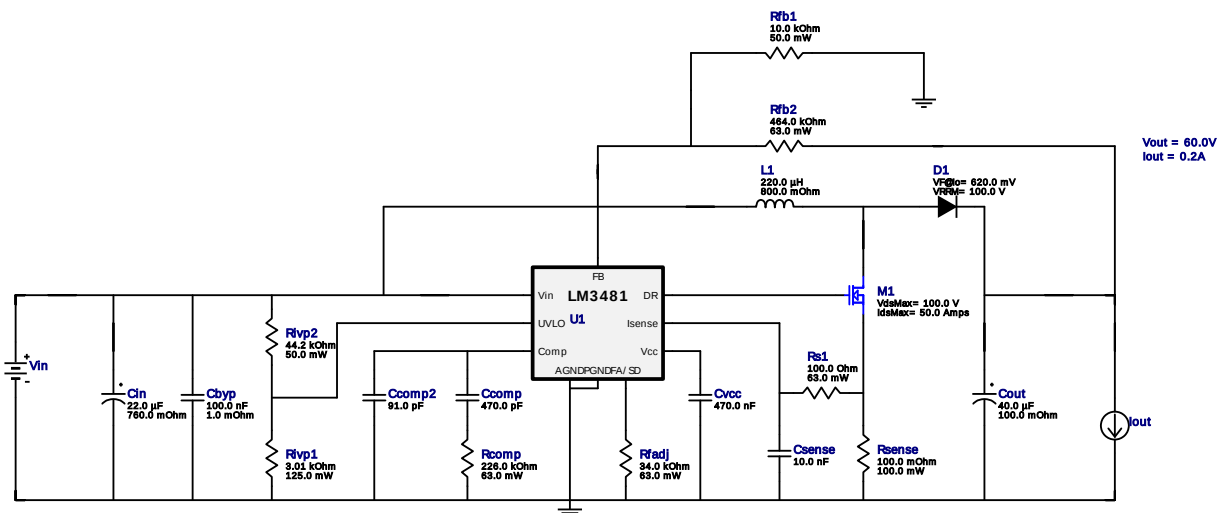
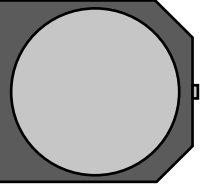
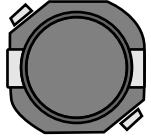
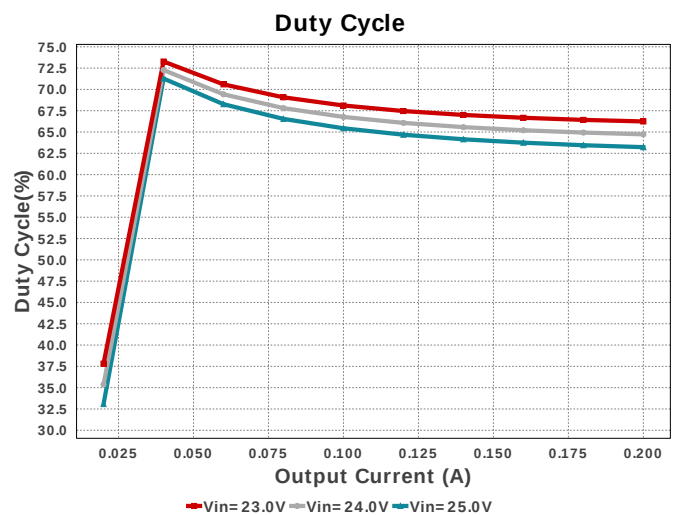
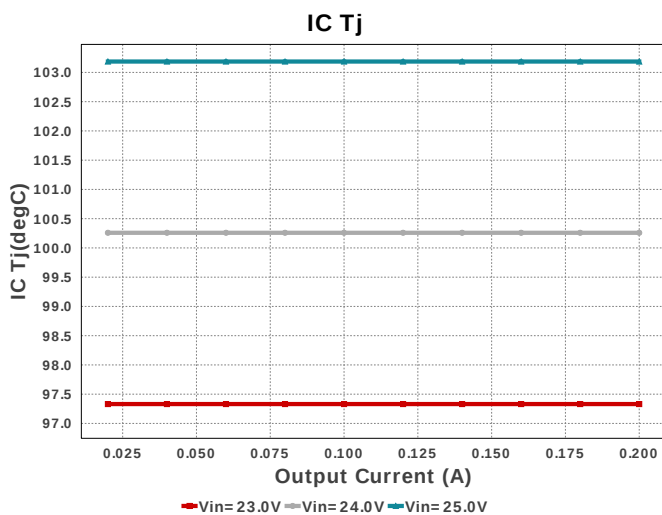


