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Efficiently Powering Nine White LEDs with the MCP1650

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INTRODUCTION

The number of applications that utilize white LEDs has steadily increased due to the increased usage of Liquid Crystal Displays (LCDs) in automotive and cellular telephone displays, PDAs, handheld electronic games and computer monitors. In order to view the information on these displays, a light source is needed. Typically, this light source has been provided by Cold Cathode Florescent Tubes (CCFT). However, since designers are tasked with improving efficiency, lowering cost and decreasing size, white LEDs are now being used. Powering white LEDs, which have a forward drop (V_F) of 3.6V, typically, becomes more difficult when the application requires multiple LEDs. In this Application Note, a solution using the MCP1650 is discussed and shown to be greater than 85% efficient.

DESIGN

The MCP1650 Boost Controller is capable of generating output voltages of over 100V. However, care must be taken when selecting the external MOSFET, Schottky diode and output capacitor as they are subjected to this high boost voltage. The MCP1650 family has numerous features that include soft-start operation, peak inductor current monitoring, scalable external MOSFET, a shutdown pin for external control, low battery detect and a power good output.

The MCP1650 can be configured in either the conventional boost topology (Figure 1), a bootstrapped boost topology or a SEPIC topology. The converter's topology is determined by the relationship of input-to-output voltage.

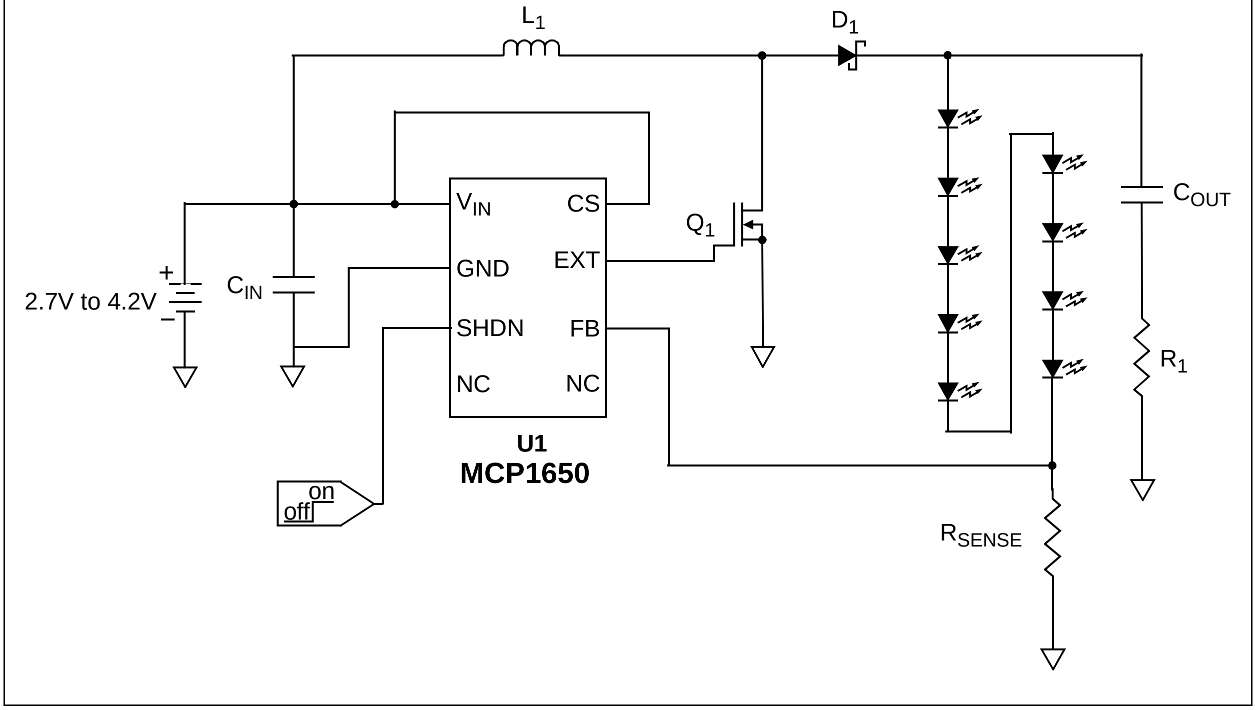

FIGURE 1: *MCP1650 Boost Application Circuit.*

The feedback voltage (V_{FB}) for the MCP1650 is 1.22V. This is only 4% of the total output voltage when powering nine white LEDs. When the voltage developed across the sense resistor (R_{SENSE}) is below the internal reference voltage, the internal oscillator is gated on and the external N-channel MOSFET is pulsed on and off to transfer energy from the source to the load. This continues until the voltage across R_{SENSE} is above the 1.22V threshold, gating off the internal oscillator. The selection of R_{SENSE} is easily determined by the following equation.

$$R_{SENSE} = \frac{V_{FB}}{I_{OUT}}$$

Typical Example

Let's consider a practical application for driving nine white LEDs with the MCP1650 using a single-cell Li-Ion input.

Input voltage:	2.8V to 4.2V
Output voltage:	32.4V (9*V_F)
Output current:	20 mA
Switching Frequency:	750 kHz
Duty Cycle:	80% for V_{IN} < 3.8V
Duty Cycle:	56% for V_{IN} > 3.8V

From the above equation, R_{SENSE} is determined to be 61Ω.

