1 General

1.1 PURPOSE

Provide the detailed data for evaluating and verifying the PMP40280. The PMP40280 is a battery initialization reference design solution for automotive and battery applications. The MCU TM4C123GH6PZ sets charging/discharging current and real time monitors battery voltage and charging/discharging current. It will calibrate system gain error to meet charging/discharging current accuracy 0.1% when environment temperature changes. When system works in any faults, MCU can disable power converter. Communication is accomplished through standard CAN bus.

1.2 TEST EQUIPMENTS

Multi-meter: Fluke Multimeter 287C, Agilent 34401A, Fluke 8845A
DC Source: TDK-Lambda, DC Load: Chroma 63103A
Ambient Temperature at 25DegC

1.3 TEST Setup Photos

![Testing Setup Image]
Top View of the Board

PMP4182
Power board

PMP40280
Mother board

ISO1050
TM4C123

DAC80004
ADS1248

Fault
## Board Pins Assignment

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>J1 12V DC Input</th>
<th>Description</th>
<th>J2 Battery Output</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>GND</td>
<td>Power Ground</td>
<td>B-</td>
<td>Battery -</td>
</tr>
<tr>
<td>2</td>
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<td>B-</td>
<td>Battery -</td>
</tr>
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<td>B-</td>
<td>Battery -</td>
</tr>
<tr>
<td>4</td>
<td>12V+</td>
<td>12V power input</td>
<td>B-</td>
<td>Battery -</td>
</tr>
<tr>
<td>5</td>
<td>12V+</td>
<td>12V power input</td>
<td>B+</td>
<td>Battery +</td>
</tr>
<tr>
<td>6</td>
<td>12V+</td>
<td>12V power input</td>
<td>B+</td>
<td>Battery +</td>
</tr>
<tr>
<td>7</td>
<td>12V</td>
<td>Aux 12V</td>
<td>B+</td>
<td>Battery +</td>
</tr>
<tr>
<td>8</td>
<td>AGND</td>
<td>Analog Ground</td>
<td>B+</td>
<td>Battery +</td>
</tr>
<tr>
<td>9</td>
<td>+5V</td>
<td>Aux +5V</td>
<td>VSET</td>
<td>Output voltage threshold setting</td>
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<tr>
<td>10</td>
<td>-5V</td>
<td>Aux -5V</td>
<td>Fault</td>
<td>Fault signal, open drain</td>
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<tr>
<td>11</td>
<td>-5V</td>
<td>Aux -5V</td>
<td>ADC_V</td>
<td>Battery voltage output</td>
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<tr>
<td>12</td>
<td>+5V</td>
<td>Aux +5V</td>
<td>MD</td>
<td>MODE setting: 0 - Buck; 1 - Boost</td>
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<tr>
<td>13</td>
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<td>Analog Ground</td>
<td>OUT_EN</td>
<td>Output on/off. 1 - on; 0 - off</td>
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<tr>
<td>14</td>
<td>12V</td>
<td>Aux 12V</td>
<td>VS_N</td>
<td>V bat - Input</td>
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<td>12V power input</td>
<td>VS_P</td>
<td>V bat + Input</td>
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<td>12V power input</td>
<td>VS_P</td>
<td>V bat + Input</td>
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<td>12V power input</td>
<td>VS_N</td>
<td>V bat - Input</td>
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<td>Power Ground</td>
<td>IN_EN</td>
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<td>19</td>
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<td>Power Ground</td>
<td>ADC_I</td>
<td>Charging/discharging current signal</td>
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<td>GND</td>
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<td>ISET</td>
<td>Charging/discharging current threshold</td>
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<tr>
<td>21</td>
<td>REF2048</td>
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<td>Input reference voltage, onboard REF5020 could be bypassed by jumper</td>
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<td>22</td>
<td>EN</td>
<td></td>
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<td>Enable PWM output, 1 - on; 0 - off</td>
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<td>23</td>
<td>B+</td>
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<td></td>
<td>Battery +</td>
</tr>
<tr>
<td>24</td>
<td>B+</td>
<td></td>
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<td>Battery +</td>
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<td>Battery +</td>
</tr>
<tr>
<td>27</td>
<td>B-</td>
<td></td>
<td></td>
<td>Battery -</td>
</tr>
<tr>
<td>28</td>
<td>B-</td>
<td></td>
<td></td>
<td>Battery -</td>
</tr>
<tr>
<td>29</td>
<td>B-</td>
<td></td>
<td></td>
<td>Battery -</td>
</tr>
<tr>
<td>30</td>
<td>B-</td>
<td></td>
<td></td>
<td>Battery -</td>
</tr>
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</table>
2 INPUT & Output CHARACTERISTICS

