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.

![MCP1650 Boost Application Circuit](image-url)

**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 \((9 \times V_F)\)
- **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.

\[
P_{OUT} = V_{OUT} \times I_{OUT}
\]
\[
P_{OUT} = 32.4V \times 20mA
\]
\[
P_{OUT} = 0.648 \text{ watts}
\]

\[
P_{IN} = \frac{P_{OUT}}{\text{Efficiency}}
\]
\[
P_{IN} = \frac{0.648 \text{w}}{80%}
\]
\[
P_{IN} = 0.810 \text{ watts}
\]

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.

\[
T_{ON} = \left( \frac{1}{F_{SW}} \right) \times \text{Duty Cycle}
\]
\[
I_{PK} (2.8V) = 636 mA
\]
\[
\text{Energy} (2.8V) = 0.951 \mu\text{Joules}
\]
\[
\text{Power} (2.8V) = 0.713W
\]

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%.

\[
T_{ON} = \left( \frac{1}{F_{SW}} \right) \times \text{Duty Cycle}
\]
\[
I_{PK} (3.8V) = 604 mA
\]
\[
\text{Energy} (3.8V) = 0.857 \mu\text{Joules}
\]
\[
\text{Power} (3.8V) = 0.643W
\]

For both operating points, the inductor power is less than the necessary 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.

\[
T_{ON} = \left( \frac{1}{F_{SW}} \right) \times \text{Duty Cycle}
\]
\[
I_{PK} (3.8V) = 905 mA
\]
\[
\text{Energy} (3.8V) = 1.014 \mu\text{Joules}
\]
\[
\text{Power} (3.8V) = 0.915 \text{W}
\]

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.

<table>
<thead>
<tr>
<th>Component</th>
<th>Manufacturer</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>C&lt;sub&gt;IN&lt;/sub&gt;</td>
<td>Kemet®</td>
<td>C0603C104K8RACTU</td>
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<tr>
<td>C&lt;sub&gt;OUT&lt;/sub&gt;</td>
<td>muRata®</td>
<td>GJ232CF50J476ZD01K</td>
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<td>D&lt;sub&gt;1&lt;/sub&gt;</td>
<td>Diodes Inc.</td>
<td>B130LDI</td>
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<tr>
<td>L&lt;sub&gt;1&lt;/sub&gt;</td>
<td>Coilcraft®</td>
<td>DO1813P-332HC</td>
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<td>Panasonic®</td>
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<td>Fairchild® Semiconductor</td>
<td>FDN337N</td>
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<tr>
<td>U&lt;sub&gt;1&lt;/sub&gt;</td>
<td>Microchip Technology Inc.</td>
<td>MCP1650</td>
</tr>
</tbody>
</table>

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.](image)

REFERENCES

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