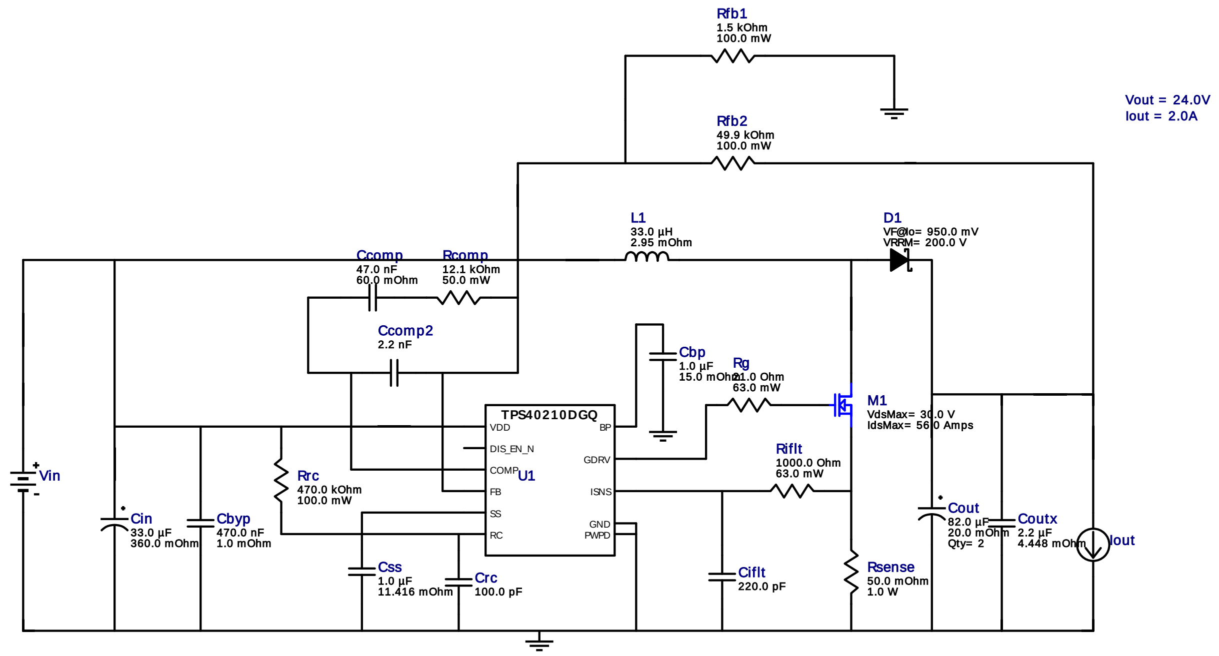
VinMin = 6.5V
VinMax = 16.0V
Vout = 24.0V
Iout = 2.0A

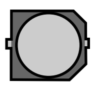
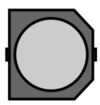
Device = TPS40210DGQR
Topology = Boost
Created = 2021-07-16 17:45:12.436
BOM Cost = $10.82
BOM Count = 22
Total Pd = 5.7W

WEBENCH ® Design Report

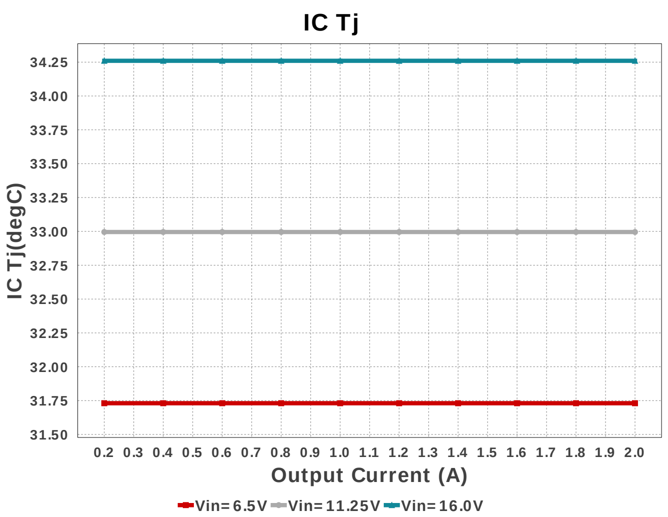
Design : 15 TPS40210DGQR
TPS40210DGQR 6.5V-16V to 24.00V @ 2A