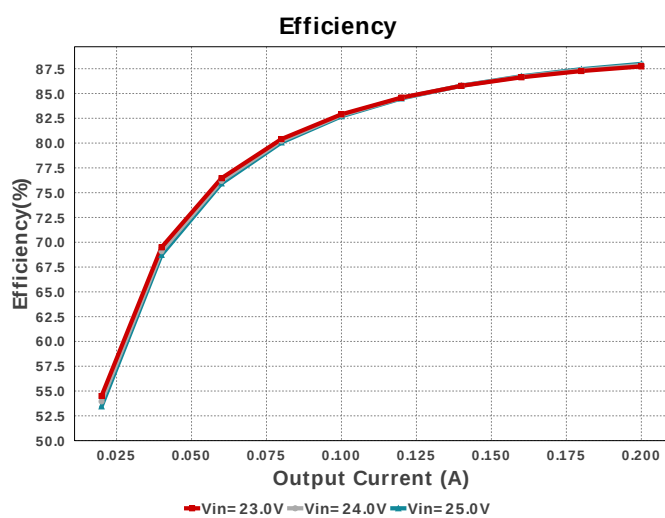
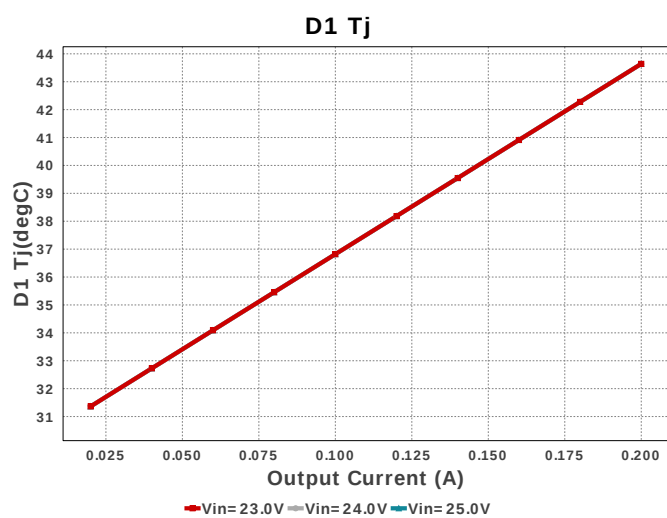
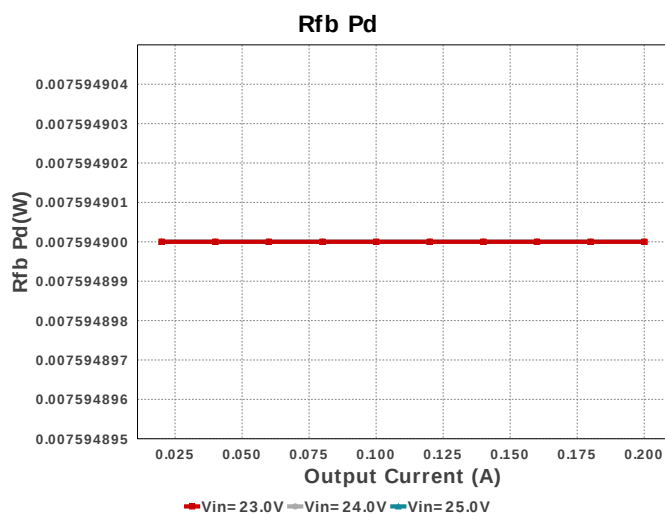
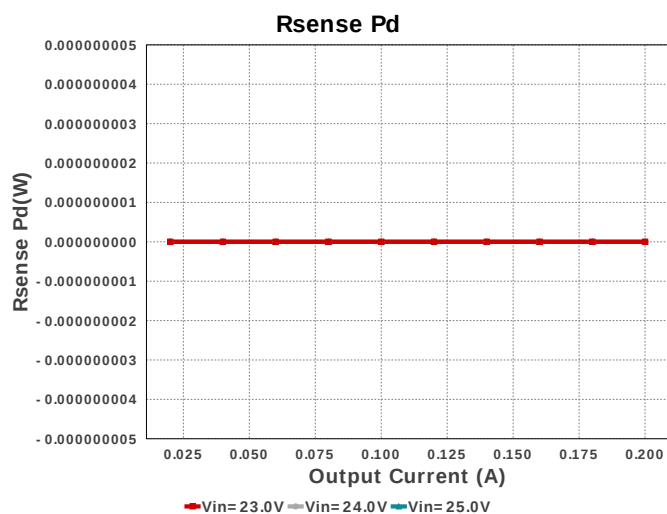
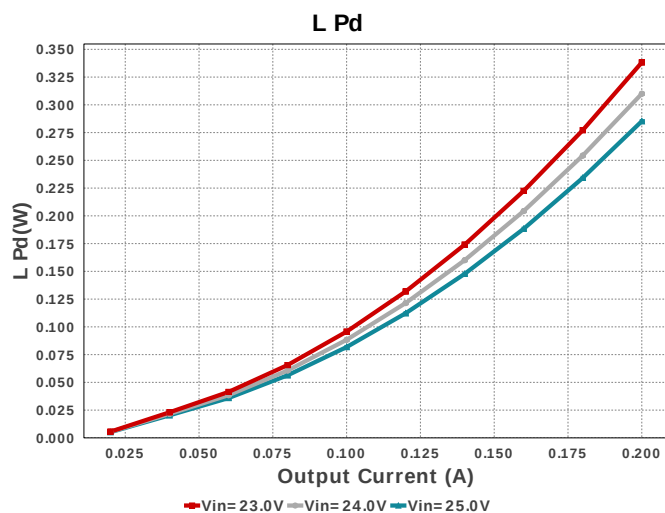
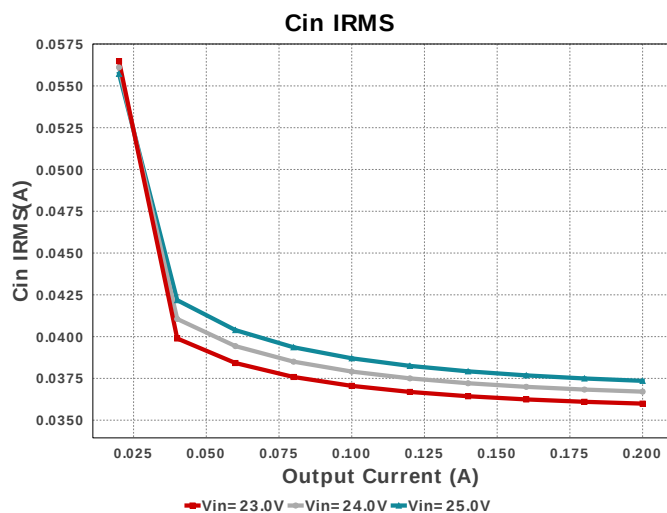