Since a high boost ratio is needed, the boost regulator will operate in Discontinuous Current mode. Therefore, the energy going into the inductor every switching cycle must be greater than the energy needed to supply the load for that switching cycle.

$$P_{OUT} = V_{OUT} \times I_{OUT}$$
$$P_{OUT} = 32.4V \times 20mA$$
$$P_{OUT} = 0.648\ watts$$

$$P_{IN} = \frac{P_{OUT}}{Efficiency}$$
$$P_{IN} = \frac{0.648w}{80\%}$$
$$P_{IN} = 0.810\ watts$$

The conservative efficiency estimate of 80% was chosen to provide margin so that the boost regulator will operate in Discontinuous Current mode. The equation for the energy flowing into the inductor is given below. The power in the inductor is equal to the inductor energy times the switching frequency (F_{SW}).

$$Energy = \frac{1}{2} \times L \times I_{PK}^{\ 2}$$

$$Power = Energy \times F_{SW}$$

The peak inductor current is:

$$I_{PK} = \frac{V_{IN}}{L} \times T_{ON}$$

Using a standard inductor value of 4.7 µH, the power in the inductor is calculated.

T_{ON} = (1/F_{SW}) * Duty Cycle
I_{PK} (2.8V) = 636 mA
Energy (2.8V) = 0.951 µ-Joules
Power (2.8V) = 0.713W

There is a second operating point that needs to be addressed. That is the case when V_{IN} is 3.8V and the duty cycle is 56%.

T_{ON} = (1/F_{SW}) * Duty Cycle
I_{PK} (3.8V) = 604 mA
Energy (3.8V) = 0.857 µ-Joules
Power (3.8V) = 0.643W

For both operating points, the inductor power is less than the neccessary maximum input power, forcing the converter to operate in Continuous Current mode. Therefore, a 4.7 µH inductor is too large and the peak input current needs to be increased. A 3.3 µH inductor is selected.

T_{ON} = (1/F_{SW}) * Duty Cycle
I_{PK} (2.8V) = 905 mA
Energy (2.8V) = 1.014 µ-Joules
Power (2.8V) = 0.915 W
I_{PK} (3.8V) = 860 mA
Energy (3.8V) = 1.22 µ-Joules
Power (3.8V) = 0.915W

Now that the inductor energy is greater than the maximum required input energy, the converter will operate in Discontinuous Current mode.

When selecting the MOSFET, a low R_{DSon} logic-level N-channel is recommended. Since the input voltage ranges from 2.8V to 4.2V, the MOSFET must have a turn-on voltage as low as 2.8V. However, a lower R_{DSon} typically results in higher gate charge, leading to slower transition times in the MOSFET, thereby causing increased switching losses. The MOSFET's drain-to-source breakdown voltage must be rated to handle the boost output voltage plus margin.

The boost diode requires very fast turn-on and turn-off characteristics because it switches at the switching frequency of the converter. Schottky diodes are recommended because they are capable of this switching characteristic and have a low forward drop. As with the MOSFET, the Schottky diode must be rated to handle the boost output voltage plus margin.

The input and output capacitor size depends on the respective voltages of the converter. While low value parts are desired because of cost and size, they typically result in higher ripple voltages. The capacitors should be chosen to provide an appropriate ripple voltage for the intended application. Ceramic or low effective series resistance (ESR) tantalum capacitors are appropriate for most applications.

COMPONENTS

The following is a list of components that were used in the test circuit.

C_{IN}	Kemet®	C0603C104K8RACTU
C_{OUT}	muRata®	GJ232CF50J476ZD01K
D_1	Diodes Inc.	B130LDI
L_1	Coilcraft®	DO1813P-332HC
R_1	Panasonic® -ECG	ERJ-3RSJR10V
R_{SENSE}	Panasonic - ECG	ERJ-3ENF0610V
Q_1	Fairchild® Semiconductor	FDN337N
U1	Microchip Technology Inc.	MCP1650

SUMMARY

The circuit shown in Figure 1 was constructed with the components listed and nine through-hole white LEDs. The efficiency was measured for different input voltages and output current settings. Figure 2 illustrates the excellent efficiency performance of the MCP1650 boost converter. Since the MCP1650 requires an external MOSFET and Schottky diode, numerous white LEDs can be driven by this boost converter. This is not true of other applications where the MOSFET and/or Schottky diode are integrated into the controller. The maximum number of white LEDs is then limited by the voltage rating of the integrated MOSFET or Schottky diode.

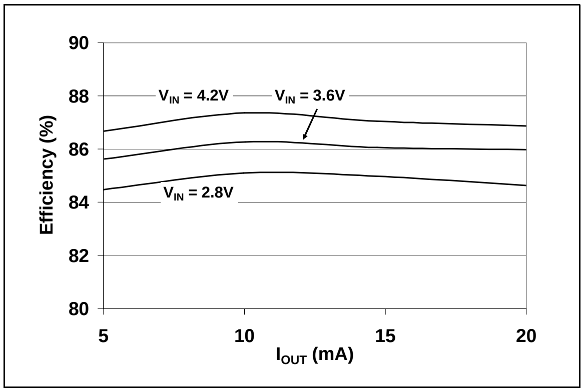

FIGURE 2: *Circuit Efficiency Over the Input Voltage Range.*

REFERENCES

1. MCP1650/51/52/53 Data Sheet, *"750 kHz Boost Converter",* DS21876, Microchip Technology Inc., 2004.

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