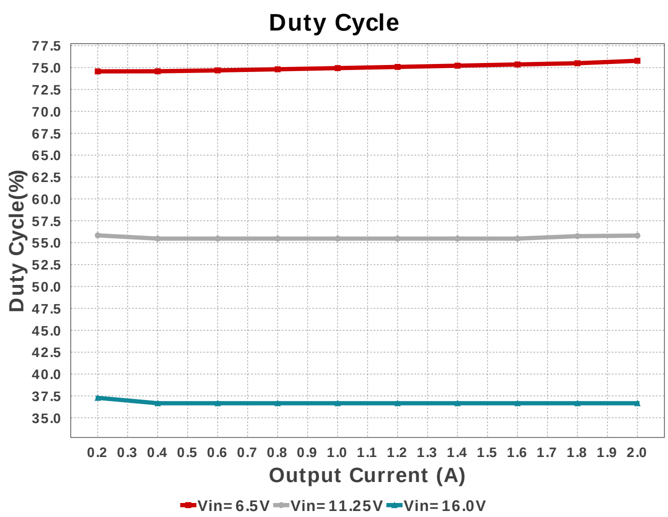


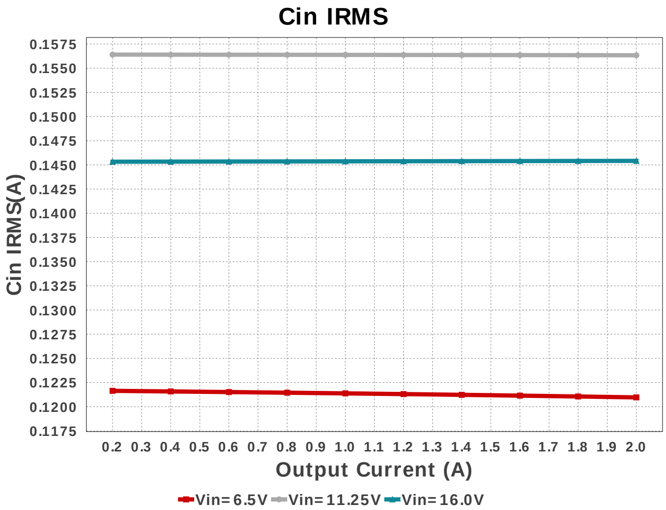
Electrical BOM

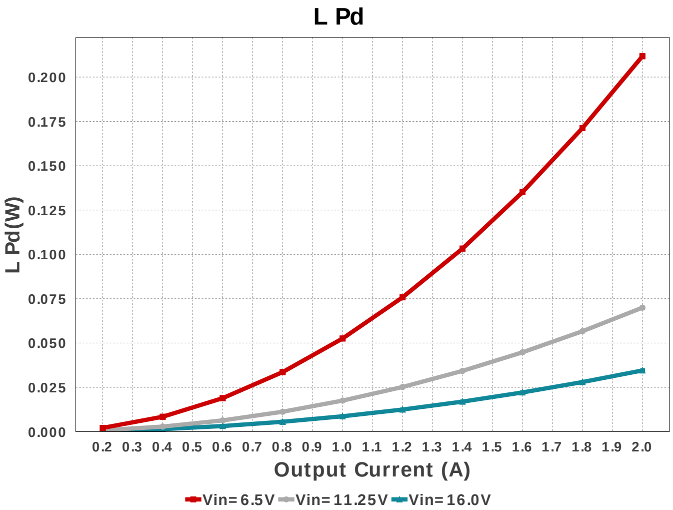
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cbp	Kemet	C0805C105K4RACTU Series= X7R	Cap= 1.0 uF ESR= 15.0 mOhm VDC= 16.0 V IRMS= 8.19 A	1	$0.02	0805 7 mm²
Cbyp	Taiyo Yuden	TMK212BJ474KD-T Series= X5R	Cap= 470.0 nF ESR= 1.0 mOhm VDC= 20.0 V IRMS= 0.0 A	1	$0.02	0805 7 mm²
Ccomp	MuRata	GRM188R71E473KA01D Series= X7R	Cap= 47.0 nF ESR= 60.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.01	0603 5 mm²
Ccomp2	Samsung Electro-Mechanics	CL21C222JBFNNNE Series= C0G/NP0	Cap= 2.2 nF VDC= 50.0 V IRMS= 0.0 A	1	$0.03	0805 7 mm²
Ciflt	Samsung Electro-Mechanics	CL21C221JBANNNC Series= C0G/NP0	Cap= 220.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm²
Cin	Panasonic	EEE-FK1E330P Series= FK	Cap= 33.0 uF ESR= 360.0 mOhm VDC= 25.0 V IRMS= 240.0 mA	1	$0.11	 SM_RADIAL_D 84 mm²
Cout	Panasonic	35SVPF82M Series= SVPF	Cap= 82.0 uF ESR= 20.0 mOhm VDC= 35.0 V IRMS= 4.0 A	2	$0.63	 CAPSMT_62_E12 106 mm²

