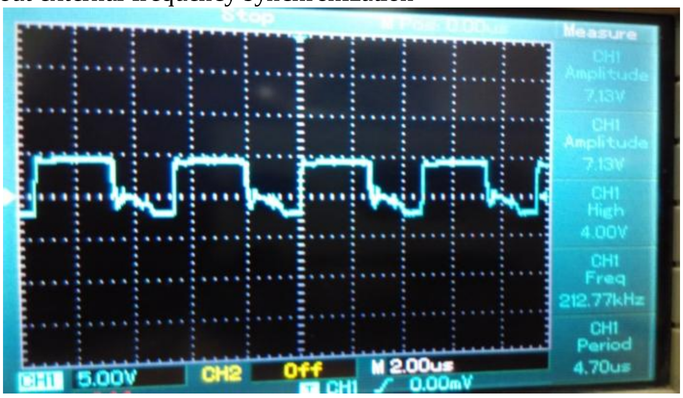


Figure 11: Gate drive voltage without external frequency synchronization

Gate drive voltage with external frequency synchronization

Figure12: Gate drive voltage with external frequency synchronization

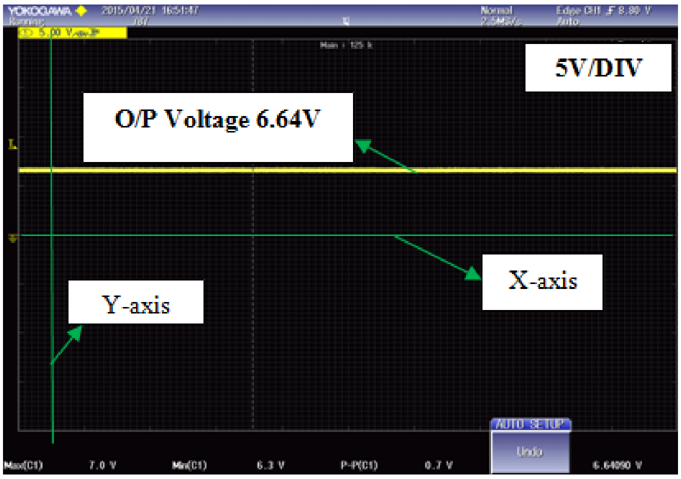


Figure :13 Output waveform

Input Voltage	Output Voltage	Output current
0.5V	0V	
2V	0V	
4.2V	0V	
4.3V	1.54V	
8.0V	3.3V	0.5A
12V	5.6V	0.5A
15	6.6	0.5A

Table 3: Current controlled output

By Comparing constant voltage mode and constant current mode it can be concluded that constant current mode has certain advantages over constant voltage mode like loop-gain variation with input voltage. Since in the present in this paper LED is taken as load, it requires constant light output.

VII. Motion integrated sensor for LED lighting for energy efficiency

To make a prototype which automatically turns on &off without human interventions with the help of sensor and integrate this technology in LED lighting applications. A Pyro Electric Infrared Sensor (PIR) motion sensor has been used in this project.

Integrating a motion sensor along with LED lighting product to save power/energy consumption. Motion sensor detects the infrared radiation around the sensor radiated by human. Human presence and absence in the range of motion sensor the light will automatically turn on/off, saves additional power/energy consumption without human interventions. This is what has been attempted in this paper.

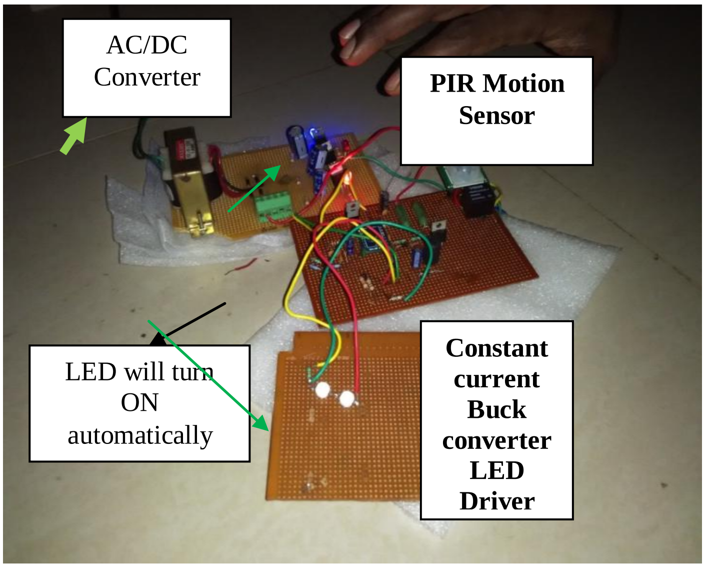


Figure 14 : Human presence in the range of motion sensor

Operation: A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. In above diagram AC-DC converter that converts 230v AC to 12v & 5v DC.5v DC supply given to the motion sensor and 12v supply will be given to the buck converter.

Human presence in the range of motion sensor a small amount of voltage will be generated that voltage applied to a relay. Relay switch can be divided in to two parts input and output .The input section has a coil which generates magnetic field when a small voltage an electronic circuit applied to it. Output section consists of contractors which connect or disconnect mechanically. At no input the COM (common) is connected to NC (Normally closed) When an operating voltage is applied, the relay coil gets energized and COM is connected to NO (Normally open), and the driver circuit will be closed and LED will be turned on. Other wise turn off.

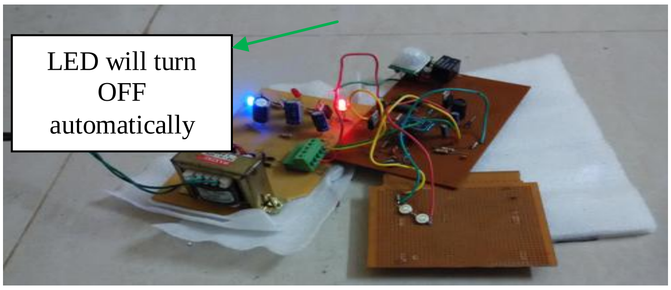


Figure 15: Human absence in the range of motion sensor

V. CONCLUSION AND FUTURE SCOPE

This paper presented a motion integrated sensor for LED lighting which saves additional power/energy consumption without human interventions. The performance of the proposed LED driver operating in constant current mode and constant voltage mode are tested and from results it can be concluded that the constant current mode has some advantages. In a constant current mode even though the input voltage is varied, the duty cycle changes to maintain the LED current at a constant value so that the light intensity does not change with large input voltage variations, this will increase the life time of LED light. The paper work can be further extended by implementing the dimming feature to the driver. Dimming feature is achieved by using a TRIACor by using a controller having an inbuilt dimming feature to control the current reference.

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