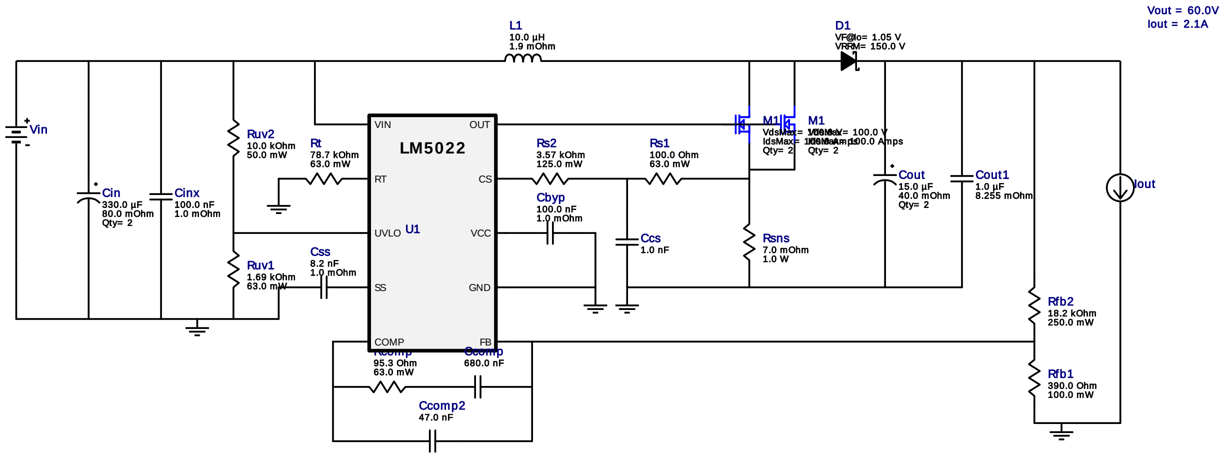
TEXAS INSTRUMENTS

WEBENCH ® Design Report

VinMin = 11.0V
VinMax = 16.0V
Vout = 60.0V
Iout = 2.1A

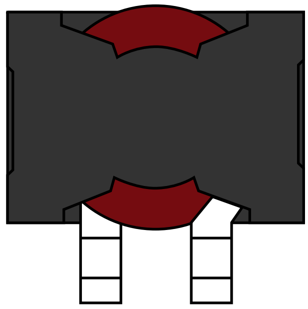
Device = LM5022MM/NOPB
Topology = Boost
Created = 2018-10-18 03:06:15.558
BOM Cost = $7.85
BOM Count = 25
Total Pd = 6.86W

Design : 5 LM5022MM/NOPB
LM5022MM/NOPB 11V-16V to 60.00V @ 2.1A

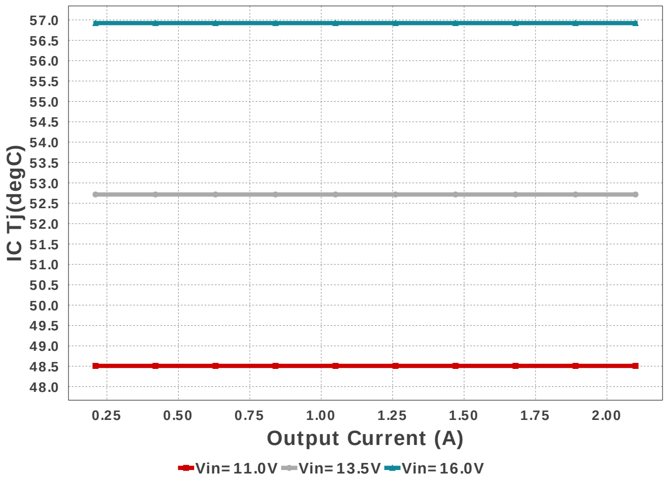


Electrical BOM

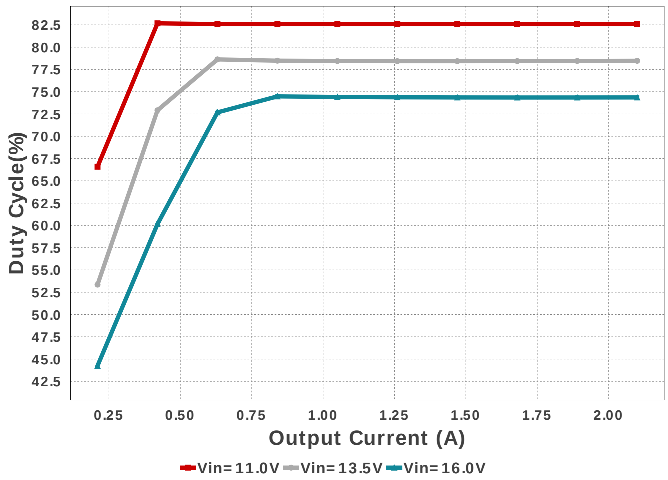
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cbyp	MuRata	GRM155R61C104KA88D Series= X5R	Cap= 100.0 nF ESR= 1.0 mOhm VDC= 16.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Ccomp	Panasonic	ECPU1C684MA5 Series= ECPU(A)	Cap= 680.0 nF VDC= 16.0 V IRMS= 0.0 A	1	$0.22	1206 11 mm^2
Ccomp2	Kemet	C0805C473J3GACAUTO Series= C0G/NP0	Cap= 47.0 nF VDC= 5.0 V IRMS= 0.0 A	1	$0.26	0805 7 mm^2
Ccs	Kemet	C0603C102J3GACTU Series= C0G/NP0	Cap= 1.0 nF VDC= 25.0 V IRMS= 0.0 A	1	$0.01	0603 5 mm^2
Cin	Panasonic	EEE-FK1V331P Series= FK	Cap= 330.0 uF ESR= 80.0 mOhm VDC= 35.0 V IRMS= 850.0 mA	2	$0.24	SM_RADIAL_G 172 mm^2
Cinx	Kemet	C0603C104Z3VACTU Series= Y5V	Cap= 100.0 nF ESR= 1.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.01	0603 5 mm^2
Cout	Panasonic	100SXV15M Series= SXV	Cap= 15.0 uF ESR= 40.0 mOhm VDC= 100.0 V IRMS= 2.35 A	2	$1.24	CAPSMT_62_E12 106 mm^2
Cout1	TDK	C2012X7S2A105K125AB Series= X7S	Cap= 1.0 uF ESR= 8.255 mOhm VDC= 100.0 V IRMS= 2.27442 A	1	$0.14	0805 7 mm^2
Css	MuRata	GRM155R71E822KA01D Series= X7R	Cap= 8.2 nF ESR= 1.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2

Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
D1	SMC Diode Solutions	SB20150TR	VF@Io= 1.05 V VRRM= 150.0 V	1	$0.19	 DO-201AD 166 mm^2
L1	Coilcraft	SER2915H-103KL	L= 10.0 µH DCR= 1.9 mOhm	1	$1.95	 SER2915H 652 mm^2
M1	Texas Instruments	CSD19537Q3	VdsMax= 100.0 V IdsMax= 100.0 Amps	2	$0.41	DQG0008A 18 mm^2
M1	Texas Instruments	CSD19537Q3	VdsMax= 100.0 V IdsMax= 100.0 Amps	2	$0.41	DQG0008A 18 mm^2
Rcomp	Vishay-Dale	CRCW040295R3FKED Series= CRCW..e3	Res= 95.3 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfb1	Susumu Co Ltd	RR1220P-391-D Series= RR12	Res= 390.0 Ohm Power= 100.0 mW Tolerance= 0.5%	1	$0.01	0805 7 mm^2
Rfb2	Vishay-Dale	CRCW120618K2FKEA Series= CRCW..e3	Res= 18.2 kOhm Power= 250.0 mW Tolerance= 1.0%	1	$0.01	1206 11 mm^2
Rs1	Vishay-Dale	CRCW0402100RFKED Series= CRCW..e3	Res= 100.0 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rs2	Panasonic	ERJ-6ENF3571V Series= ERJ-6E	Res= 3.57 kOhm Power= 125.0 mW Tolerance= 1.0%	1	$0.01	0805 7 mm^2
Rsns	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	CRCW040278K7FKED Series= CRCW..e3	Res= 78.7 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Ruv1	Vishay-Dale	CRCW04021K69FKED Series= CRCW..e3	Res= 1.69 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Ruv2	Yageo	RC0201FR-0710KL Series= ?	Res= 10.0 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm^2
U1	Texas Instruments	LM5022MM/NOPB	Switcher	1	$0.99	 MUB10A 24 mm^2