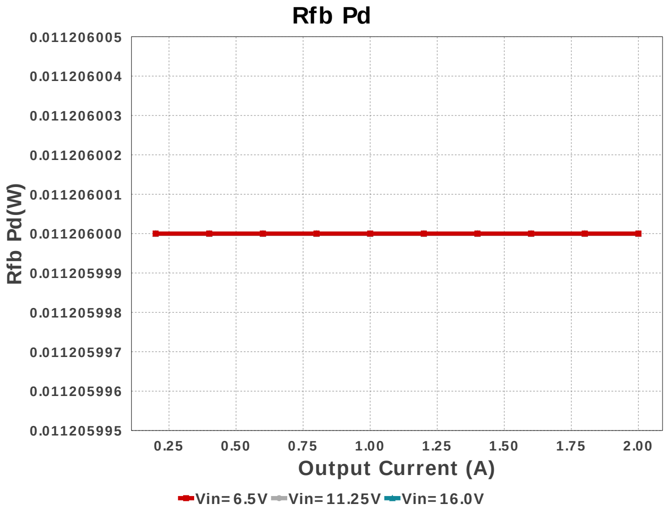
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Coutx	MuRata	GRM31CR61H225KA88L Series= X5R	Cap= 2.2 uF ESR= 4.448 mOhm VDC= 50.0 V IRMS= 2.2252 A	1	$0.10	1206_190 11 mm^2
Crc	Samsung Electro-Mechanics	CL21C101JBANNNC Series= C0G/NP0	Cap= 100.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm^2
Css	TDK	C1005X5R1V105K050BC Series= X5R	Cap= 1.0 uF ESR= 11.416 mOhm VDC= 35.0 V IRMS= 1.483 A	1	$0.03	0402 3 mm^2
D1	SMC Diode Solutions	SBRD10200TR	VF@Io= 950.0 mV VRRM= 200.0 V	1	$0.12	DPAK 102 mm^2
L1	Coilcraft	AGP4233-333ME	L= 33.0 µH 2.95 mOhm	1	$7.84	AGP4233_Mid 1671 mm^2
M1	Texas Instruments	CSD17304Q3	VdsMax= 30.0 V IdsMax= 56.0 Amps	1	$0.27	DQG0008A 18 mm^2
Rcomp	Yageo	RC0201FR-0712K1L Series= ?	Res= 12.1 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm^2
Rfb1	Yageo	RC0603FR-071K5L Series= ?	Res= 1.5 kOhm Power= 100.0 mW Tolerance= 1.0%	1	$0.01	0603 5 mm^2
Rfb2	Vishay-Dale	CRCW060349K9FKEA Series= CRCW..e3	Res= 49.9 kOhm Power= 100.0 mW Tolerance= 1.0%	1	$0.01	0603 5 mm^2
Rg	Vishay-Dale	CRCW040221R0FKED Series= CRCW..e3	Res= 21.0 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Riflt	Vishay-Dale	CRCW04021K00FKED Series= CRCW..e3	Res= 1000.0 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rrc	Yageo	RC0603FR-07470KL Series= ?	Res= 470.0 kOhm Power= 100.0 mW Tolerance= 1.0%	1	$0.01	0603 5 mm^2
Rsense	Bourns	CRM2010-FZ-R050ELF Series= ?	Res= 50.0 mOhm Power= 1.0 W Tolerance= 1.0%	1	$0.20	2010 32 mm^2
U1	Texas Instruments	TPS40210DGQR	Switcher	1	$0.73	S-PDSO-G10 24 mm^2