Input is DC source and output is electrical load. TM4C123GH6PZ sets different charging current to check the constant current characteristics using electrical load CV mode simulating different battery voltage.

2.1: Buck CC Mode Efficiency vs Output
Vset=4.0V

<table>
<thead>
<tr>
<th>Vin (V)</th>
<th>Iin (A)</th>
<th>Vout (V)</th>
<th>Iout (A)</th>
<th>Eff. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
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<td></td>
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<td></td>
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<tr>
<td>12.459</td>
<td>0.0124</td>
<td>0.099</td>
<td>0.9960</td>
<td>63.7%</td>
</tr>
<tr>
<td>12.456</td>
<td>0.0385</td>
<td>0.411</td>
<td>0.9958</td>
<td>85.4%</td>
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<tr>
<td>12.452</td>
<td>0.0720</td>
<td>0.803</td>
<td>0.9958</td>
<td>89.1%</td>
</tr>
<tr>
<td>12.449</td>
<td>0.0940</td>
<td>1.056</td>
<td>0.9959</td>
<td>89.9%</td>
</tr>
<tr>
<td>12.444</td>
<td>0.1369</td>
<td>1.548</td>
<td>0.9960</td>
<td>90.5%</td>
</tr>
<tr>
<td>12.439</td>
<td>0.1816</td>
<td>2.055</td>
<td>0.9965</td>
<td>90.7%</td>
</tr>
<tr>
<td>12.433</td>
<td>0.2243</td>
<td>2.543</td>
<td>0.9970</td>
<td>90.9%</td>
</tr>
<tr>
<td>12.428</td>
<td>0.2689</td>
<td>3.054</td>
<td>0.9975</td>
<td>91.2%</td>
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<tr>
<td>12.423</td>
<td>0.3118</td>
<td>3.543</td>
<td>0.9979</td>
<td>91.3%</td>
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<td>12.421</td>
<td>0.3305</td>
<td>3.758</td>
<td>0.9981</td>
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<td>5A</td>
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<tr>
<td>12.436</td>
<td>0.2025</td>
<td>0.376</td>
<td>4.9827</td>
<td>74.5%</td>
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<td>12.424</td>
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<td>4.9826</td>
<td>81.6%</td>
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<tr>
<td>12.412</td>
<td>0.4042</td>
<td>0.864</td>
<td>4.9830</td>
<td>85.8%</td>
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<tr>
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<td>1.061</td>
<td>4.9828</td>
<td>87.9%</td>
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<tr>
<td>12.379</td>
<td>0.6722</td>
<td>1.510</td>
<td>4.9831</td>
<td>90.4%</td>
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<tr>
<td>12.354</td>
<td>0.8767</td>
<td>1.999</td>
<td>4.9837</td>
<td>92.0%</td>
</tr>
<tr>
<td>12.329</td>
<td>1.0904</td>
<td>2.510</td>
<td>4.9843</td>
<td>93.1%</td>
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<tr>
<td>12.304</td>
<td>1.2965</td>
<td>2.999</td>
<td>4.9851</td>
<td>93.7%</td>
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<td>1.5116</td>
<td>3.503</td>
<td>4.9856</td>
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</tr>
<tr>
<td>12.267</td>
<td>1.5946</td>
<td>3.703</td>
<td>4.9860</td>
<td>94.4%</td>
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<td>10A</td>
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<tr>
<td>12.365</td>
<td>0.7838</td>
<td>0.699</td>
<td>9.9540</td>
<td>71.8%</td>
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<tr>
<td>12.338</td>
<td>1.0071</td>
<td>0.966</td>
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<td>12.298</td>
<td>1.3351</td>
<td>1.358</td>
<td>9.9540</td>
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<tr>
<td>12.276</td>
<td>1.5171</td>
<td>1.573</td>
<td>9.9550</td>
<td>84.1%</td>
</tr>
<tr>
<td>12.256</td>
<td>1.6828</td>
<td>1.768</td>
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<tr>
<td>12.225</td>
<td>1.9329</td>
<td>2.063</td>
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<tr>
<td>12.172</td>
<td>2.3699</td>
<td>2.570</td>
<td>9.9570</td>
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</table>
### Efficiency vs Output Voltage - Buck CC Mode

