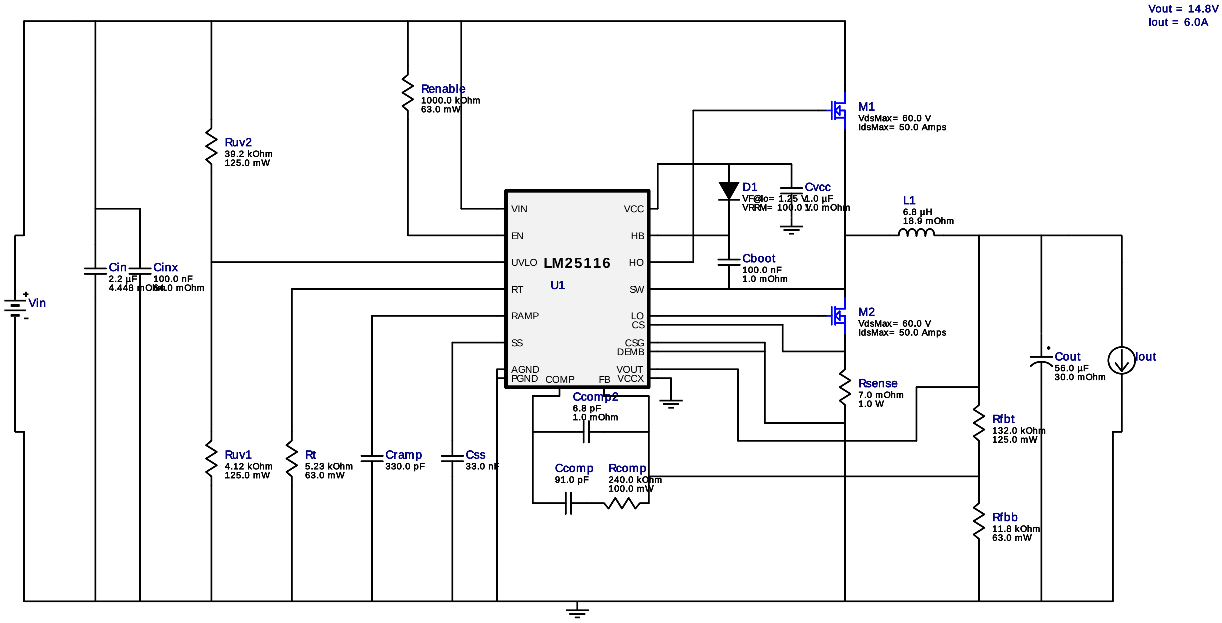
TEXAS INSTRUMENTS

WEBENCH ® Design Report

VinMin = 16.0V
VinMax = 36.0V
Vout = 14.8V
Iout = 6.0A

Device = LM25116MHX/NOPB
Topology = Buck
Created = 2021-07-22 11:14:14.905
BOM Cost = $4.31
BOM Count = 26
Total Pd = 2.92W

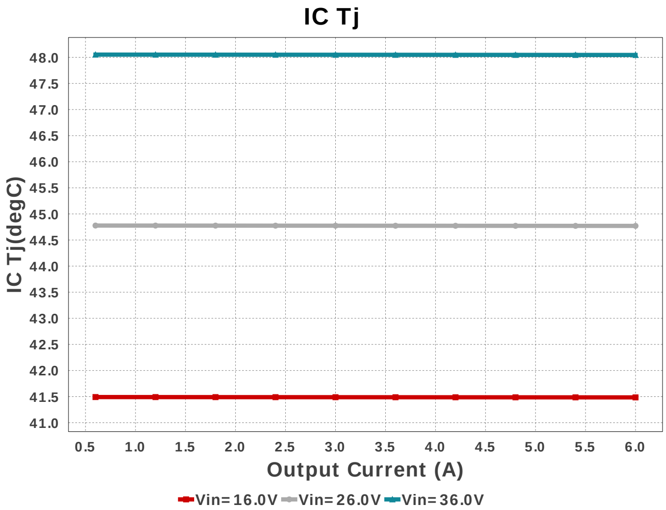
Design : 64 LM25116MHX/NOPB
LM25116MHX/NOPB 16V-36V to 14.81V @ 6A