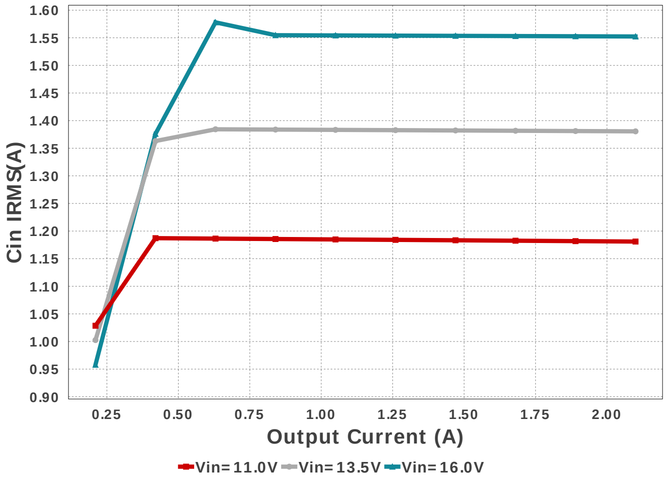
IC Tj



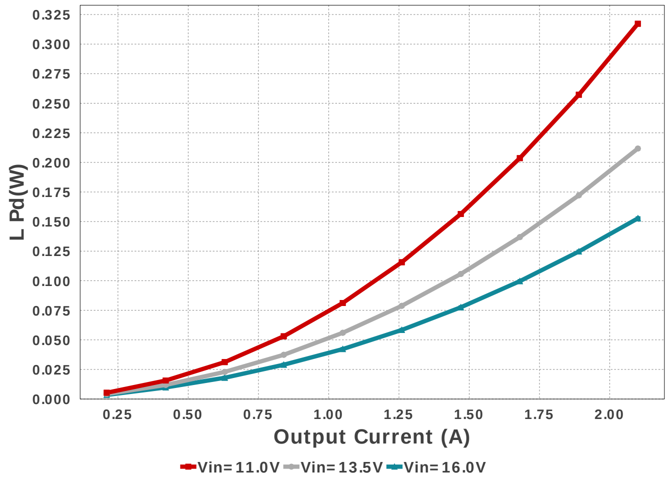
Duty Cycle



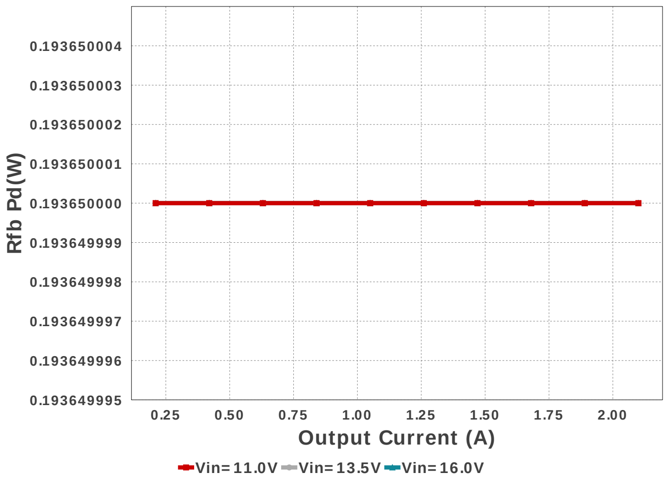
Cin IRMS



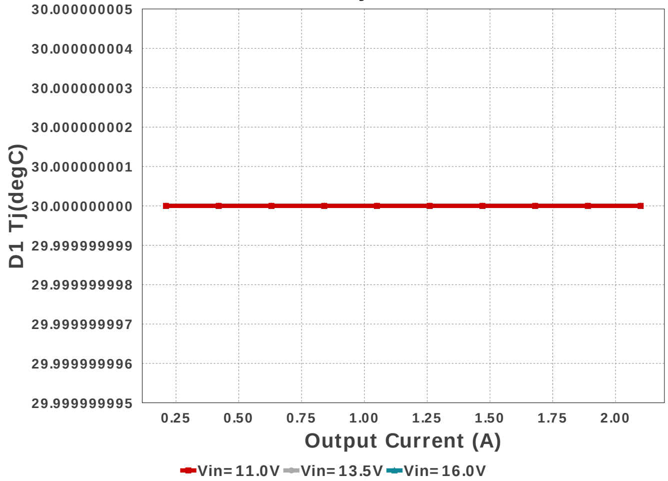
L Pd

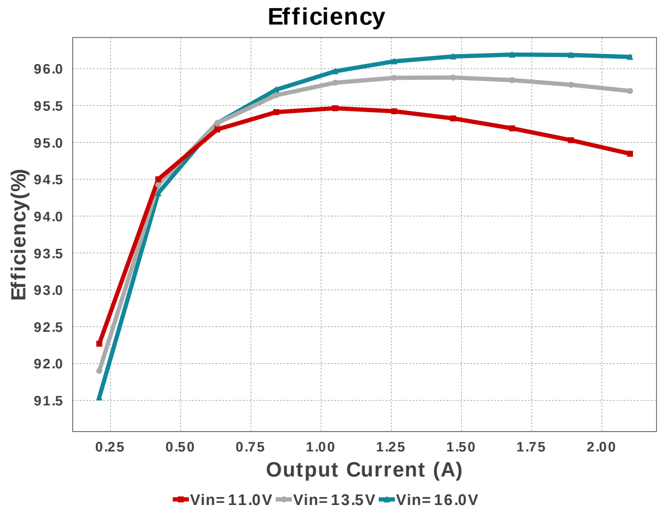


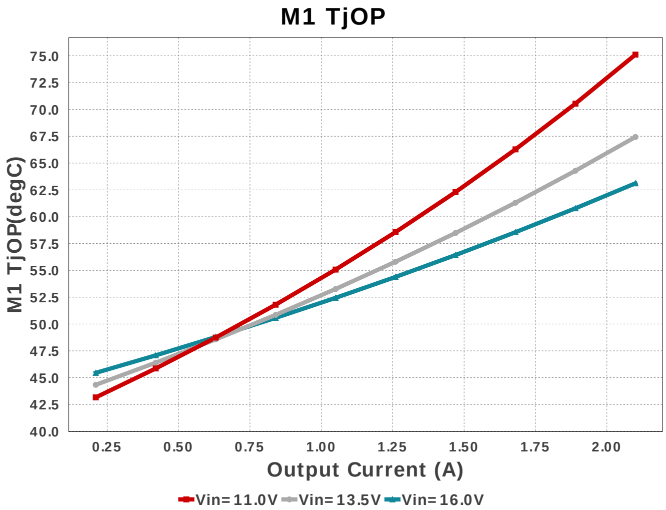
Rfb Pd

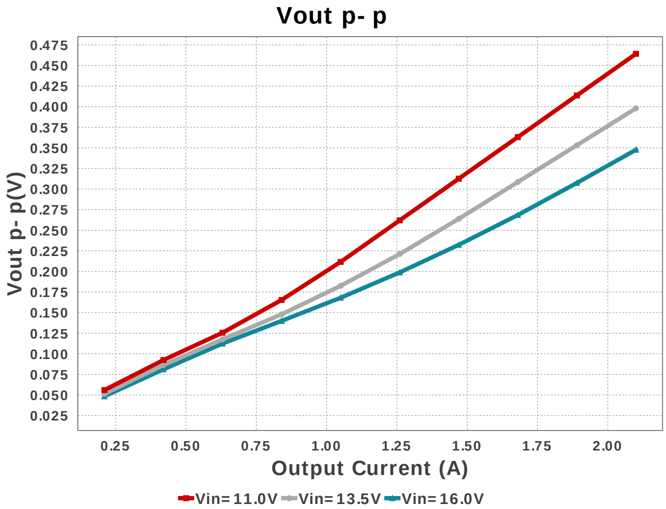


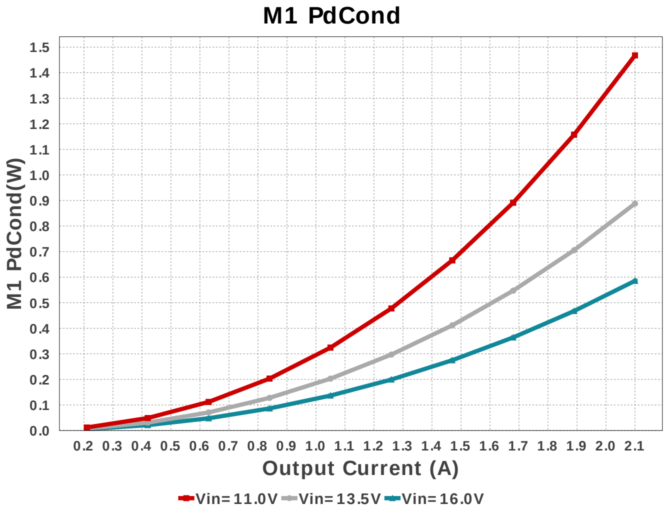
D1 Tj

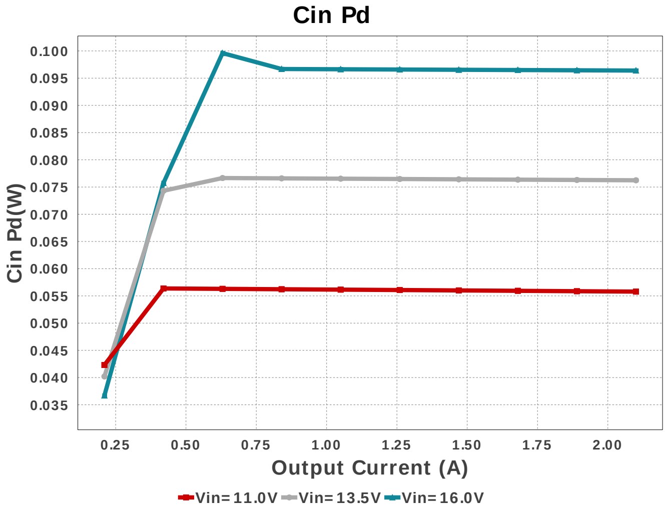


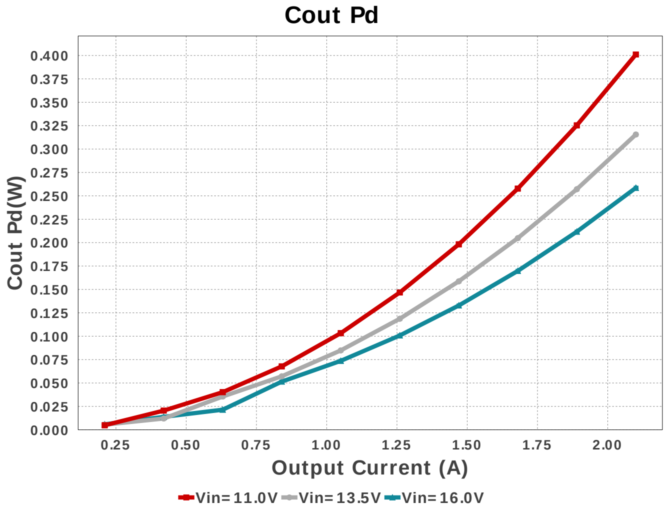

Efficiency
Efficiency(%)
96.0
95.5
95.0
94.5
94.0
93.5
93.0
92.5
92.0
91.5