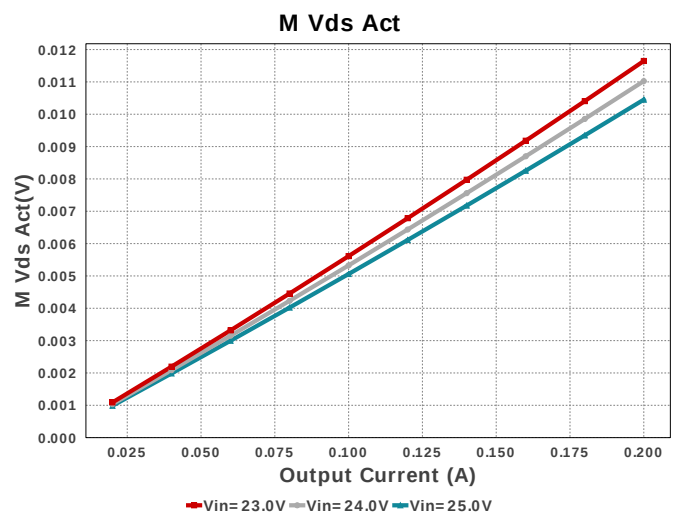
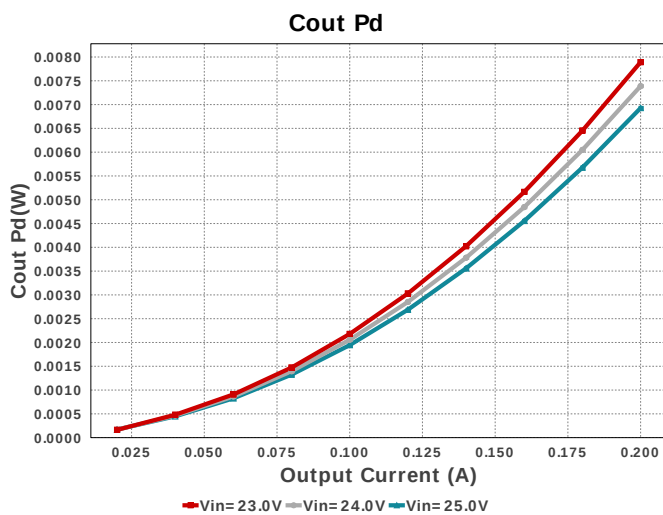
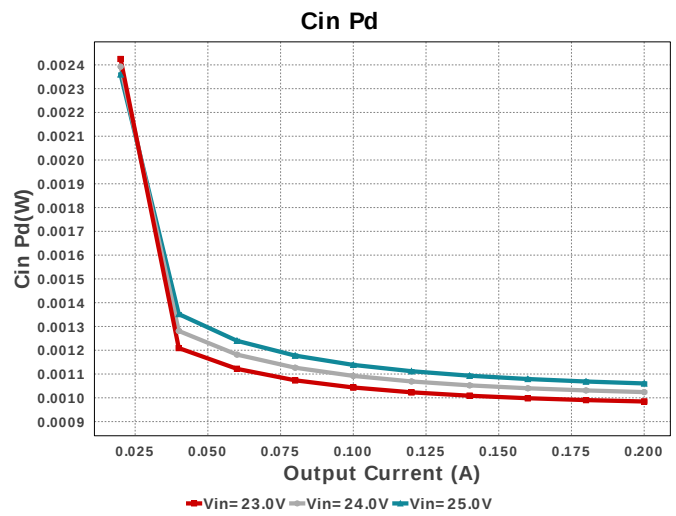
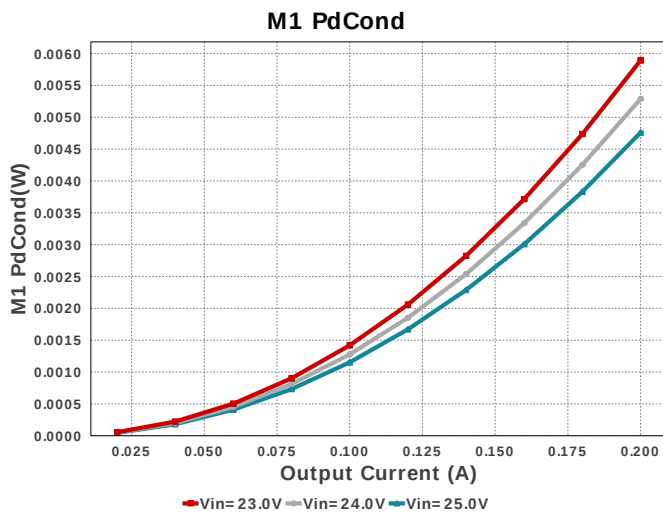
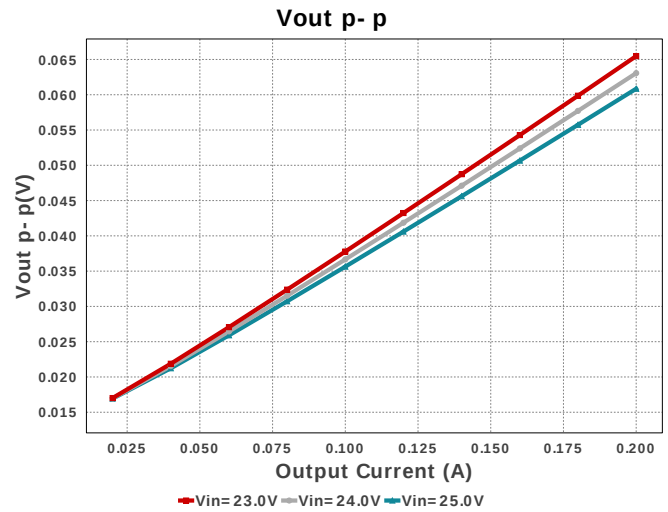
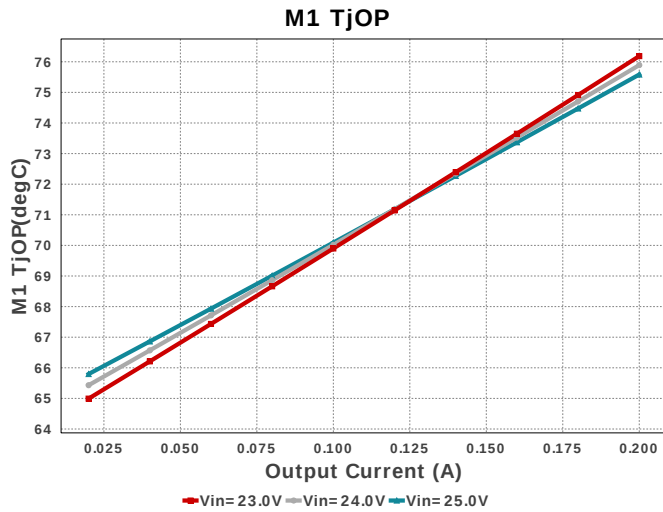
## Electrical BOM