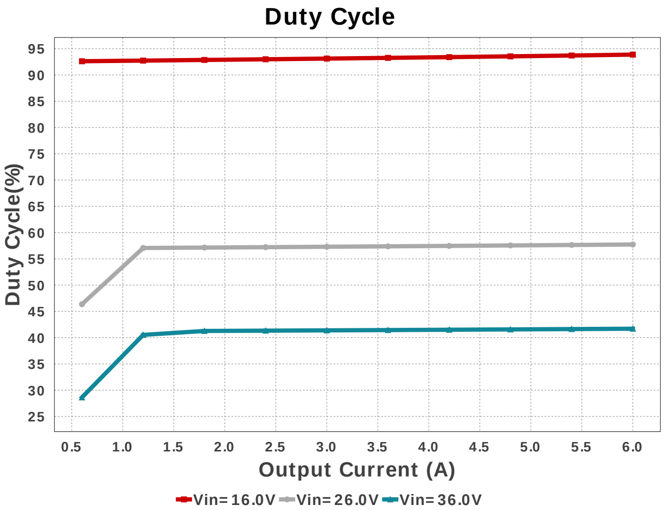


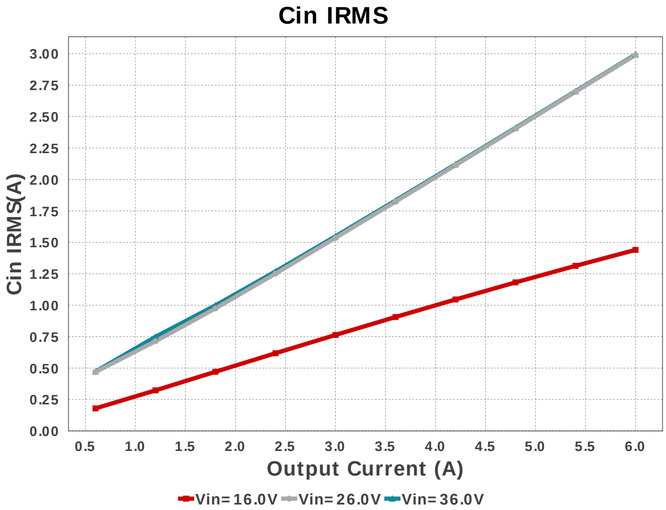
Electrical BOM

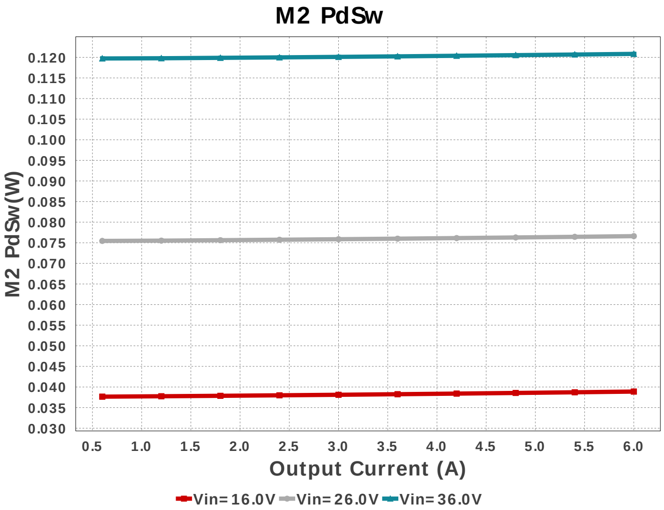
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cboot	MuRata	GRM155R71C104KA88D Series= X7R	Cap= 100.0 nF ESR= 1.0 mOhm VDC= 16.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Ccomp	Samsung Electro-Mechanics	CL05C910JB5NNNC Series= C0G/NP0	Cap= 91.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Ccomp	Samsung Electro-Mechanics	CL05C910JB5NNNC Series= C0G/NP0	Cap= 91.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Ccomp2	MuRata	GRM1555C1E6R8CA01D Series= C0G/NP0	Cap= 6.8 pF ESR= 1.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Ccomp2	MuRata	GRM1555C1E6R8CA01D Series= C0G/NP0	Cap= 6.8 pF ESR= 1.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Cin	MuRata	GRM31CR71H225KA88L Series= X7R	Cap= 2.2 uF ESR= 4.448 mOhm VDC= 50.0 V IRMS= 2.2252 A	1	$0.10	1206_190 11 mm^2
Cinx	Kemet	C0805C104M5RACTU Series= X7R	Cap= 100.0 nF ESR= 64.0 mOhm VDC= 50.0 V IRMS= 1.64 A	1	$0.01	0805 7 mm^2
Cout	Panasonic	20SVPF56MX Series= SVPF	Cap= 56.0 uF ESR= 30.0 mOhm VDC= 20.0 V IRMS= 2.8 A	1	$0.36	CAPSMT_62_E61 53 mm^2

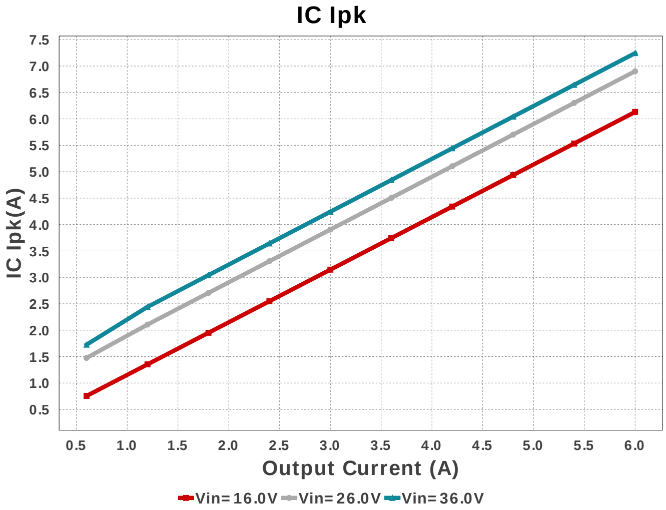
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cramp	Taiyo Yuden	UMK105CG331JV-F Series= C0G/NP0	Cap= 330.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Css	TDK	CGA4J2C0G1H333J125AA Series= C0G/NP0	Cap= 33.0 nF VDC= 50.0 V IRMS= 0.0 A	1	$0.09	0805 7 mm^2
Cvcc	Taiyo Yuden	TMK212B7105KG-T Series= X7R	Cap= 1.0 uF ESR= 1.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.02	0805 7 mm^2
D1	Nexperia	BAS516,115	VF@Io= 1.25 V VRRM= 100.0 V	1	$0.21	SOD-523 5 mm^2
L1	Coilcraft	XAL6060-682MEB	L= 6.8 µH 18.9 mOhm	1	$0.82	XAL6060 72 mm^2
M1	Texas Instruments	CSD18534Q5A	VdsMax= 60.0 V IdsMax= 50.0 Amps	1	$0.33	DQJ0008A 55 mm^2
M2	Texas Instruments	CSD18534Q5A	VdsMax= 60.0 V IdsMax= 50.0 Amps	1	$0.33	DQJ0008A 55 mm^2
Rcomp	Yageo	RC0603FR-07240KL Series= ?	Res= 240.0 kOhm Power= 100.0 mW Tolerance= 1.0%	1	$0.01	0603 5 mm^2
Rcomp	Yageo	RC0603FR-07240KL Series= ?	Res= 240.0 kOhm Power= 100.0 mW Tolerance= 1.0%	1	$0.01	0603 5 mm^2
Renable	Vishay-Dale	CRCW04021M00FKED Series= CRCW..e3	Res= 1000.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbb	Vishay-Dale	CRCW040211K8FKED Series= CRCW..e3	Res= 11.8 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbt	Yageo	RT0805BRD07132KL Series= RT0805	Res= 132.0 kOhm Power= 125.0 mW Tolerance= 0.1%	1	$0.05	0805 7 mm^2
Rramp	Vishay-Dale	CRCW0402294KFKED Series= CRCW..e3	Res= 294.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rsense	Susumu Co Ltd	PRL1632-R007-F-T1 Series= PRL1632	Res= 7.0 mOhm Power= 1.0 W Tolerance= 1.0%	1	$0.20	0612 11 mm^2
Rt	Vishay-Dale	CRCW04025K23FKED Series= CRCW..e3	Res= 5.23 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Ruv1	Panasonic	ERJ-6ENF4121V Series= ERJ-6E	Res= 4.12 kOhm Power= 125.0 mW Tolerance= 1.0%	1	$0.01	0805 7 mm^2
Ruv2	Vishay-Dale	CRCW080539K2FKEA Series= CRCW..e3	Res= 39.2 kOhm Power= 125.0 mW Tolerance= 1.0%	1	$0.01	0805 7 mm^2
U1	Texas Instruments	LM25116MHX/NOPB	Switcher	1	$1.65	MXA20A 71 mm^2