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Output Current (A)
Vin=11.0V
Vin=13.5V
Vin=16.0V

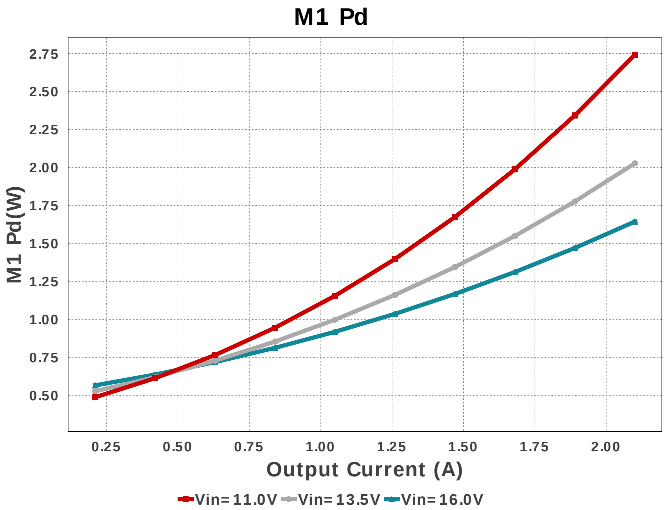

M1 TjOP
M1 TjOP(degC)
75.0
72.5
70.0
67.5
65.0
62.5
60.0
57.5
55.0
52.5
50.0
47.5
45.0
42.5
40.0
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Output Current (A)
Vin=11.0V
Vin=13.5V
Vin=16.0V

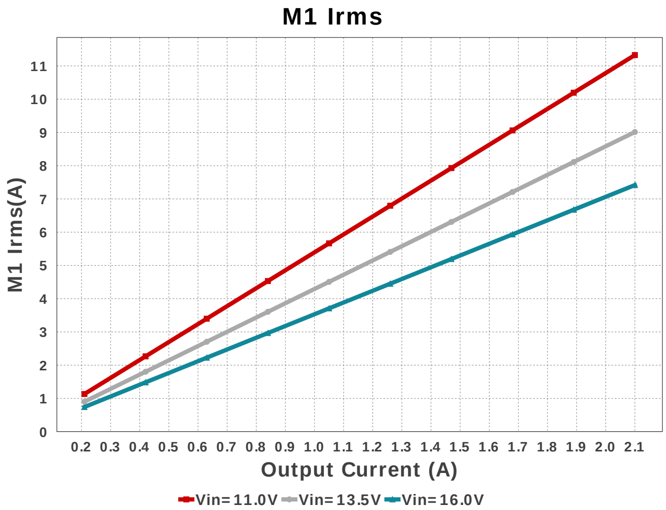

Vout p-p
Vout p-p(V)
0.475
0.450
0.425
0.400
0.375
0.350
0.325
0.300
0.275
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Output Current (A)
Vin=11.0V
Vin=13.5V
Vin=16.0V