![Efficiency vs Output Voltage - Buck CC Mode](image)

### Buck CC Mode, Repeat Power Up

<table>
<thead>
<tr>
<th>Vin (V)</th>
<th>Iin (A)</th>
<th>Vout (V)</th>
<th>Iout (A)</th>
<th>Eff. (%)</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>5A</td>
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<td>93.7%</td>
<td>1</td>
</tr>
<tr>
<td>12.304</td>
<td>1.2959</td>
<td>3.00</td>
<td>4.9855</td>
<td>93.7%</td>
<td>2</td>
</tr>
<tr>
<td>12.304</td>
<td>1.2960</td>
<td>3.00</td>
<td>4.9854</td>
<td>93.7%</td>
<td>3</td>
</tr>
<tr>
<td>12.304</td>
<td>1.2960</td>
<td>3.00</td>
<td>4.9853</td>
<td>93.7%</td>
<td>4</td>
</tr>
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<td>12.304</td>
<td>1.2961</td>
<td>3.00</td>
<td>4.9854</td>
<td>93.7%</td>
<td>5</td>
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</table>
**Buck CC Mode, Iset Curve**

Vset=4.0V

<table>
<thead>
<tr>
<th>Vin  (V)</th>
<th>Iin  (A)</th>
<th>Vout (V)</th>
<th>Iout (A)</th>
<th>Iset  (V)</th>
<th>Eff. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.444</td>
<td>0.1417</td>
<td>3.006</td>
<td>0.4997</td>
<td>0.09967</td>
<td>85.2%</td>
</tr>
<tr>
<td>12.429</td>
<td>0.2638</td>
<td>2.996</td>
<td>0.9983</td>
<td>0.19972</td>
<td>91.2%</td>
</tr>
<tr>
<td>12.413</td>
<td>0.3896</td>
<td>3.006</td>
<td>1.4965</td>
<td>0.29971</td>
<td>93.0%</td>
</tr>
<tr>
<td>12.398</td>
<td>0.5164</td>
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<td>1.9947</td>
<td>0.39970</td>
<td>93.8%</td>
</tr>
<tr>
<td>12.383</td>
<td>0.6413</td>
<td>3.000</td>
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<td>0.49969</td>
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<td>2.9913</td>
<td>0.59973</td>
<td>94.2%</td>
</tr>
<tr>
<td>12.351</td>
<td>0.8984</td>
<td>3.000</td>
<td>3.4892</td>
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<td>94.3%</td>
</tr>
<tr>
<td>12.335</td>
<td>1.0324</td>
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<td>3.9872</td>
<td>0.79710</td>
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<td>3.014</td>
<td>4.4855</td>
<td>0.89976</td>
<td>93.9%</td>
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<td>12.303</td>
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<td>4.9835</td>
<td>0.99974</td>
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<tr>
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<td>5.4810</td>
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</tr>
<tr>
<td>12.269</td>
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<td>5.9790</td>
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<tr>
<td>12.251</td>
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<td>6.4770</td>
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<tr>
<td>12.196</td>
<td>2.1716</td>
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<td>7.9680</td>
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<tr>
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<td>8.4660</td>
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<td>8.9630</td>
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<td>12.142</td>
<td>2.6165</td>
<td>3.030</td>
<td>9.4600</td>
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<td>90.2%</td>
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<td>12.124</td>
<td>2.7589</td>
<td>3.021</td>
<td>9.9580</td>
<td>1.99980</td>
<td>89.9%</td>
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</tbody>
</table>
\[ y = 0.497779x + 0.004105 \]
\[ R^2 = 1.000000 \]