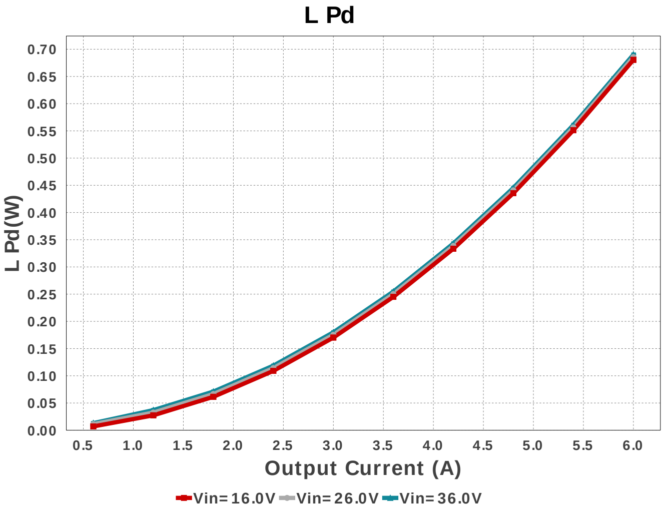

IC Tj
IC Tj(degC)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

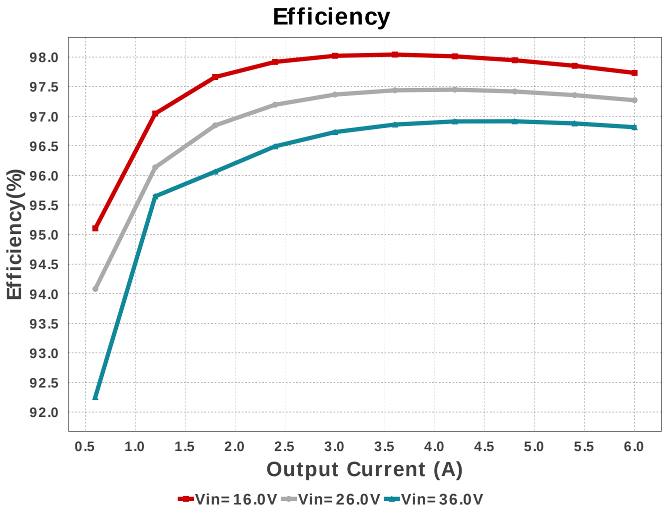

Duty Cycle
Duty Cycle(%)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

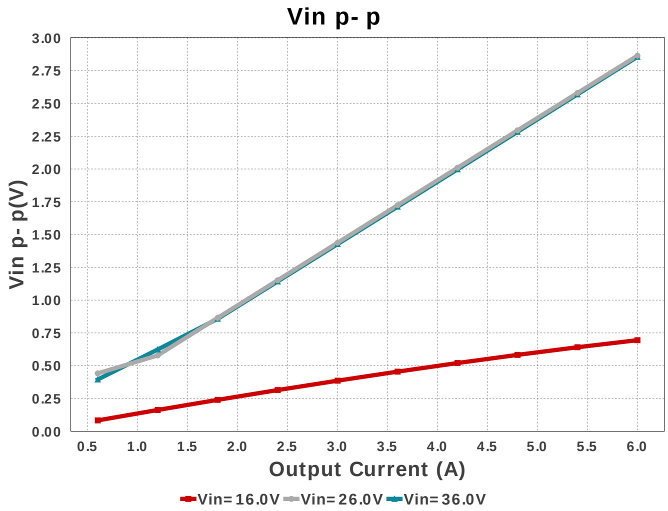

Cin IRMS
Cin IRMS(A)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

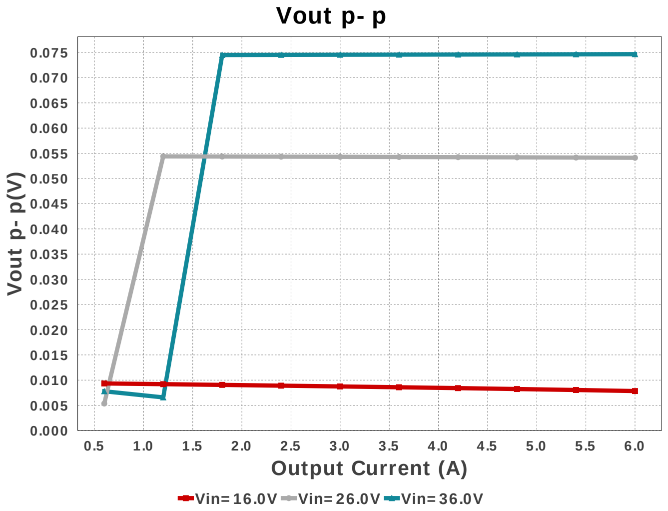

M2 PdSw
M2 PdSw(W)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

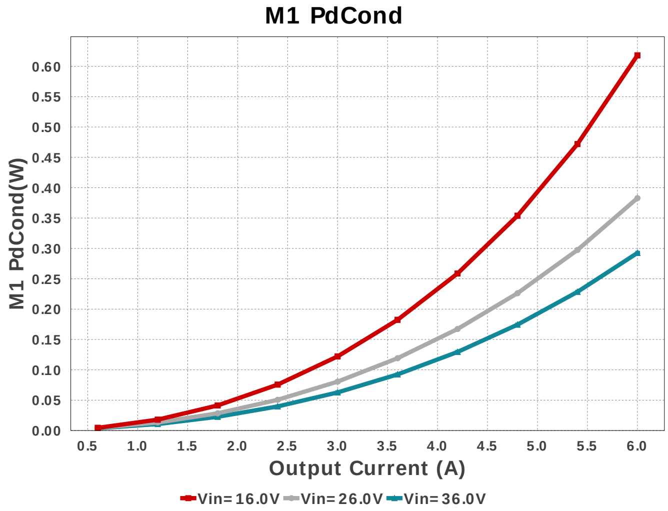