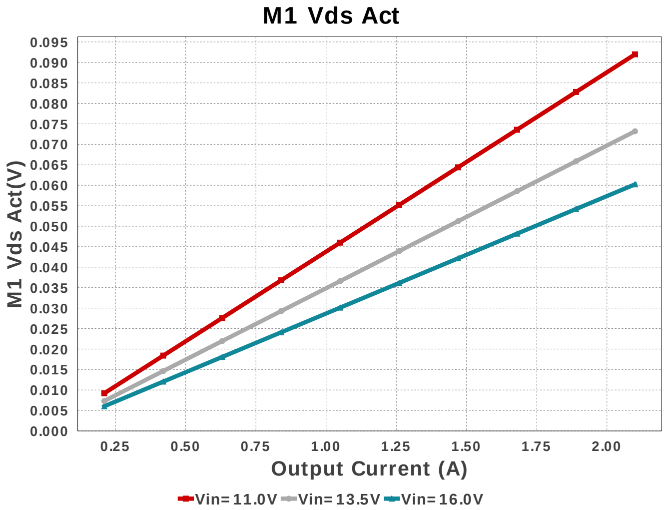

M1 PdCond
M1 PdCond(W)
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0 2.1
Output Current (A)
Vin=11.0V
Vin=13.5V
Vin=16.0V

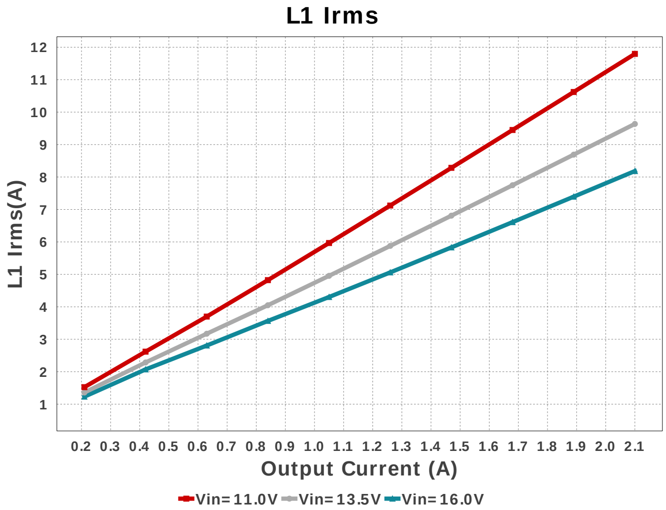

Cin Pd
Cin Pd(W)
0.100
0.095
0.090
0.085
0.080
0.075
0.070
0.065
0.060
0.055
0.050
0.045
0.040
0.035
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Output Current (A)
Vin=11.0V
Vin=13.5V
Vin=16.0V

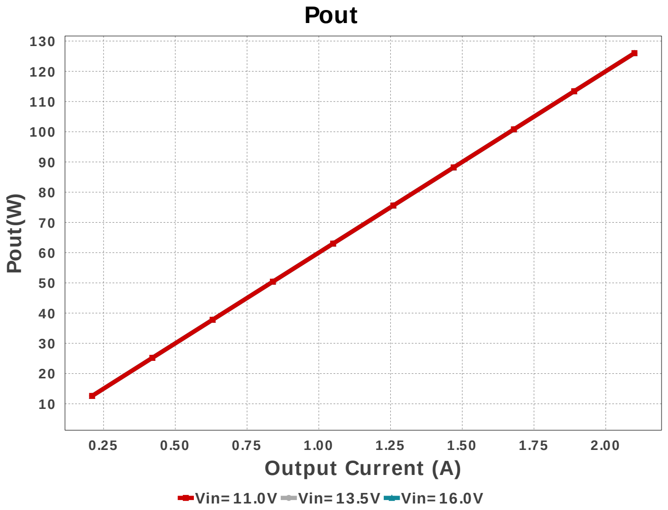

Cout Pd
Cout Pd(W)
0.400
0.375
0.350
0.325
0.300
0.275
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Output Current (A)
Vin=11.0V
Vin=13.5V
Vin=16.0V