Output Current vs Iset Voltage - Buck CC Mode

- $\text{Vout}=3.0\text{V}$
- Linear
  (\(\text{Vout}=3.0\text{V}\))
Efficiency vs Output Current - Buck CC Mode

Buck CV Mode, Vset Curve

Iset=10A(2.00V)

<table>
<thead>
<tr>
<th>Vin (V)</th>
<th>Iin (A)</th>
<th>Vout (V)</th>
<th>Iout (A)</th>
<th>Vset (V)</th>
<th>Eff. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.458</td>
<td>0.0207</td>
<td>0.1957</td>
<td>0.9940</td>
<td>0.1998</td>
<td>75.4%</td>
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<tr>
<td>12.456</td>
<td>0.0376</td>
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<td>0.9940</td>
<td>0.3998</td>
<td>84.4%</td>
</tr>
<tr>
<td>12.453</td>
<td>0.0548</td>
<td>0.6001</td>
<td>0.9940</td>
<td>0.5999</td>
<td>87.4%</td>
</tr>
<tr>
<td>12.450</td>
<td>0.0720</td>
<td>0.8022</td>
<td>0.9940</td>
<td>0.7998</td>
<td>89.0%</td>
</tr>
<tr>
<td>12.449</td>
<td>0.0896</td>
<td>1.0044</td>
<td>0.9940</td>
<td>0.9999</td>
<td>89.5%</td>
</tr>
<tr>
<td>12.446</td>
<td>0.1072</td>
<td>1.2066</td>
<td>0.9940</td>
<td>1.1999</td>
<td>89.9%</td>
</tr>
<tr>
<td>12.443</td>
<td>0.1248</td>
<td>1.4088</td>
<td>0.9940</td>
<td>1.3999</td>
<td>90.2%</td>
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<td>0.9940</td>
<td>1.5999</td>
<td>90.4%</td>
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<td>0.9940</td>
<td>1.7999</td>
<td>90.5%</td>
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<td>0.9940</td>
<td>1.9999</td>
<td>90.7%</td>
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<td>0.9941</td>
<td>2.1999</td>
<td>90.8%</td>
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<td>12.431</td>
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<td>2.6218</td>
<td>0.9940</td>
<td>2.5999</td>
<td>91.0%</td>
</tr>
<tr>
<td>12.428</td>
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<td>0.9940</td>
<td>2.8000</td>
<td>91.1%</td>
</tr>
<tr>
<td>Lit. Number</td>
<td>Number</td>
<td>Output Voltage</td>
<td>Vset</td>
<td>Efficiency</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>--------</td>
<td>----------------</td>
<td>------</td>
<td>------------</td>
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<td>3.0262</td>
<td>3.2284</td>
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<td>3.6328</td>
<td>3.8349</td>
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<tr>
<td></td>
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<td>3.2000</td>
<td>3.4000</td>
<td>3.6000</td>
<td>3.8000</td>
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<tr>
<td></td>
<td>91.2%</td>
<td>91.2%</td>
<td>91.3%</td>
<td>91.4%</td>
<td>91.5%</td>
</tr>
</tbody>
</table>

\[ y = 0.202180x - 0.006502 \]

\[ R^2 = 1.000000 \]