IC Ipk
IC Ipk(A)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

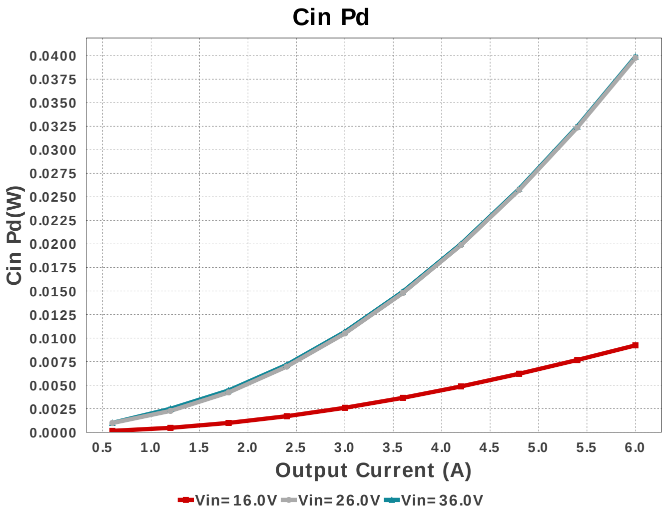

L Pd
L Pd(W)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

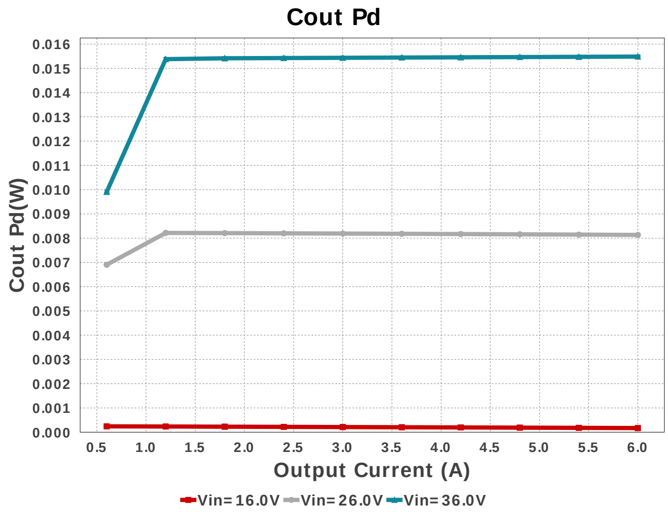

Efficiency
Efficiency(%)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

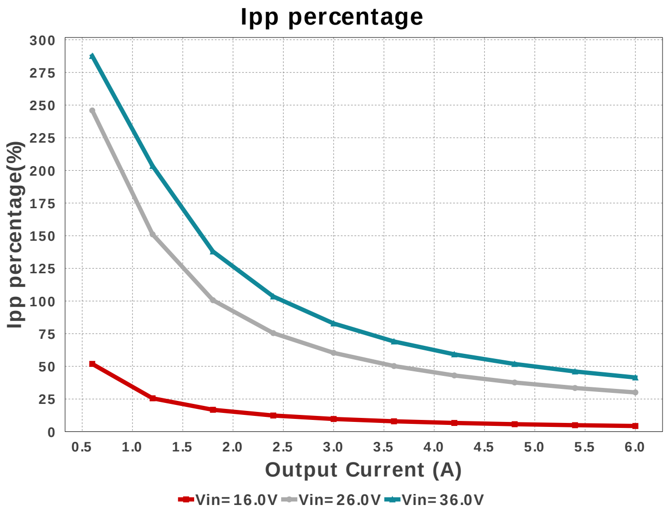

Vin p-p
Vin p-p(V)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

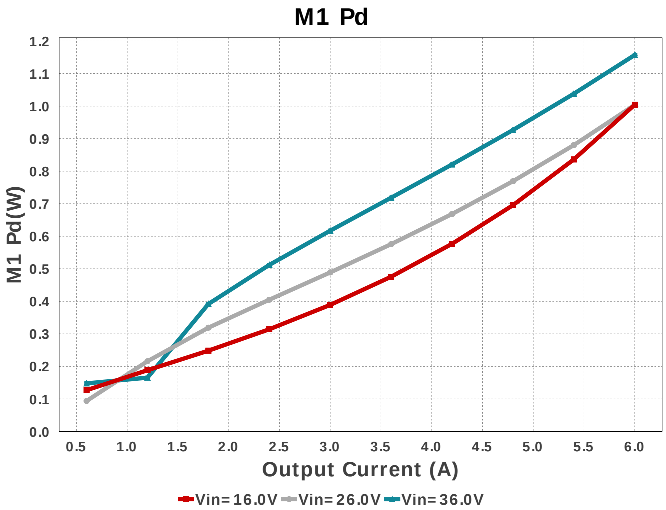

Vout p-p
Vout p-p(V)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