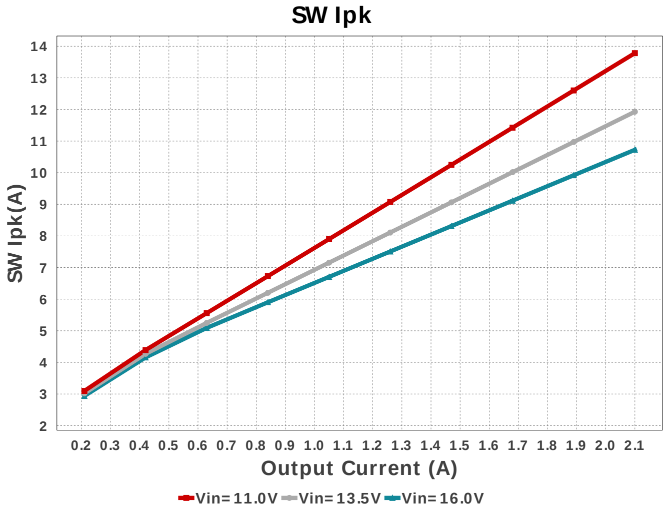

M1 Pd
M1 Pd(W)
Output Current (A)
Vin=11.0V Vin=13.5V Vin=16.0V


M1 Irms
M1 Irms(A)
Output Current (A)
Vin=11.0V Vin=13.5V Vin=16.0V

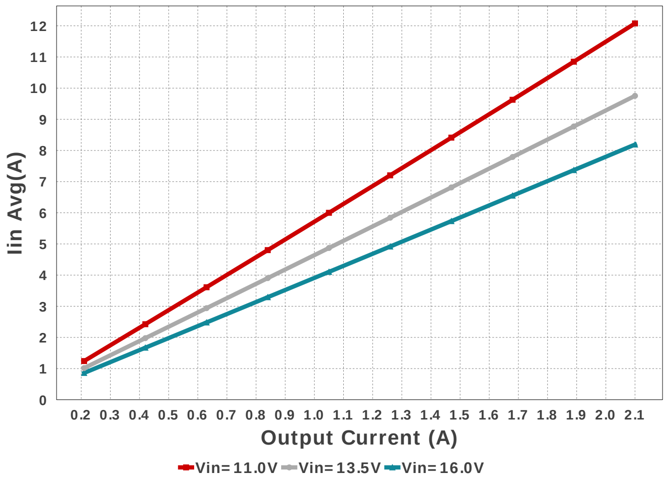

M1 Vds Act
M1 Vds Act(V)
Output Current (A)
Vin=11.0V Vin=13.5V Vin=16.0V


L1 Irms
L1 Irms(A)
Output Current (A)
Vin=11.0V Vin=13.5V Vin=16.0V

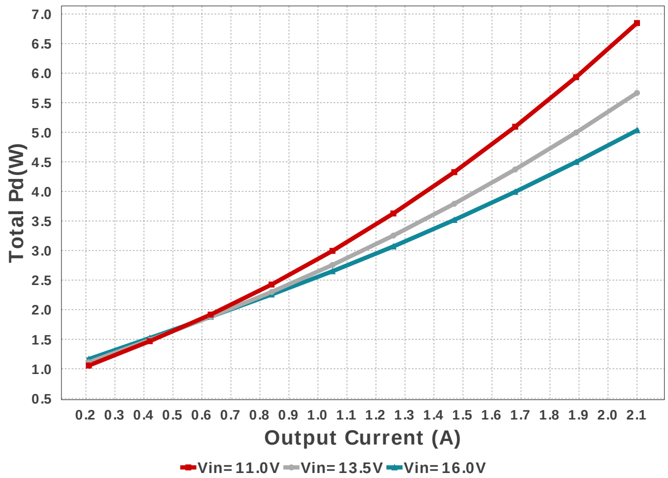

Pout
Pout(W)
Output Current (A)
Vin=11.0V Vin=13.5V Vin=16.0V


SW Ipk
SW Ipk(A)
Output Current (A)
Vin=11.0V Vin=13.5V Vin=16.0V

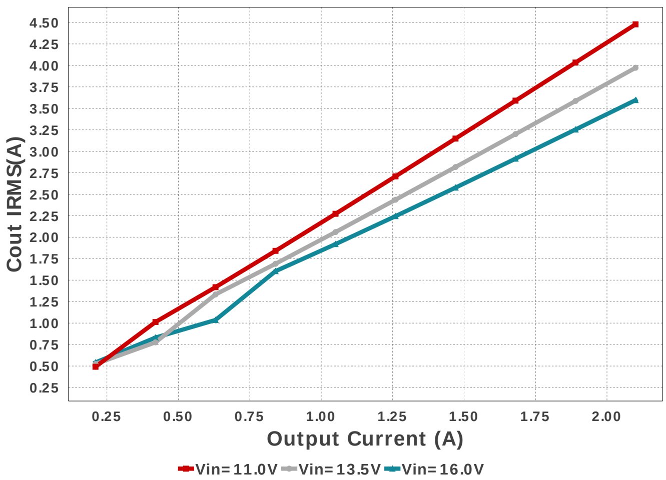
Iin Avg



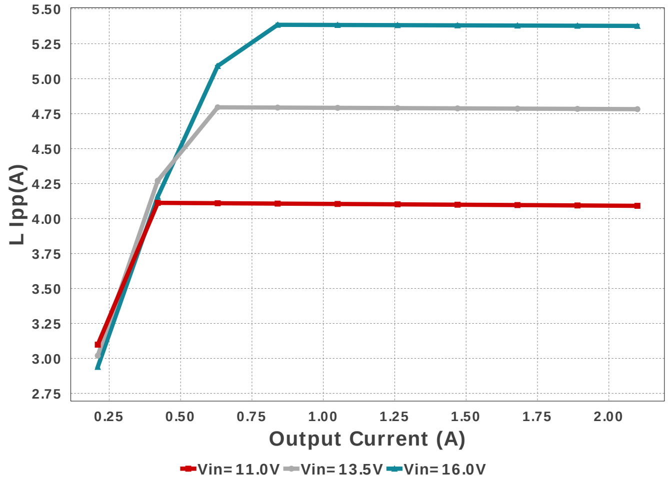
Total Pd



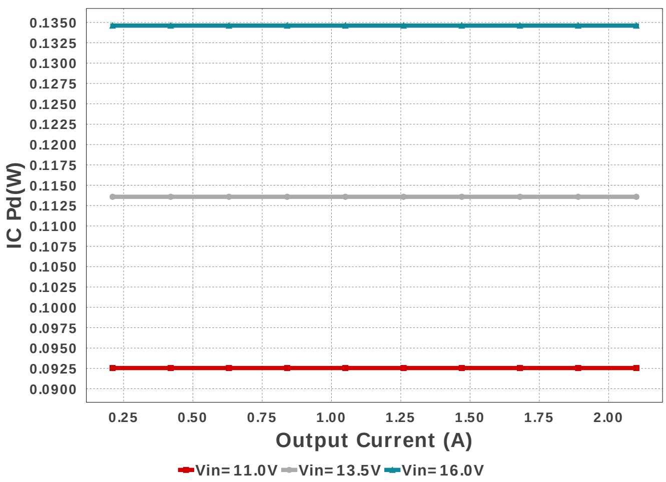
Cout IRMS



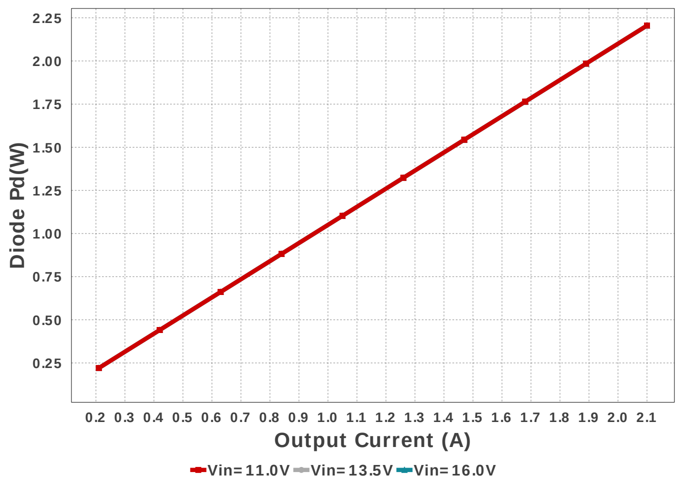
L Ipp

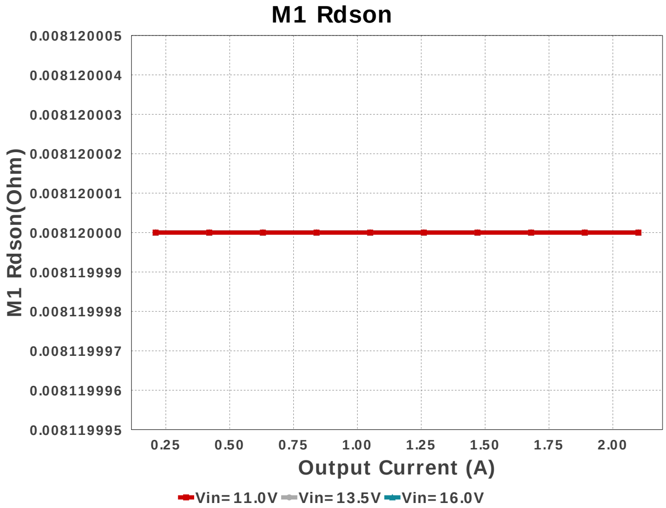


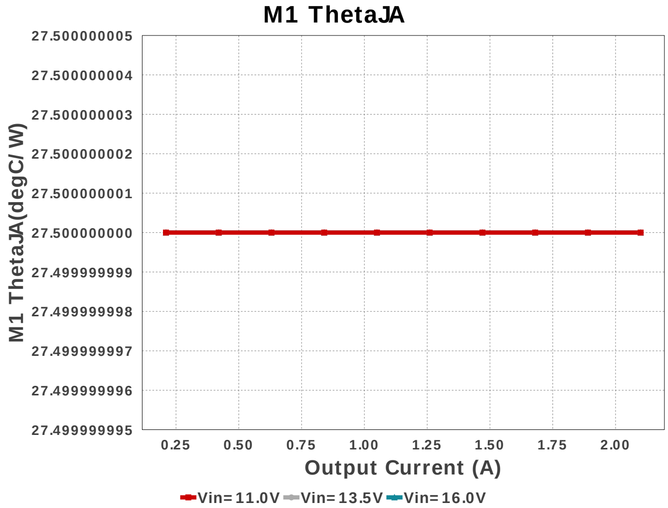
IC Pd

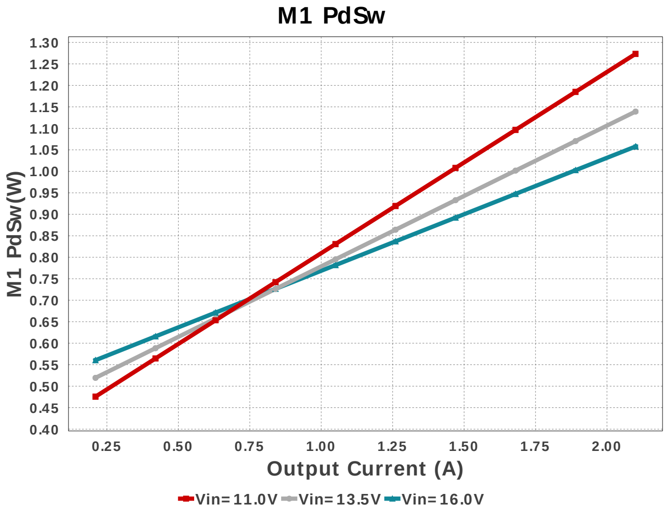


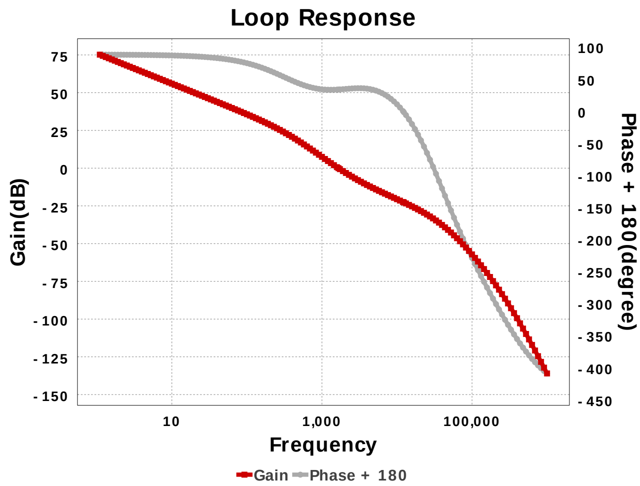
Diode Pd











Operating Values

#	Name	Value	Category	Description
1.	Cin IRMS	1.193 A	Capacitor	Input capacitor RMS ripple current
2.	Cin Pd	56.928 mW	Capacitor	Input capacitor power dissipation
3.	Cout IRMS	4.478 A	Capacitor	Output capacitor RMS ripple current
4.	Cout Pd	401.13 mW	Capacitor	Output capacitor power dissipation
5.	D1 Tj	30.0 degC	Diode	D1 junction temperature
6.	Diode Pd	2.205 W	Diode	Diode power dissipation
7.	IC Pd	197.41 mW	IC	IC power dissipation
8.	IC Tj	69.482 degC	IC	IC junction temperature
9.	IC Tolerance	25.0 mV	IC	IC Feedback Tolerance
10.	ICThetaJA	200.0 degC/W	IC	IC junction-to-ambient thermal resistance
11.	Iin Avg	12.078 A	IC	Average input current