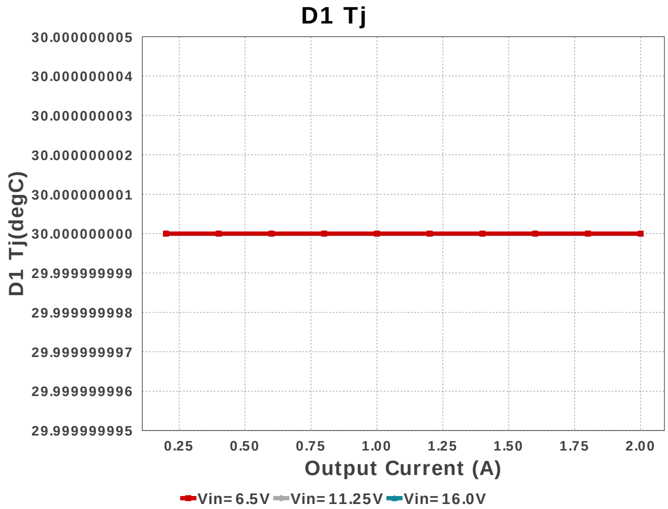


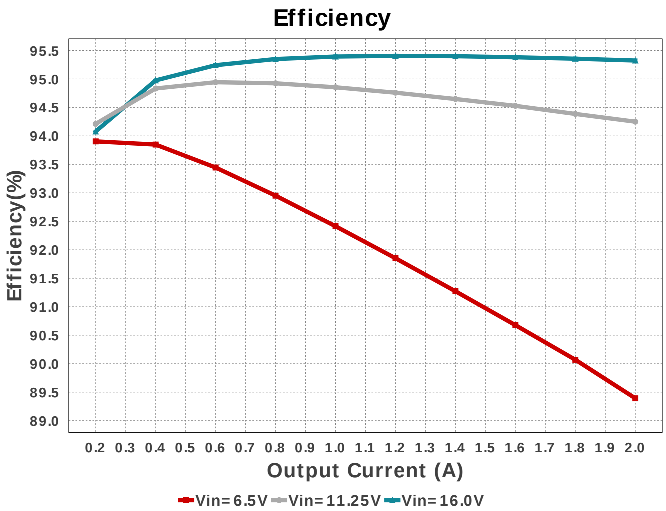


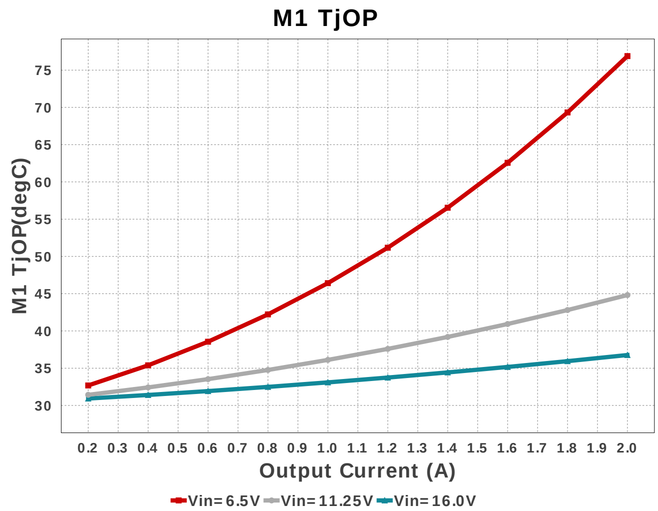

Cin IRMS
Cin IRMS(A)
0.1575
0.1550
0.1525
0.1500
0.1475
0.1450
0.1425
0.1400
0.1375
0.1350
0.1325
0.1300
0.1275
0.1250
0.1225
0.1200
0.1175
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

