**Test Report: PMP30805**

**Tiny Automotive SEPIC Reference Design**

**Description**

This tiny automotive SEPIC reference design contains a 6 W auxiliary power supply and is designed for a 12 V bias rail. The wide input accepts cranking down to 4.5 Vmin and surge up to 40 Vmax. Due to switching frequency of 2 MHz, the dual inductor is fairly small, resulting in excellent dynamic behavior. TI controller LM5155x-Q1 is cost effective and its housekeeping currents are minimized. The optional input filter attenuates reflected ripple, and the SEPIC topology supports fine EMI behavior by continuous input current.

![Tiny Automotive SEPIC Reference Design Board](image-url)
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>Input Voltage Range</td>
<td>6.0 V-18 V, 12.0 V nom., 4.5 V cranking, 40.0 V peak</td>
</tr>
<tr>
<td>Output Voltage</td>
<td>12 V @ 500 mA</td>
</tr>
<tr>
<td>Switching Frequency</td>
<td>2 MHz</td>
</tr>
<tr>
<td>Topology</td>
<td>Nonsynchronous SEPIC</td>
</tr>
</tbody>
</table>

1.2 Considerations

- Due to availability BSZ340N08NS3 was used as Q1A.
- The circuit started up at 5.7 V input voltage and shut down at 4.4 V.
- Switching frequency has been verified at 2.022MHz for this prototype.
- Current sense trips at load current 670mA at minimum input voltage 4.5V, margin 30%+.
- At nominal input 12V the converter has been tested up to 800mA.

Unless otherwise indicated, the input voltage was set to 12 V and the output current was adjusted to full load 500 mA with a variable resistor.
2 Testing and Results

2.1 Efficiency Graphs

![Efficiency vs Output Current](image)

Figure 1 Efficiency vs Output Current

2.2 Loss

![Loss vs Output Current](image)

Figure 2 Loss vs Output Current
2.3 Load Regulation

Figure 3 Output Voltage vs Output Current
2.4 Line Regulation

Figure 4 Output Voltage vs Input Voltage

Efficiency and Loss were also calculated.

Figure 5 Efficiency and Loss vs Input Voltage
2.5  Thermal Images

Figure 6 IR-Image @ 6 V Input Voltage

Figure 7 IR-Image @ 12 V Input Voltage – at nominal input dt < +35K (!)

Figure 8 IR-Image @ 18 V Input Voltage

2.6  Dimensions
The size of this PCB is 68.6 mm x 25.4 mm, two layers board 70um each and assembly is single sided
3 Waveforms

3.1 Switching

3.1.1 Q1 Drain to GND

3.1.1.1 6 V Input Voltage

![Figure 9 Waveform Q1 Drain to GND @ 6 Vin](image-url)
3.1.1.2 12 V Input Voltage

Figure 10 Waveform Q1 Drain to GND @ 12 Vin – almost neither overshoot nor ringing (!)
3.1.1.3 18 V Input Voltage

Figure 11 Waveform Q1 Drain to GND @ 18 Vin
3.1.2 Q1 Gate to GND

![Waveform Q1 Gate to GND @ 12 Vin](image)

Figure 12 Waveform Q1 Gate to GND @ 12 Vin
3.1.3 Diode D2 (referenced to VOUT)

3.1.3.1 6 V Input Voltage

Figure 13 Waveform D2 to VOUT @ 6 Vin
3.1.3.2 12 V Input Voltage

Figure 14 Waveform D2 to VOUT @ 12 Vin
3.1.3.3 18 V Input Voltage

Figure 15 Waveform D2 to VOUT @ 18 Vin
3.2 **Output Voltage Ripple**

![Output Voltage Ripple Graph]

Figure 16 Output Ripple @ 12 V Input Voltage, output ripple 90mVpp, <1% Vout (!)

3.3 **Input Voltage Ripple**

![Input Voltage Ripple Graph]

Figure 17 Filtered Input Ripple @ 12 V Input Voltage, reflected ripple 20mVpp (!)
3.4 **Bode Plot**

<table>
<thead>
<tr>
<th></th>
<th>4.5 Vin</th>
<th>6 Vin</th>
<th>12 Vin</th>
<th>18 Vin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bandwidth (kHz)</td>
<td>5.28</td>
<td>7.32</td>
<td>12.7</td>
<td>16.6</td>
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<tr>
<td>Phasemargin</td>
<td>74°</td>
<td>75°</td>
<td>76°</td>
<td>71°</td>
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<tr>
<td>slope (20dB/decade)</td>
<td>-0.98</td>
<td>-1.0</td>
<td>-1.0</td>
<td>-1.0</td>
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<tr>
<td>gain margin (dB)</td>
<td>-13.3</td>
<td>-14.9</td>
<td>-17.4</td>
<td>-17.6</td>
</tr>
<tr>
<td>slope (20dB/decade)</td>
<td>-0.7</td>
<td>-0.74</td>
<td>-1.31</td>
<td>-1.45</td>
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<tr>
<td>freq (kHz)</td>
<td>33.1</td>
<td>45.1</td>
<td>72.4</td>
<td>84.6</td>
</tr>
</tbody>
</table>

Table 1 Summary of the Bode Plots

**Figure 18 Bode Plot for 4.5 V Input Voltage**

Loop bandwidth >5kHz ensures best dynamic behavior. Due to high Fsw 2MHz resulting in small magnetizing inductance the RHPZ is fairly high, so Fco could be increased.
Figure 19 Bode Plot for 6 V Input Voltage

Figure 20 Bode Plot for 12 V Input Voltage
Figure 21 Bode Plot for 18 V Input Voltage
3.5 Load Transients
The electronic load switches from 0.25 A to 0.5 A @ 100 Hz

3.5.1 6 V Input Voltage

Figure 22 Load Transient @ 6 V Input Voltage – worst case deviation 240mVpk, 2% of Vout (!)

3.5.2 12 V Input Voltage

Figure 23 Load Transient @ 12 V Input Voltage
3.5.3 18 V Input Voltage

Output Voltage => 100 mV / div
Output Current => 200 mA / div
10 kHz bw

Figure 24 Load Transient @ 18 V Input Voltage
3.6 Start-up Sequence, soft start time 10ms

Figure 25 Start-Up @ 12 V Input Voltage, tss 10ms ensures low inrush current during startup

3.7 Shutdown Sequence

Figure 26 Shutdown @ 12 V Input Voltage
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