12.	L Ipp	4.133 A	Inductor	Peak-to-peak inductor ripple current
13.	L Pd	317.25 mW	Inductor	Inductor power dissipation
14.	L1 Irms	11.796 A	Inductor	Inductor ripple current
15.	M1 Irms	11.303 A	Mosfet	M1 MOSFET Irms
16.	M1 Pd	2.647 W	Mosfet	M1 MOSFET total power dissipation
17.	M1 PdCond	1.444 W	Mosfet	M1 MOSFET conduction losses
18.	M1 PdSw	1.203 W	Mosfet	M1 MOSFET switching losses
19.	M1 Rdson	8.12 mOhm	Mosfet	Drain-Source On-resistance
20.	M1 ThetaJA	27.5 degC/W	Mosfet	MOSFET junction-to-ambient thermal resistance
21.	M1 TjOP	73.015 degC	Mosfet	M1 MOSFET junction temperature
22.	Cin Pd	56.928 mW	Power	Input capacitor power dissipation
23.	Cout Pd	401.13 mW	Power	Output capacitor power dissipation
24.	Diode Pd	2.205 W	Power	Diode power dissipation
25.	IC Pd	197.41 mW	Power	IC power dissipation
26.	L Pd	317.25 mW	Power	Inductor power dissipation
27.	M1 Pd	2.647 W	Power	M1 MOSFET total power dissipation
28.	M1 PdCond	1.444 W	Power	M1 MOSFET conduction losses
29.	M1 PdSw	1.203 W	Power	M1 MOSFET switching losses
30.	Rfb Pd	193.65 mW	Power	Rfb Power Dissipation
31.	Total Pd	6.859 W	Power	Total Power Dissipation
32.	Rfb Pd	193.65 mW	Resistor	Rfb Power Dissipation

#	Name	Value	Category	Description
33.	BOM Count	25	System Information	Total Design BOM count
34.	Cross Freq	1.319 kHz	System Information	Bode plot crossover frequency
35.	Duty Cycle	82.583 %	System Information	Duty cycle
36.	Efficiency	94.837 %	System Information	Steady state efficiency
37.	FootPrint	1.525 k mm^2	System Information	Total Foot Print Area of BOM components