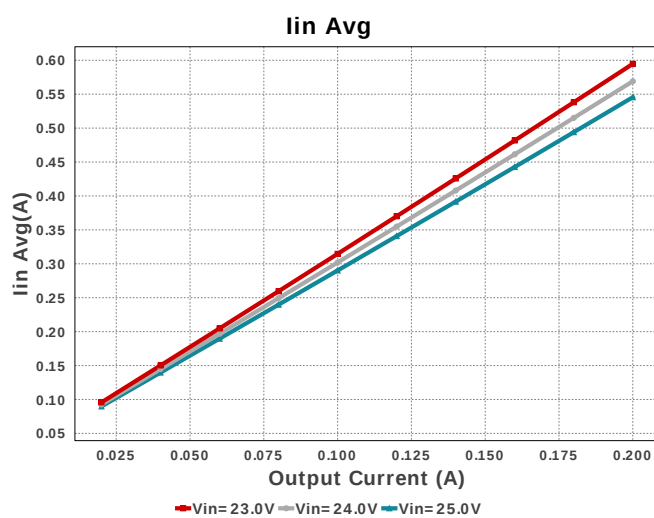
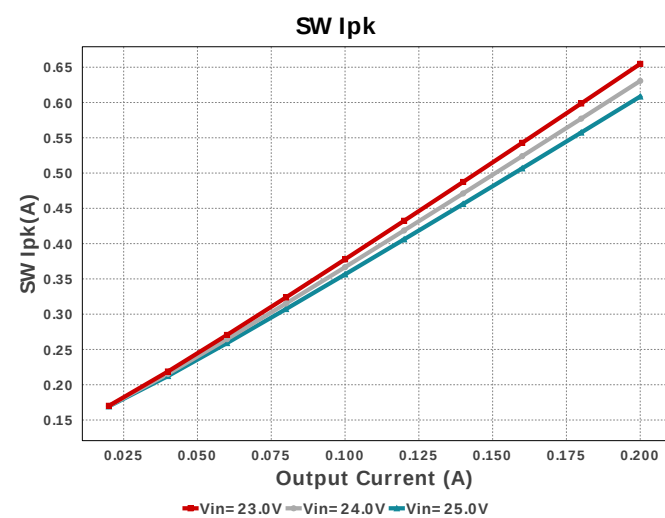
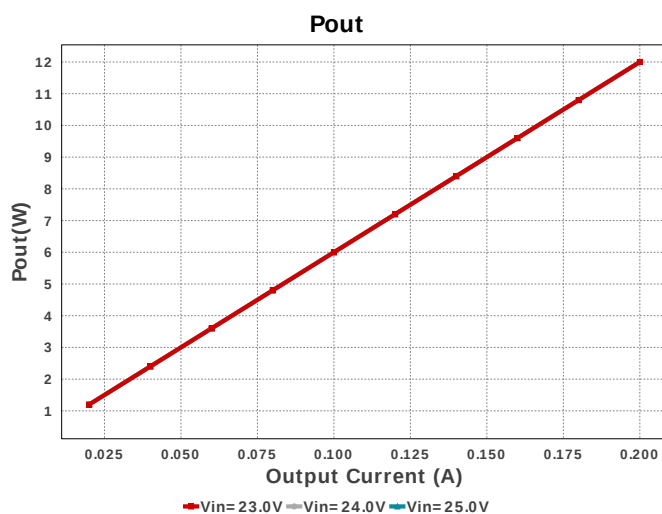
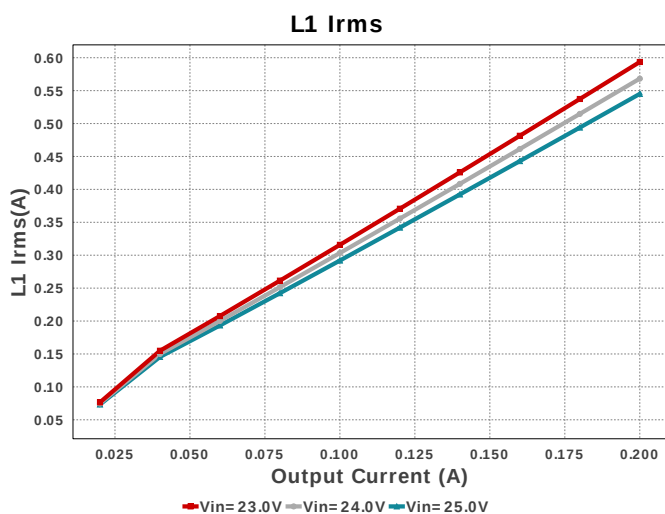
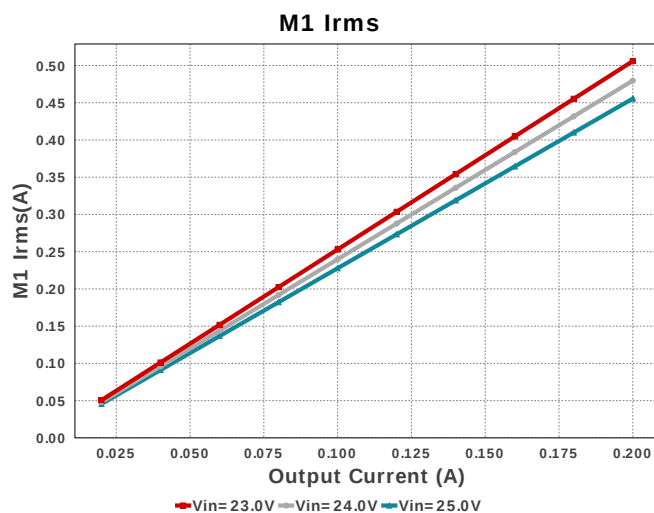
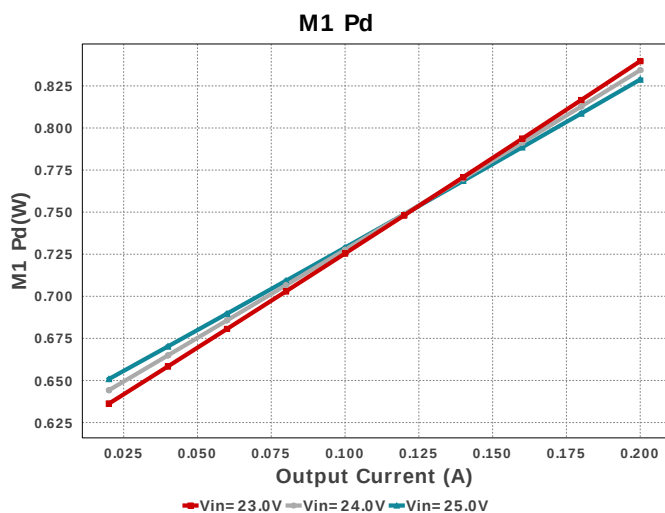
| Name   | Manufacturer              | Part Number                             | Properties                                                        | Qty | Price  | Footprint                                                                                                                 |
|--------|---------------------------|-----------------------------------------|-------------------------------------------------------------------|-----|--------|---------------------------------------------------------------------------------------------------------------------------|
| Chyp   | Kemet                     | C0603C104Z3VACTU<br>Series= Y5V         | Cap= 100.0 nF<br>ESR= 1.0 mOhm<br>VDC= 25.0 V<br>IRMS= 0.0 A      | 1   | \$0.01 | <br>0603 5 mm <sup>2</sup>           |
| Ccomp  | Samsung Electro-Mechanics | CL21C471KBANNNC<br>Series= C0G/NP0      | Cap= 470.0 pF<br>VDC= 50.0 V<br>IRMS= 0.0 A                       | 1   | \$0.01 | <br>0805 7 mm <sup>2</sup>           |
| Ccomp2 | Samsung Electro-Mechanics | CL21C910JBANNNC<br>Series= C0G/NP0      | Cap= 91.0 pF<br>VDC= 50.0 V<br>IRMS= 0.0 A                        | 1   | \$0.01 | <br>0805 7 mm <sup>2</sup>           |
| Cin    | Nichicon                  | UUD1V220MCL1GS<br>Series= uD            | Cap= 22.0 uF<br>ESR= 760.0 mOhm<br>VDC= 35.0 V<br>IRMS= 150.0 mA  | 1   | \$0.10 | <br>SM_RADIAL_5MM 58 mm <sup>2</sup> |
| Cout   | CUSTOM                    | CUSTOM<br>Series= FK                    | Cap= 40.0 uF<br>ESR= 100.0 mOhm<br>VDC= 100.0 V<br>IRMS= 793.0 mA | 1   | NA     | <br>SM_RADIAL_J16 0 mm <sup>2</sup>  |
| Csense | TDK                       | CGA4C2C0G1H103J060AA<br>Series= C0G/NP0 | Cap= 10.0 nF<br>VDC= 50.0 V<br>IRMS= 0.0 A                        | 1   | \$0.07 | <br>0805 7 mm <sup>2</sup>           |
| Cvcc   | Panasonic                 | ECPU1C474MA5<br>Series= ECPU(A)         | Cap= 470.0 nF<br>VDC= 16.0 V<br>IRMS= 0.0 A                       | 1   | \$0.20 | <br>1206 11 mm <sup>2</sup>          |
| D1     | Vishay-Semiconductor      | SS2PH10-M3                              | VF@Io= 620.0 mV<br>VRRM= 100.0 V                                  | 1   | \$0.14 | <br>DO-220AA 14 mm <sup>2</sup>      |

