Test Report: PMP30491
Tiny SEPIC Reference Design With 12-V/2.5-A Output

Description
This reference design uses the LM5122 device. The output voltage is 12 V and has a 3-A_{max} output current. The input voltage range is from 6 V to 12 V. The circuit is designed to withstand input voltages as low as 5 V (automotive cranking) and load dump up to 36 V. Switching frequency (F_{SW}) has been measured for this board at 210 kHz.

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1 Test Prerequisites

1.1 Voltage and Current Requirements

Table 1. Voltage and Current Requirements

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SPECIFICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IN}$</td>
<td>6 V - 18 V</td>
</tr>
<tr>
<td>$V_{OUT}$</td>
<td>12 V</td>
</tr>
<tr>
<td>$I_{OUT}$</td>
<td>2.5 $I_{core}$ / 3 $I_{max}$</td>
</tr>
</tbody>
</table>

1.2 Considerations

The switching frequency is approximately 210 kHz. With an output current of 1.13 A, the circuit switches on at 5.99 V and switches off at 4.78 V. All measurements were done using the MODE diode emulation that improves light load efficiency (LLE).

The output current was adjusted to a full load of 3 A with the resistor as the load.
2 Testing and Results

2.1 Efficiency Graphs

Figure 1. Efficiency vs Output Current

Figure 2. Loss vs Output Current
2.2 Load Regulation

Figure 3. Output Current vs Output Voltage

- 6Vin
- 12Vin

Output Voltage (V) vs Output Current (A) chart showing the relationship between output voltage and output current for 6Vin and 12Vin inputs.
2.3 Thermal Images

2.3.1 6-V Input Voltage

Figure 4 shows the thermal image at 6-V input voltage and 3-A output current. This enables short-term cranking of less than 60 seconds. This measurement was taken after 30 minutes of operation.

![Figure 4. 6 V_in / 3-A_max Output](image)

<table>
<thead>
<tr>
<th>NAME</th>
<th>TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3</td>
<td>92.6°C</td>
</tr>
<tr>
<td>L1</td>
<td>105.7°C</td>
</tr>
<tr>
<td>Q2</td>
<td>116.9°C</td>
</tr>
<tr>
<td>Q2</td>
<td>91.5°C</td>
</tr>
<tr>
<td>R2</td>
<td>97.3°C</td>
</tr>
</tbody>
</table>
2.3.2 12-V Input Voltage

2.3.2.1 3-A Output Current

Figure 5. 12 V\textsubscript{in} at 3-A\textsubscript{max} Output

<table>
<thead>
<tr>
<th>NAME</th>
<th>TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3</td>
<td>66.1°C</td>
</tr>
<tr>
<td>L1</td>
<td>75.2°C</td>
</tr>
<tr>
<td>Q1</td>
<td>66.1°C</td>
</tr>
<tr>
<td>Q2</td>
<td>69.0°C</td>
</tr>
<tr>
<td>R2</td>
<td>63.9°C</td>
</tr>
</tbody>
</table>
2.3.2.2  2.5-A Output Current

Figure 6. 12 V\textsubscript{in} at 2.5 A\textsubscript{out}

<table>
<thead>
<tr>
<th>NAME</th>
<th>TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3</td>
<td>58.3°C</td>
</tr>
<tr>
<td>L1</td>
<td>66.5°C</td>
</tr>
<tr>
<td>Q1</td>
<td>57.6°C</td>
</tr>
<tr>
<td>Q2</td>
<td>60.6°C</td>
</tr>
<tr>
<td>R2</td>
<td>55.9°C</td>
</tr>
</tbody>
</table>
2.3.2.3  2-A Output Current

Figure 7. 12 V_{in} at 2 A_{out}

<table>
<thead>
<tr>
<th>NAME</th>
<th>TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3</td>
<td>53.8°C</td>
</tr>
<tr>
<td>L1</td>
<td>61.3°C</td>
</tr>
<tr>
<td>Q1</td>
<td>52.5°C</td>
</tr>
<tr>
<td>Q2</td>
<td>55.3°C</td>
</tr>
<tr>
<td>R2</td>
<td>51.4°C</td>
</tr>
</tbody>
</table>
### 2.3.2.4 1.5-A Output Current

![Image of thermography](image)

#### Table 1: Temperature Measurement

<table>
<thead>
<tr>
<th>NAME</th>
<th>TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3</td>
<td>49.0°C</td>
</tr>
<tr>
<td>L1</td>
<td>56.5°C</td>
</tr>
<tr>
<td>Q1</td>
<td>48.1°C</td>
</tr>
<tr>
<td>Q2</td>
<td>50.1°C</td>
</tr>
<tr>
<td>R2</td>
<td>48.1°C</td>
</tr>
</tbody>
</table>

*Figure 8. 12 V<sub>in</sub> at 1.5 A<sub>out</sub>*
2.3.2.5 1-A Output Current

Figure 9. 12 V_in at 1 A_out

<table>
<thead>
<tr>
<th>NAME</th>
<th>TEMPERATURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>D3</td>
<td>61.9°C</td>
</tr>
<tr>
<td>L1</td>
<td>58.1°C</td>
</tr>
<tr>
<td>Q1</td>
<td>54.8°C</td>
</tr>
<tr>
<td>Q2</td>
<td>52.5°C</td>
</tr>
<tr>
<td>R2</td>
<td>47.9°C</td>
</tr>
</tbody>
</table>
3 Waveforms

3.1 Switching

All switching waveforms in this section were measured with full bandwidth setting.