38.	Frequency	216.818 kHz	System Information	Switching frequency
39.	Gain Marg	-22.196 dB	System Information	Bode Plot Gain Margin
40.	Iout	2.1 A	System Information	Iout operating point
41.	Low Freq Gain	71.82 dB	System Information	Gain at 1Hz
42.	Mode	CCM	System Information	Conduction Mode
43.	Phase Marg	32.543 deg	System Information	Bode Plot Phase Margin
44.	Pout	126.0 W	System Information	Total output power
45.	SW Ipk	13.802 A	System Information	Peak switch current
46.	Total BOM	$7.85	System Information	Total BOM Cost
47.	Vin	11.0 V	System Information	Vin operating point
48.	Vout	60.0 V	System Information	Operational Output Voltage
49.	Vout Actual	60.06 V	System Information	Vout Actual calculated based on selected voltage divider resistors
50.	Vout Tolerance	3.489 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
51.	Vout p-p	466.444 mV	System Information	Peak-to-peak output ripple voltage
52.	M1 Vds Act	91.783 mV		M Vds

Design Inputs

Name	Value	Description
Iout	2.1	Maximum Output Current
VinMax	16.0	Maximum input voltage
VinMin	11.0	Minimum input voltage
Vout	60.0	Output Voltage
base_pn	LM5022	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 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

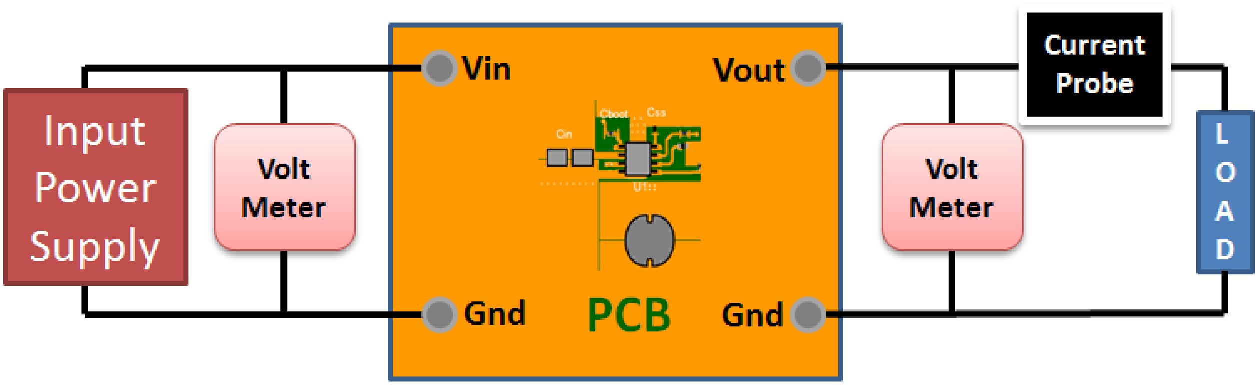
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. 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 11.0V 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 : 658511B4AE4828C4[v1]

2. **LM5022** Product Folder : http://www.ti.com/product/LM5022 : contains the data sheet and other resources.

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