Output Voltage vs Vset Voltage - Buck CV Mode

Iout=1.0A

Linear

(Iout=1.0A)
2.2: Boost CC Mode Efficiency vs Output

Vset=4.0V

<table>
<thead>
<tr>
<th>Vin  (V)</th>
<th>Iin  (A)</th>
<th>Vout (V)</th>
<th>Iout (A)</th>
<th>Eff. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.006</td>
<td>0.0282</td>
<td>0.4032</td>
<td>1.0003</td>
<td>84.0%</td>
</tr>
<tr>
<td>12.008</td>
<td>0.0440</td>
<td>0.6048</td>
<td>1.0003</td>
<td>87.3%</td>
</tr>
<tr>
<td>12.009</td>
<td>0.0596</td>
<td>0.8065</td>
<td>0.9999</td>
<td>88.8%</td>
</tr>
<tr>
<td>12.011</td>
<td>0.0750</td>
<td>1.0081</td>
<td>0.9999</td>
<td>89.4%</td>
</tr>
<tr>
<td>12.014</td>
<td>0.1124</td>
<td>1.5019</td>
<td>0.9995</td>
<td>90.0%</td>
</tr>
<tr>
<td>12.018</td>
<td>0.1509</td>
<td>2.0063</td>
<td>0.9987</td>
<td>90.5%</td>
</tr>
<tr>
<td>12.021</td>
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<td>0.9981</td>
<td>90.7%</td>
</tr>
<tr>
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<td>0.2267</td>
<td>3.0043</td>
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<td>91.0%</td>
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<td>0.2642</td>
<td>3.4986</td>
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<td>91.1%</td>
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<td>12.029</td>
<td>0.2796</td>
<td>3.7002</td>
<td>0.9965</td>
<td>91.2%</td>
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<tr>
<td>12.014</td>
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<td>0.4024</td>
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<td>67.9%</td>
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<tr>
<td>12.022</td>
<td>0.1955</td>
<td>0.6040</td>
<td>4.9877</td>
<td>78.0%</td>
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<tr>
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<tr>
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<td>-----</td>
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<td>-----</td>
</tr>
<tr>
<td>12.029</td>
<td>0.2769</td>
<td>0.8053</td>
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<td>82.9%</td>
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<tr>
<td>12.037</td>
<td>0.3584</td>
<td>1.0069</td>
<td>4.9872</td>
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<tr>
<td>12.055</td>
<td>0.5573</td>
<td>1.5008</td>
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<tr>
<td>12.073</td>
<td>0.7589</td>
<td>2.0047</td>
<td>4.9862</td>
<td>91.7%</td>
</tr>
<tr>
<td>12.09</td>
<td>0.9596</td>
<td>2.5086</td>
<td>4.9855</td>
<td>92.8%</td>
</tr>
<tr>
<td>12.109</td>
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<td>3.0026</td>
<td>4.9848</td>
<td>93.5%</td>
</tr>
<tr>
<td>12.127</td>
<td>1.3553</td>
<td>3.5060</td>
<td>4.9843</td>
<td>94.1%</td>
</tr>
<tr>
<td>12.134</td>
<td>1.4348</td>
<td>3.7070</td>
<td>4.9841</td>
<td>94.2%</td>
</tr>
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<tr>
<td>12.015</td>
<td>0.1216</td>
<td>0.4045</td>
<td>9.9640</td>
<td>36.3%</td>
</tr>
<tr>
<td>12.03</td>
<td>0.2868</td>
<td>0.6078</td>
<td>9.9640</td>
<td>57.0%</td>
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<tr>
<td>12.044</td>
<td>0.4421</td>
<td>0.8004</td>
<td>9.9640</td>
<td>66.8%</td>
</tr>
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<td>0.6049</td>
<td>1.0026</td>
<td>9.9640</td>
<td>73.0%</td>
</tr>
<tr>
<td>12.095</td>
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<td>1.5076</td>
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<td>85.3%</td>
</tr>
<tr>
<td>12.167</td>
<td>1.7947</td>
<td>2.4991</td>
<td>9.9630</td>
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</tr>
<tr>
<td>12.203</td>
<td>2.1913</td>
<td>3.0054</td>
<td>9.9630</td>
<td>89.3%</td>
</tr>
<tr>
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<td>90.5%</td>
</tr>
<tr>
<td>12.252</td>
<td>2.7394</td>
<td>3.7070</td>
<td>9.9630</td>
<td>90.9%</td>
</tr>
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</table>
Efficiency vs Output Voltage - Boost CC Mode