3.1.1 Q1 (HiSide FET) Source-Drain

3.1.1.1 6-V Input Voltage

Figure 10. Q1 Source to V_{OUT} at 6-V Input Voltage

- 5 V/div
- 1 µs/div

- 50 ns/major div
3.1.1.2 12-V Input Voltage

Figure 11. Q1 Source to V_out at 12-V Input Voltage

- 10 V/div
- 1 μs/div
- 50 ns/major div
3.1.2 Q1 Gate

3.1.2.1 6-V Input Voltage

Figure 12. Q1 Gate to Secondary Switch Node at 6-V Input Voltage

- 5 V/div
- 1 µs/div

- 50 ns/major div
3.1.2.2 12-V Input Voltage

Figure 13. Q1 Gate to Secondary Switch Node at 12-V Input Voltage

- 5 V/div
- 50 ns/major div

- 50 ns/major div
3.1.3 Q2 (LoSide FET) Drain-Source

3.1.3.1 6-V Input Voltage

Figure 14. Q2 Drain to GND at 6-V Input Voltage

- 10 V/div
- 1 µs/div
- 50 ns/major div

- 50 ns/major div
3.1.3.2 12-V Input Voltage

Figure 15. Q2 Drain to GND at 12-V Input Voltage

- 10 V/div
- 1 μs/div

- 50 ns/major div
3.1.4 Q2 Gate

3.1.4.1 6-V Input Voltage

- 2 V/div
- 1 µs/major div

- 50 ns/major div
3.1.4.2 12-V Input Voltage

Figure 16. Q2 Gate to GND at 12-V Input Voltage

- 2 V/div
- 1 µs/div

- 50 ns/major div
3.2 Output Voltage Ripple (AC)

Figure 17. Output Voltage Ripple

- Ch1 (blue): 200 mV/div at 6 V<sub>IN</sub>
- Ch2 (brown): 200 mV/div at 12 V<sub>IN</sub>
- 2 µs/div
- 20-MHz bandwidth setting
3.3 Input Voltage Ripple (AC)

- Ch1 (blue): 500 mV/div at 6 $V_{IN}$
- Ch2 (brown): 500 mV/div at 12 $V_{IN}$
- 2 µs/div
- 20-MHz bandwidth setting
3.4 **Control Loop Frequency Response**

Table 2. Summary of the Following Figures

<table>
<thead>
<tr>
<th>$V_{in}$</th>
<th>6 V</th>
<th>12 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth (kHz)</td>
<td>1.71</td>
<td>3.92</td>
</tr>
<tr>
<td>Phase margin</td>
<td>67.8°</td>
<td>69.6°</td>
</tr>
<tr>
<td>Slope (20 dB/decade)</td>
<td>-1</td>
<td>-1</td>
</tr>
<tr>
<td>Gain margin (dB)</td>
<td>-14.2</td>
<td>-17.6</td>
</tr>
<tr>
<td>Slope (20 dB/decade)</td>
<td>-0.7</td>
<td>-1.4</td>
</tr>
<tr>
<td>Frequency (kHz)</td>
<td>11.6</td>
<td>21.9</td>
</tr>
</tbody>
</table>

3.4.1 **6-V Input Voltage**

**Figure 19. Bode Plot at 6-V Input Voltage**
3.4.2 12-V Input Voltage

Figure 20. Bode Plot at 12-V Input Voltage
3.5  **Load Transients**

Electronic load was used in this measurement. The load switches from 1.5 A to 3 A with a frequency of 100 Hz.

3.5.1  **6-V Input Voltage**

![Waveform 1](image)

- Ch1 (blue): output voltage (AC) = 100 mV/div, 10-kHz bandwidth
- Ch2 (red): output current = 1 A/div, 20-MHz bandwidth
- 2 ms/div
3.5.2 12-V Input Voltage

Figure 22. 1.5-A to 3-A Load Transient at 12-V Input Voltage

- Ch1 (blue): output voltage (AC) = 100 mV/div, 10-kHz bandwidth
- Ch2 (red): output current = 1 A/div, 20-MHz bandwidth
- 2 ms/div
3.6 Start-up Sequence

3.6.1 6-V Input Voltage

Figure 23. Start-up With 6-V Input Voltage

- Ch1 (violet): input voltage = 2 V/div
- Ch2 (green): output voltage = 5 V/div
- 4 ms/div
3.6.2  12-V Input Voltage

Figure 24. Start-up With 12-V Input Voltage

- Ch1 (violet): input voltage = 5 V/div
- Ch2 (green): output voltage = 5 V/div
- 4 ms/div
3.7 **Shut-down Sequence**

The power supply was disconnected in the following measurements. The waveforms were done with a 20-MHz bandwidth setting.

3.7.1 **6-V Input Voltage**

![Figure 25. Shut-down With 6-V Input Voltage](image)

- Ch1 (violet): input voltage = 2 V/div
- Ch2 (green): output voltage = 5 V/div
- 2 ms/div
3.7.2  12-V Input Voltage

Figure 26. Shut-down With 12-V Input Voltage

- Ch1 (violet): input voltage = 5 V/div
- Ch2 (green): output voltage = 5 V/div
- 2 ms/div
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