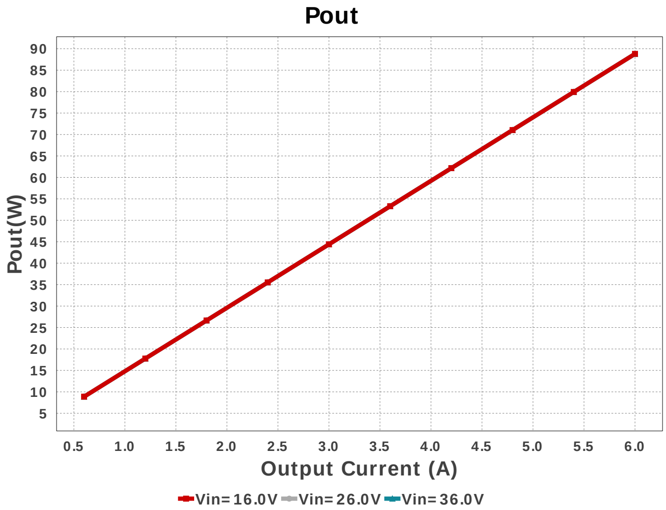

M1 PdCond
M1 PdCond(W)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

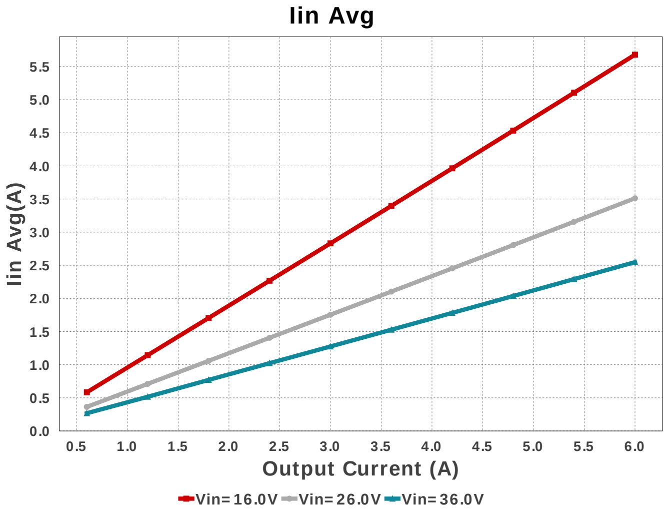

Cin Pd
Cin Pd(W)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

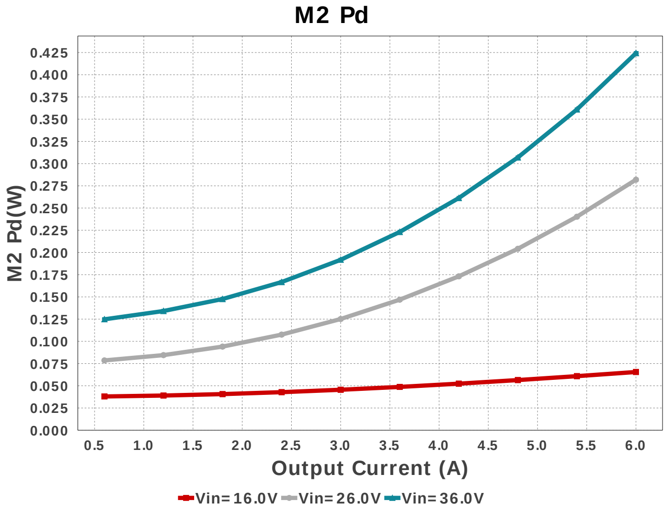

Cout Pd
Cout Pd(W)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

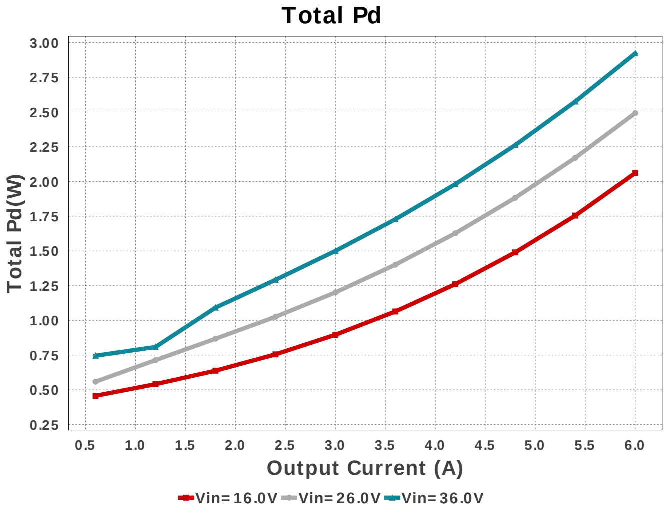

Ipp percentage
Ipp percentage(%)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