Boost CC Mode, Repeat Power Up

<table>
<thead>
<tr>
<th>Vin (V)</th>
<th>Iin (A)</th>
<th>Vout (V)</th>
<th>Iout (A)</th>
<th>Eff. (%)</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>5A</td>
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<td></td>
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<tr>
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<td>1.1568</td>
<td>3.00</td>
<td>4.9864</td>
<td>93.6%</td>
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<tr>
<td>12.110</td>
<td>1.1563</td>
<td>3.00</td>
<td>4.9863</td>
<td>93.6%</td>
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</tr>
<tr>
<td>12.110</td>
<td>1.1561</td>
<td>3.00</td>
<td>4.9863</td>
<td>93.6%</td>
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</tr>
<tr>
<td>12.110</td>
<td>1.1559</td>
<td>3.00</td>
<td>4.9862</td>
<td>93.6%</td>
<td>4</td>
</tr>
<tr>
<td>12.110</td>
<td>1.1557</td>
<td>3.00</td>
<td>4.9862</td>
<td>93.6%</td>
<td>5</td>
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</table>
Boost CC Mode, Iset Curve

Vset=4.0V

<table>
<thead>
<tr>
<th>Vin (V)</th>
<th>lin (A)</th>
<th>Vout (V)</th>
<th>Iout (A)</th>
<th>Iset (V)</th>
<th>Eff. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.014</td>
<td>0.1042</td>
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<td>0.4994</td>
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<tr>
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<td>0.2266</td>
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<td>1.84770</td>
<td>91.0%</td>
</tr>
<tr>
<td>12.036</td>
<td>0.3459</td>
<td>3.000</td>
<td>1.4962</td>
<td>1.74780</td>
<td>92.8%</td>
</tr>
<tr>
<td>12.047</td>
<td>0.4661</td>
<td>3.000</td>
<td>1.9947</td>
<td>1.64780</td>
<td>93.8%</td>
</tr>
<tr>
<td>12.058</td>
<td>0.5833</td>
<td>3.000</td>
<td>2.4933</td>
<td>1.54770</td>
<td>94.0%</td>
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<tr>
<td>12.068</td>
<td>0.7010</td>
<td>3.000</td>
<td>2.9915</td>
<td>1.44770</td>
<td>94.3%</td>
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<tr>
<td>12.079</td>
<td>0.8147</td>
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<td>3.4898</td>
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<td>94.0%</td>
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<tr>
<td>12.089</td>
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<td>3.9884</td>
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<td>93.9%</td>
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<tr>
<td>12.100</td>
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<td>4.4866</td>
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<td>1.04773</td>
<td>93.3%</td>
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<tr>
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<td>0.94774</td>
<td>93.0%</td>
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<tr>
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<tr>
<td>12.138</td>
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<tr>
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<tr>
<td>12.157</td>
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<td>0.54772</td>
<td>91.4%</td>
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<tr>
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<td>1.7879</td>
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<td>91.0%</td>
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<tr>
<td>12.176</td>
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<td>12.185</td>
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<td>90.3%</td>
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<tr>
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<tr>
<td>12.203</td>
<td>2.1862</td>
<td>3.000</td>
<td>9.9610</td>
<td>0.04765</td>
<td>89.3%</td>
</tr>
</tbody>
</table>
Output Current vs Iset Voltage - Boost CC Mode

Efficiency vs Output Current - Boost CC Mode
2.3: Calibration test result

With the system demo board, do basic linear system calibration firstly at room temperature and then test the current sampling accuracy at +/-15°C of room temperature. Test result shown as below.

![Calibration test result graph](image)

3. IR Scan Thermal Gradient (Without Fan Cooling)

12V Input, Buck CC Mode 10A/3.7V Load (15 minutes)
12V Output, Boost CC Mode 10A/3.7V Input (15 minutes)
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