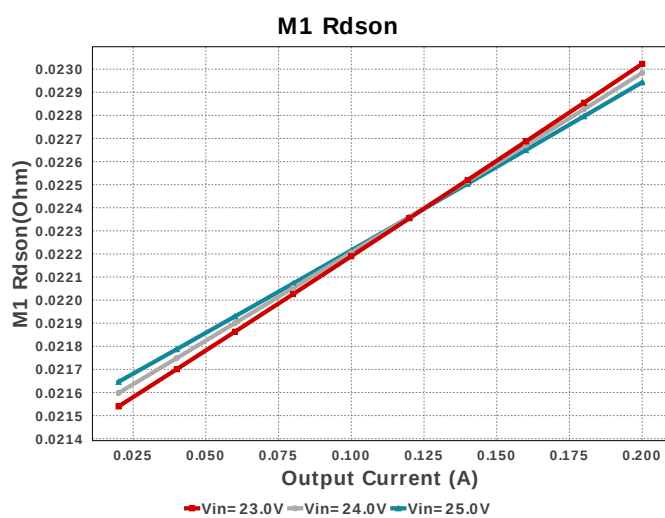
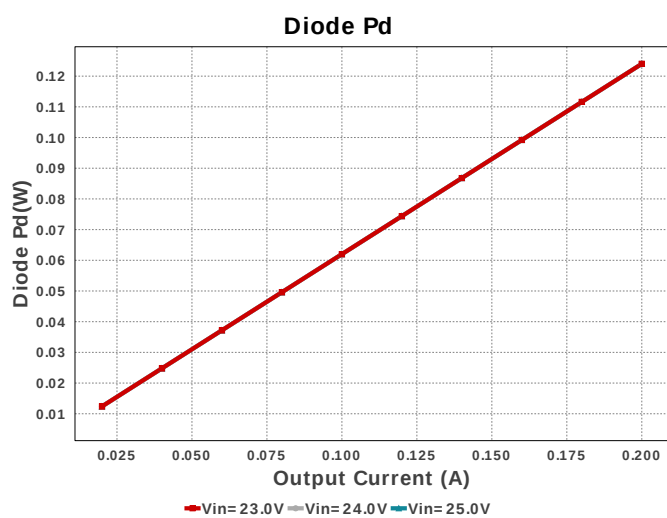
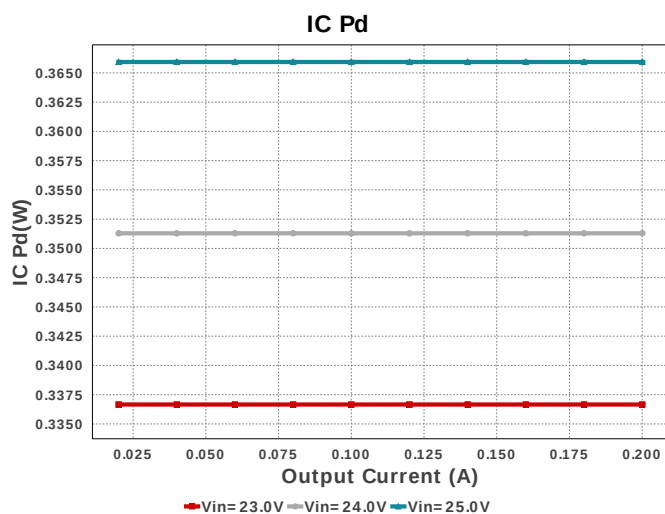
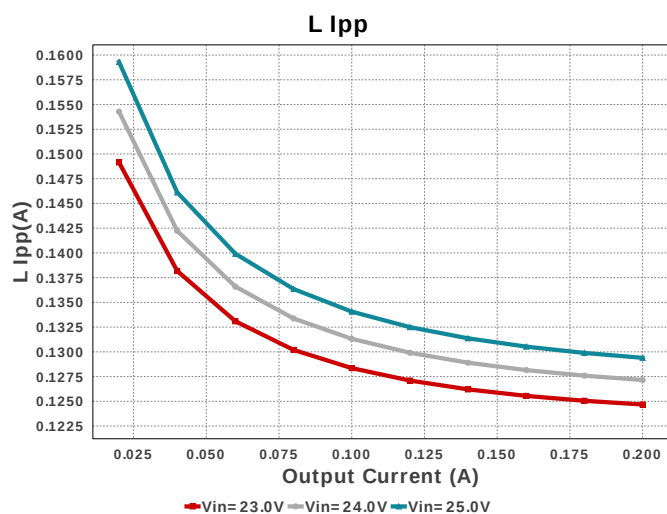
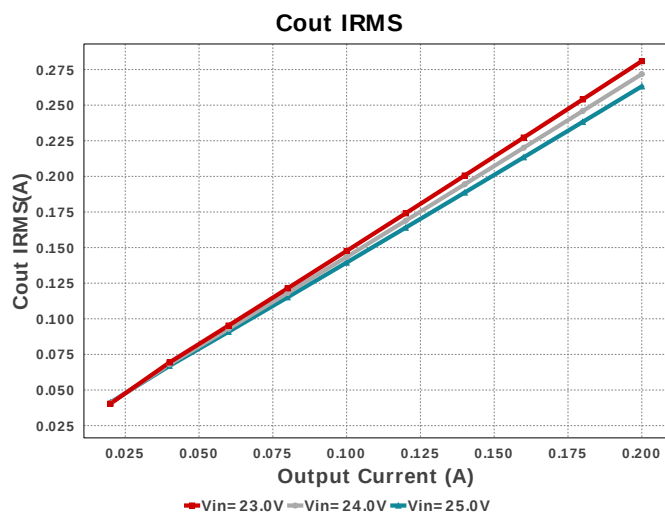
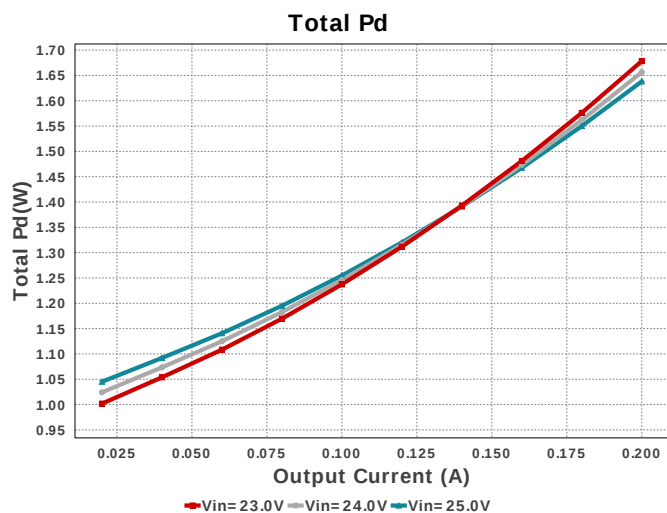
| Name   | Manufacturer      | Part Number                          | Properties                                            | Qty | Price  | Footprint                                                                                                          |
|--------|-------------------|--------------------------------------|-------------------------------------------------------|-----|--------|--------------------------------------------------------------------------------------------------------------------|
| L1     | CUSTOM            | CUSTOM                               | L= 220.0 $\mu$ H<br>DCR= 800.0 mOhm                   | 1   | NA     | <br>CLF12555 0 mm <sup>2</sup>  |
| M1     | Texas Instruments | CSD19537Q3                           | VdsMax= 100.0 V<br>IdsMax= 50.0 Amps                  | 1   | \$0.41 | <br>DQG0008A 18 mm <sup>2</sup> |
| Rcomp  | Vishay-Dale       | CRCW0402226KFKED<br>Series= CRCW..e3 | Res= 226.0 kOhm<br>Power= 63.0 mW<br>Tolerance= 1.0%  | 1   | \$0.01 | <br>0402 3 mm <sup>2</sup>      |