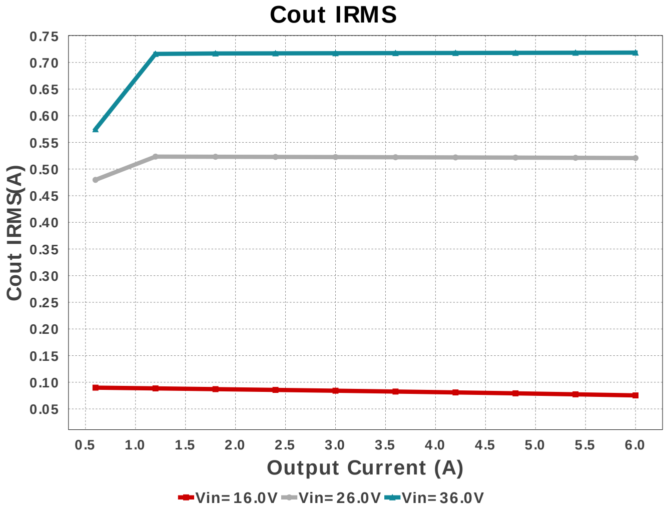

M1 Pd
M1 Pd(W)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

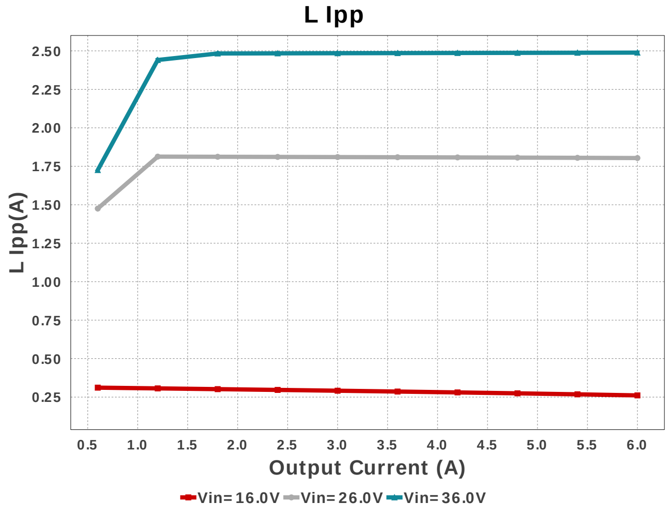

Pout
Pout(W)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

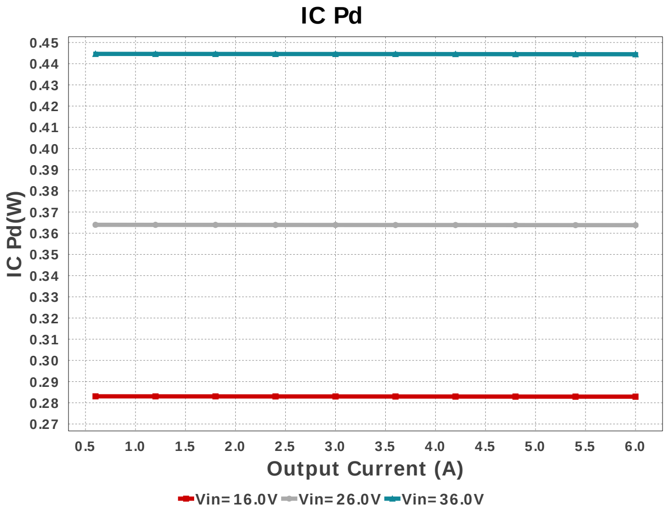

Iin Avg
Iin Avg(A)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

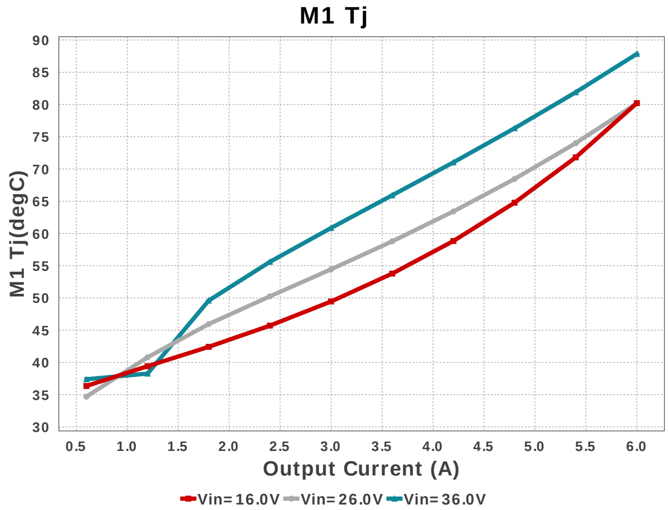

M2 Pd
M2 Pd(W)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

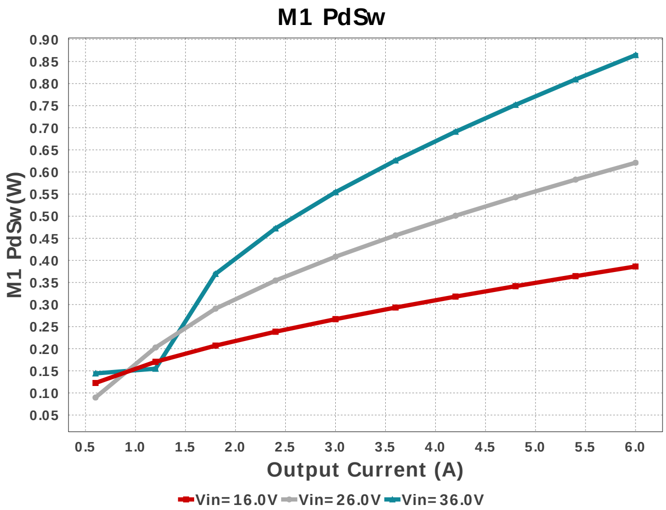

Total Pd
Total Pd(W)
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

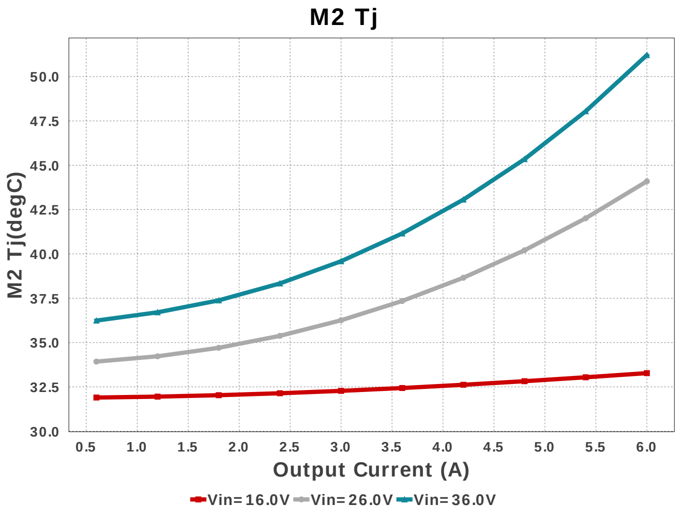

Cout IRMS
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
Cout IRMS(A)
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

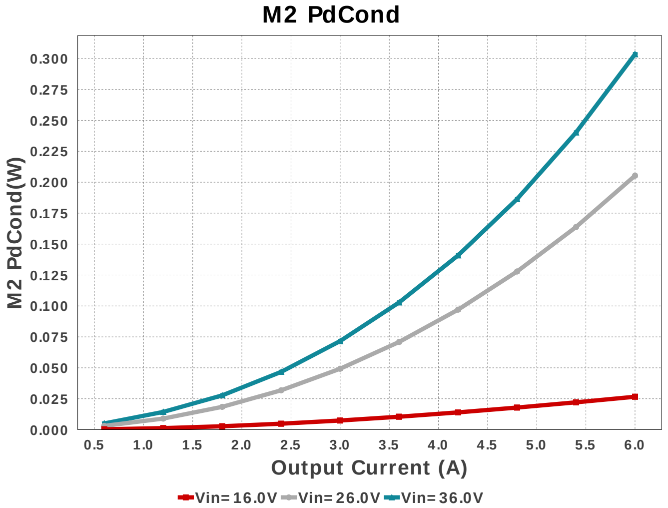

L Ipp
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
L Ipp(A)
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V

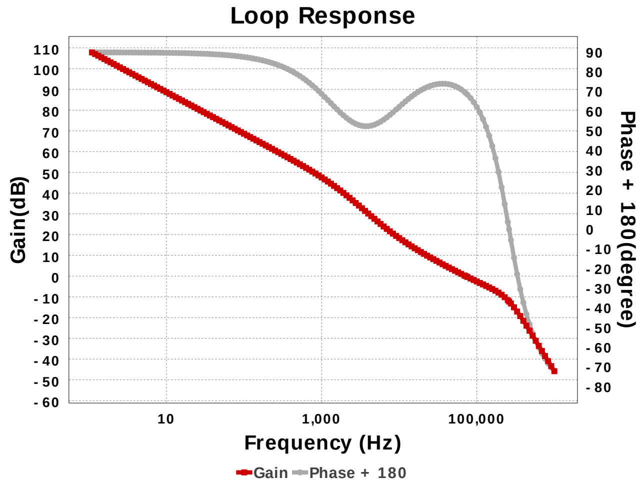

IC Pd
0.45
0.44
0.43
0.42
0.41
0.40
0.39
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
0.30
0.29
0.28
0.27
IC Pd(W)
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V


M1 Tj
90
85
80
75
70
65
60
55
50
45
40
35
30
M1 Tj(degC)
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V


M1 PdSw
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
M1 PdSw(W)
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V


M2 Tj
50.0
47.5
45.0
42.5
40.0
37.5
35.0
32.5
30.0
M2 Tj(degC)
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0
Output Current (A)
Vin=16.0V Vin=26.0V Vin=36.0V