| Rfadj  | Vishay-Dale       | CRCW040234K0FKED<br>Series= CRCW..e3 | Res= 34.0 kOhm<br>Power= 63.0 mW<br>Tolerance= 1.0%   | 1   | \$0.01 | <br>0402 3 mm <sup>2</sup>      |
| Rfb1   | Yageo             | RC0201FR-0710KL<br>Series= ?         | Res= 10.0 kOhm<br>Power= 50.0 mW<br>Tolerance= 1.0%   | 1   | \$0.01 | <br>0201 2 mm <sup>2</sup>      |
| Rfb2   | Vishay-Dale       | CRCW0402464KFKED<br>Series= CRCW..e3 | Res= 464.0 kOhm<br>Power= 63.0 mW<br>Tolerance= 1.0%  | 1   | \$0.01 | <br>0402 3 mm <sup>2</sup>      |
| Rivp1  | Panasonic         | ERJ-6ENF3011V<br>Series= ERJ-6E      | Res= 3.01 kOhm<br>Power= 125.0 mW<br>Tolerance= 1.0%  | 1   | \$0.01 | <br>0805 7 mm <sup>2</sup>      |
| Rivp2  | Yageo             | RC0201FR-0744K2L<br>Series= ?        | Res= 44.2 kOhm<br>Power= 50.0 mW<br>Tolerance= 1.0%   | 1   | \$0.01 | <br>0201 2 mm <sup>2</sup>      |
| Rs1    | Vishay-Dale       | CRCW0402100RFKED<br>Series= CRCW..e3 | Res= 100.0 Ohm<br>Power= 63.0 mW<br>Tolerance= 1.0%   | 1   | \$0.01 | <br>0402 3 mm <sup>2</sup>    |
| Rsense | Panasonic         | ERJ-3RSFR10V<br>Series= ERJ-3R       | Res= 100.0 mOhm<br>Power= 100.0 mW<br>Tolerance= 1.0% | 1   | \$0.03 | <br>0603 5 mm <sup>2</sup>    |
| U1     | Texas Instruments | LM3481MM/NOPB                        | Switcher                                              | 1   | \$0.80 | <br>MUB10A 24 mm <sup>2</sup> |