Operating Values

#	Name	Value	Category	Description
1.	Cin IRMS	2.995 A	Capacitor	Input capacitor RMS ripple current
2.	Cin Pd	39.891 mW	Capacitor	Input capacitor power dissipation
3.	Cout IRMS	718.537 mA	Capacitor	Output capacitor RMS ripple current
4.	Cout Pd	15.489 mW	Capacitor	Output capacitor power dissipation
5.	IC Ipk	7.245 A	IC	Peak switch current in IC
6.	IC Pd	444.46 mW	IC	IC power dissipation
7.	IC Tj	47.778 degC	IC	IC junction temperature
8.	IC Tolerance	16.0 mV	IC	IC Feedback Tolerance
9.	ICThetaJA	40.0 degC/W	IC	IC junction-to-ambient thermal resistance
10.	Iin Avg	2.549 A	IC	Average input current
11.	Ipp percentage	41.485 %	Inductor	Inductor ripple current percentage (with respect to average inductor current)
12.	L Ipp	2.489 A	Inductor	Peak-to-peak inductor ripple current
13.	L Pd	690.16 mW	Inductor	Inductor power dissipation
14.	M1 Pd	1.157 W	Mosfet	M1 MOSFET total power dissipation
15.	M1 PdCond	292.65 mW	Mosfet	M1 MOSFET conduction losses
16.	M1 PdSw	864.47 mW	Mosfet	M1 MOSFET switching losses
17.	M1 Tj	87.856 degC	Mosfet	M1 MOSFET junction temperature
18.	M2 Pd	424.17 mW	Mosfet	M2 MOSFET total power dissipation
19.	M2 PdCond	303.33 mW	Mosfet	M2 MOSFET conduction losses
20.	M2 PdSw	120.84 mW	Mosfet	M2 MOSFET switching losses
21.	M2 Tj	51.208 degC	Mosfet	M2 MOSFET junction temperature
22.	Cin Pd	39.891 mW	Power	Input capacitor power dissipation
23.	Cout Pd	15.489 mW	Power	Output capacitor power dissipation
24.	IC Pd	444.46 mW	Power	IC power dissipation
25.	L Pd	690.16 mW	Power	Inductor power dissipation
26.	M1 Pd	1.157 W	Power	M1 MOSFET total power dissipation
27.	M1 PdCond	292.65 mW	Power	M1 MOSFET conduction losses
28.	M1 PdSw	864.47 mW	Power	M1 MOSFET switching losses
29.	M2 Pd	424.17 mW	Power	M2 MOSFET total power dissipation
30.	M2 PdCond	303.33 mW	Power	M2 MOSFET conduction losses
31.	M2 PdSw	120.84 mW	Power	M2 MOSFET switching losses
32.	Total Pd	2.921 W	Power	Total Power Dissipation
33.	BOM Count	26	System Information	Total Design BOM count
34.	Cross Freq	72.092 kHz	System Information	Bode plot crossover frequency
35.	Duty Cycle	41.716 %	System Information	Duty cycle
36.	Efficiency	96.817 %	System Information	Steady state efficiency
37.	FootPrint	413.0 mm^2	System Information	Total Foot Print Area of BOM components
38.	Frequency	516.71 kHz	System Information	Switching frequency
39.	Gain Marg	-12.231 dB	System Information	Bode Plot Gain Margin
40.	Iout	6.0 A	System Information	Iout operating point
41.	Low Freq Gain	107.833 dB	System Information	Gain at 1Hz

#	Name	Value	Category	Description
42.	Mode	CCM	System Information	Conduction Mode
43.	Phase Marg	69.339 deg	System Information	Bode Plot Phase Margin
44.	Pout	88.839 W	System Information	Total output power
45.	Total BOM	$4.31	System Information	Total BOM Cost
46.	Vin	36.0 V	System Information	Vin operating point
47.	Vin p-p	2.775 V	System Information	Peak-to-peak input voltage
48.	Vout	14.807 V	System Information	Operational Output Voltage
49.	Vout Actual	14.807 V	System Information	Vout Actual calculated based on selected voltage divider resistors
50.	Vout Tolerance	2.35 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
51.	Vout p-p	74.673 mV	System Information	Peak-to-peak output ripple voltage

Design Inputs

Name	Value	Description
Iout	6.0	Maximum Output Current
SoftStart	3.0 ms	Soft Start Time (ms)
VinMax	36.0	Maximum input voltage
VinMin	16.0	Minimum input voltage
Vout	14.8	Output Voltage
base_pn	LM25116	Base Product Number
source	DC	Input Source Type
Ta	30.0	Ambient temperature
UserFsw	252.0 k	Customer Selected Frequency

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 Cin and Cout, 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

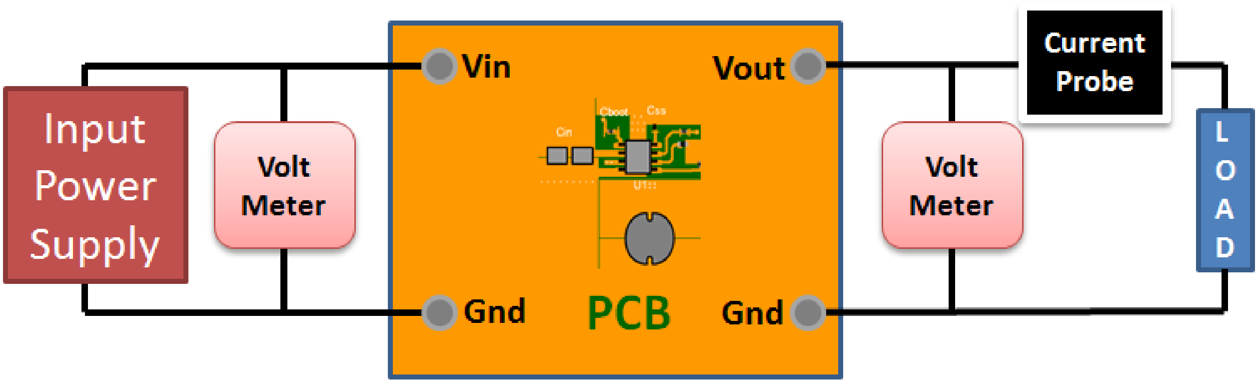
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. To solder the tab town 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 16.0V and set the input supply's current limit to zero. With the input supply off connect up the input supply to Vin and GND. Connect a digital volt meter and a load if needed to set the minimum Iout of the design from Vout 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 Vin and GND, a load is connected between Vout and GND and a current meter is connected in series between Vout 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 : E0EE381740B36D2A[v1]

2. **LM25116** Product Folder : http://www.ti.com/product/LM25116 : contains the data sheet and other resources.

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