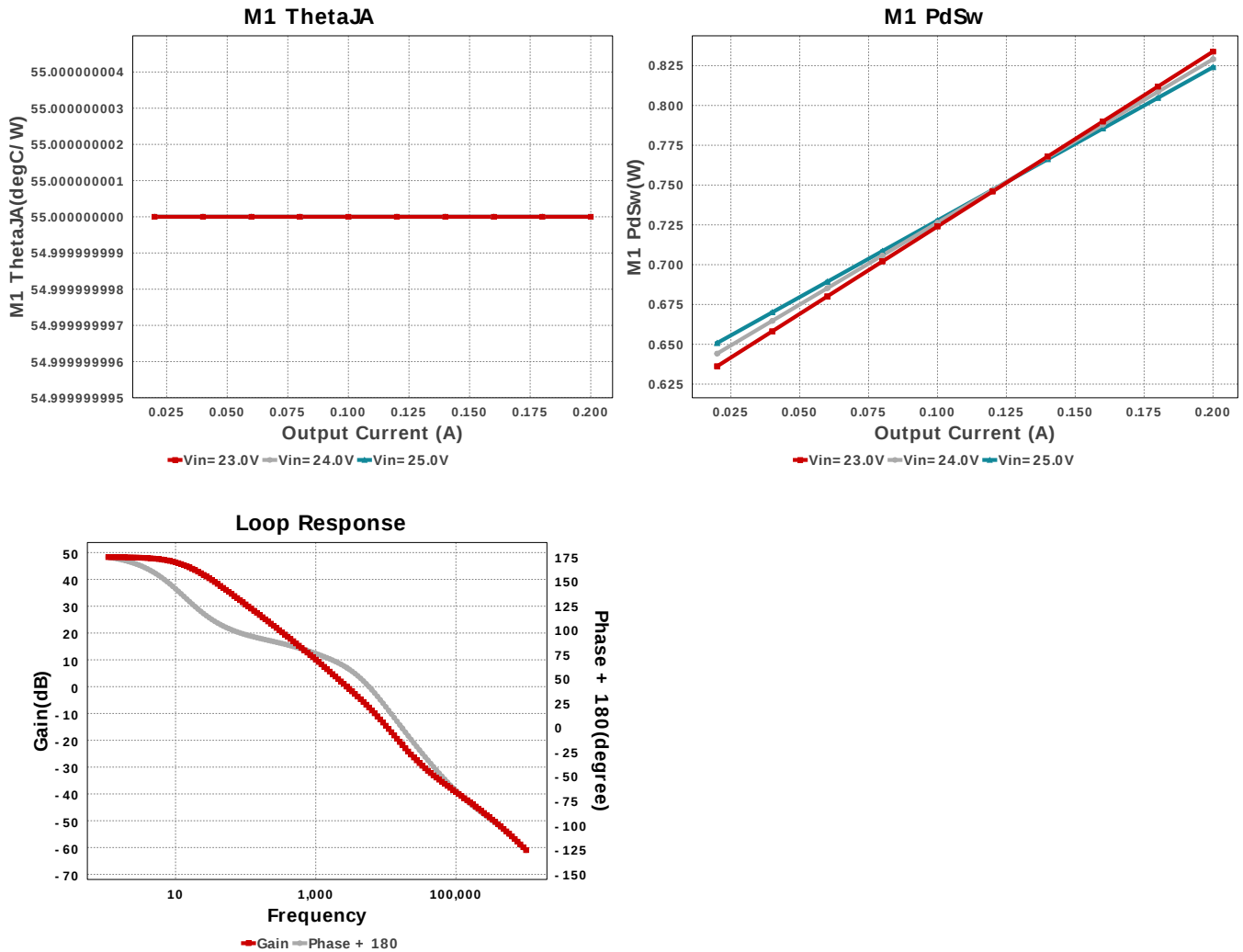












## Operating Values

| #   | Name         | Value          | Category  | Description                                   |
|-----|--------------|----------------|-----------|-----------------------------------------------|
| 1.  | Total BOM    | NA             |           | Total BOM Cost                                |
| 2.  | Cin IRMS     | 35.991 mA      | Capacitor | Input capacitor RMS ripple current            |
| 3.  | Cin Pd       | 984.46 $\mu$ W | Capacitor | Input capacitor power dissipation             |
| 4.  | Cout IRMS    | 280.932 mA     | Capacitor | Output capacitor RMS ripple current           |
| 5.  | Cout Pd      | 7.892 mW       | Capacitor | Output capacitor power dissipation            |
| 6.  | D1 Tj        | 43.64 degC     | Diode     | D1 junction temperature                       |
| 7.  | Diode Pd     | 124.0 mW       | Diode     | Diode power dissipation                       |
| 8.  | IC Pd        | 336.66 mW      | IC        | IC power dissipation                          |
| 9.  | IC Tj        | 97.331 degC    | IC        | IC junction temperature                       |
| 10. | IC Tolerance | 19.0 mV        | IC        | IC Feedback Tolerance                         |
| 11. | ICThetaJA    | 200.0 degC/W   | IC        | IC junction-to-ambient thermal resistance     |
| 12. | Iin Avg      | 594.71 mA      | IC        | Average input current                         |
| 13. | L Ipp        | 124.676 mA     | Inductor  | Peak-to-peak inductor ripple current          |
| 14. | L Pd         | 338.17 mW      | Inductor  | Inductor power dissipation                    |
| 15. | L1 Irms      | 593.518 mA     | Inductor  | Inductor ripple current                       |
| 16. | M Vds Act    | 11.647 mV      | Mosfet    | M Vds                                         |
| 17. | M1 Irms      | 505.872 mA     | Mosfet    | M1 MOSFET Irms                                |
| 18. | M1 Pd        | 839.74 mW      | Mosfet    | M1 MOSFET total power dissipation             |
| 19. | M1 PdCond    | 5.892 mW       | Mosfet    | M1 MOSFET conduction losses                   |
| 20. | M1 PdSw      | 833.85 mW      | Mosfet    | M1 MOSFET switching losses                    |
| 21. | M1 Rdson     | 23.023 mOhm    | Mosfet    | Drain-Source On-resistance                    |
| 22. | M1 ThetaJA   | 55.0 degC/W    | Mosfet    | MOSFET junction-to-ambient thermal resistance |
| 23. | M1 TJOP      | 76.186 degC    | Mosfet    | M1 MOSFET junction temperature                |
| 24. | Cin Pd       | 984.46 $\mu$ W | Power     | Input capacitor power dissipation             |
| 25. | Cout Pd      | 7.892 mW       | Power     | Output capacitor power dissipation            |
| 26. | Diode Pd     | 124.0 mW       | Power     | Diode power dissipation                       |
| 27. | IC Pd        | 336.66 mW      | Power     | IC power dissipation                          |
| 28. | L Pd         | 338.17 mW      | Power     | Inductor power dissipation                    |
| 29. | M1 Pd        | 839.74 mW      | Power     | M1 MOSFET total power dissipation             |
| 30. | M1 PdCond    | 5.892 mW       | Power     | M1 MOSFET conduction losses                   |
| 31. | M1 PdSw      | 833.85 mW      | Power     | M1 MOSFET switching losses                    |
| 32. | Rfb Pd       | 7.595 mW       | Power     | Rfb Power Dissipation                         |

| #   | Name           | Value                 | Category    | Description                                                                                |
|-----|----------------|-----------------------|-------------|--------------------------------------------------------------------------------------------|
| 33. | Rsense Pd      | 0.0 W                 | Power       | LED Current Rsns Power Dissipation                                                         |
| 34. | Total Pd       | 1.678 W               | Power       | Total Power Dissipation                                                                    |
| 35. | Rfb Pd         | 7.595 mW              | Resistor    | Rfb Power Dissipation                                                                      |
| 36. | Rsense Pd      | 0.0 W                 | Resistor    | LED Current Rsns Power Dissipation                                                         |
| 37. | BOM Count      | 1                     | System      | Total Design BOM count                                                                     |
|     |                |                       | Information |                                                                                            |
| 38. | Cross Freq     | 2.592 kHz             | System      | Bode plot crossover frequency                                                              |
|     |                |                       | Information |                                                                                            |
| 39. | Duty Cycle     | 66.241 %              | System      | Duty cycle                                                                                 |
|     |                |                       | Information |                                                                                            |
| 40. | Efficiency     | 87.73 %               | System      | Steady state efficiency                                                                    |
|     |                |                       | Information |                                                                                            |
| 41. | FootPrint      | 677.0 mm <sup>2</sup> | System      | Total Foot Print Area of BOM components                                                    |
|     |                |                       | Information |                                                                                            |
| 42. | Frequency      | 554.021 kHz           | System      | Switching frequency                                                                        |
|     |                |                       | Information |                                                                                            |
| 43. | Gain Marg      | -20.756 dB            | System      | Bode Plot Gain Margin                                                                      |
|     |                |                       | Information |                                                                                            |
| 44. | Iout           | 200.0 mA              | System      | Iout operating point                                                                       |
|     |                |                       | Information |                                                                                            |
| 45. | Low Freq Gain  | 47.548 dB             | System      | Gain at 1Hz                                                                                |
|     |                |                       | Information |                                                                                            |
| 46. | Mode           | CCM                   | System      | Conduction Mode                                                                            |
|     |                |                       | Information |                                                                                            |
| 47. | Phase Marg     | 62.32 deg             | System      | Bode Plot Phase Margin                                                                     |
|     |                |                       | Information |                                                                                            |
| 48. | Pout           | 12.0 W                | System      | Total output power                                                                         |
|     |                |                       | Information |                                                                                            |
| 49. | SW Ipk         | 654.764 mA            | System      | Peak switch current                                                                        |
|     |                |                       | Information |                                                                                            |
| 50. | Vin            | 23.0 V                | System      | Vin operating point                                                                        |
|     |                |                       | Information |                                                                                            |
| 51. | Vout           | 60.0 V                | System      | Operational Output Voltage                                                                 |
|     |                |                       | Information |                                                                                            |
| 52. | Vout Actual    | 59.724 V              | System      | Vout Actual calculated based on selected voltage divider resistors                         |
|     |                |                       | Information |                                                                                            |
| 53. | Vout Tolerance | 3.515 %               | System      | Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable |
|     |                |                       | Information |                                                                                            |
| 54. | Vout p-p       | 65.476 mV             | System      | Peak-to-peak output ripple voltage                                                         |
|     |                |                       | Information |                                                                                            |

## Design Inputs

| Name    | Value   | Description            |
|---------|---------|------------------------|
| Iout    | 200.0 m | Maximum Output Current |
| VinMax  | 25.0    | Maximum input voltage  |
| VinMin  | 23.0    | Minimum input voltage  |
| Vout    | 60.0    | Output Voltage         |
| base_pn | LM3481  | Base Product Number    |
| source  | DC      | Input Source Type      |
| Ta      | 30.0    | Ambient temperature    |

## WEBENCH® Assembly

### Component Testing

Some published data on components in datasheets such as Capacitor ESR and Inductor DC resistance is based on conservative values that will guarantee that the components always exceed the specification. For design purposes it is usually better to work with typical values. Since this data is not always available it is a good practice to measure the Capacitance and ESR values of  $C_{in}$  and  $C_{out}$ , and the inductance and DC resistance of  $L1$  before assembly of the board. Any large discrepancies in values should be electrically simulated in WEBENCH to check for instabilities and thermally simulated in WebTHERM to make sure critical temperatures are not exceeded.

### Soldering Component to Board

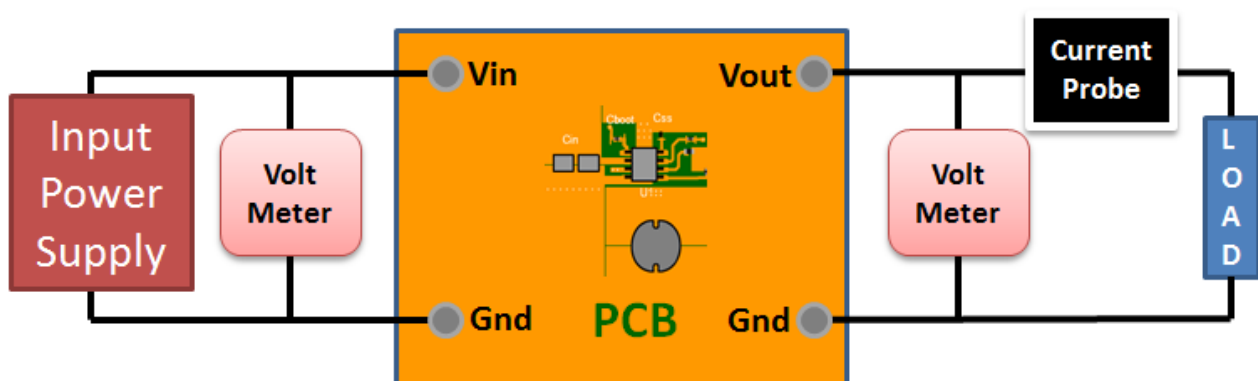
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. To solder the tab down to the board place the iron down on the board while resting against the tab, heating both surfaces simultaneously. Apply light pressure to the top of the plastic case until the solder flows around the part and the part is flush with the PCB. If the solder is not flowing around the board you may need a higher wattage iron (generally 25W to 30W is enough).

### Initial Startup of Circuit

It is best to initially power up the board by setting the input supply voltage to the lowest operating input voltage 23.0V and set the input supply's current limit to zero. With the input supply off connect up the input supply to  $V_{in}$  and GND. Connect a digital volt meter and a load if needed to set the minimum load of the design from  $V_{out}$  and GND. Turn on the input supply and slowly turn up the current limit on the input supply. If the voltage starts to rise on the input supply continue increasing the input supply current limit while watching the output voltage. If the current increases on the input supply, but the voltage remains near zero, then there may be a short or a component misplaced on the board. Power down the board and visually inspect for solder bridges and recheck the diode and capacitor polarities. Once the power supply circuit is operational then more extensive testing may include full load testing, transient load and line tests to compare with simulation results.

### Load Testing

The setup is the same as the initial startup, except that an additional digital voltmeter is connected between  $V_{in}$  and GND, a load is connected between  $V_{out}$  and GND and a current meter is connected in series between  $V_{out}$  and the load. The load must be able to handle at least rated output power + 50% ( 7.5 watts for this design). Ideally the load is supplied in the form of a variable load test unit. It can also be done in the form of suitably large power resistors. When using an oscilloscope to measure waveforms on the prototype board, the ground leads of the oscilloscope probes should be as short as possible and the area of the loop formed by the ground lead should be kept to a minimum. This will help reduce ground lead inductance and eliminate EMI noise that is not actually present in the circuit.



### Design Assistance

1. Master key : 1757F98E998CE406[v1]
2. **LM3481** Product Folder : <http://www.ti.com/product/LM3481> : contains the data sheet and other resources.

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