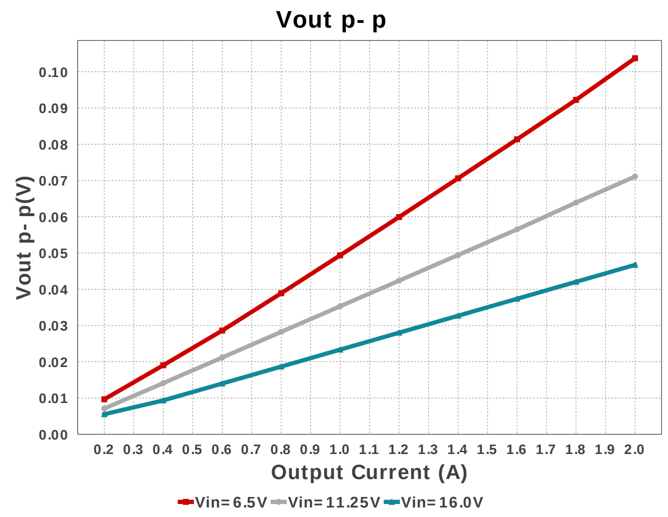

L Pd
L Pd(W)
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

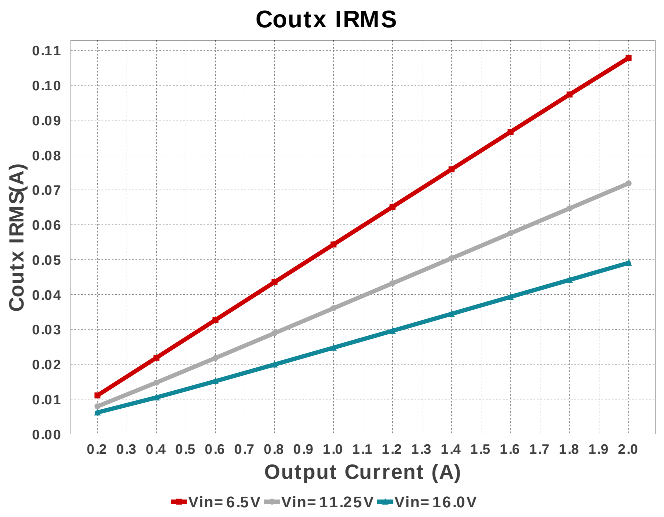

Rfb Pd
Rfb Pd(W)
0.011206005
0.011206004
0.011206003
0.011206002
0.011206001
0.011206000
0.011205999
0.011205998
0.011205997
0.011205996
0.011205995
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

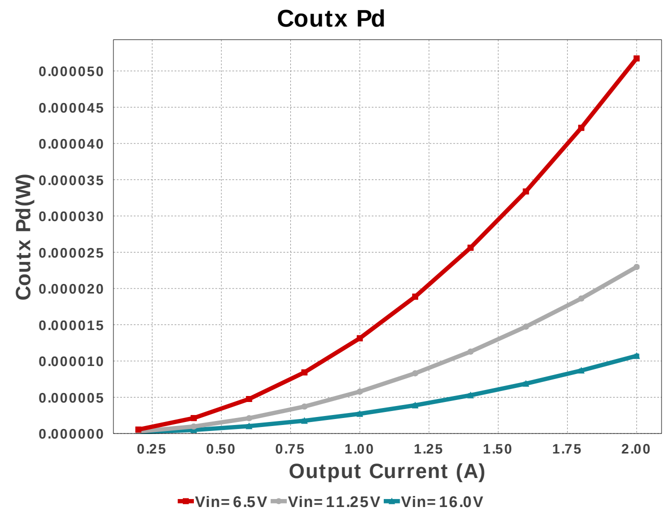

D1 Tj
D1 Tj(degC)
30.000000005
30.000000004
30.000000003
30.000000002
30.000000001
30.000000000
29.999999999
29.999999998
29.999999997
29.999999996
29.999999995
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

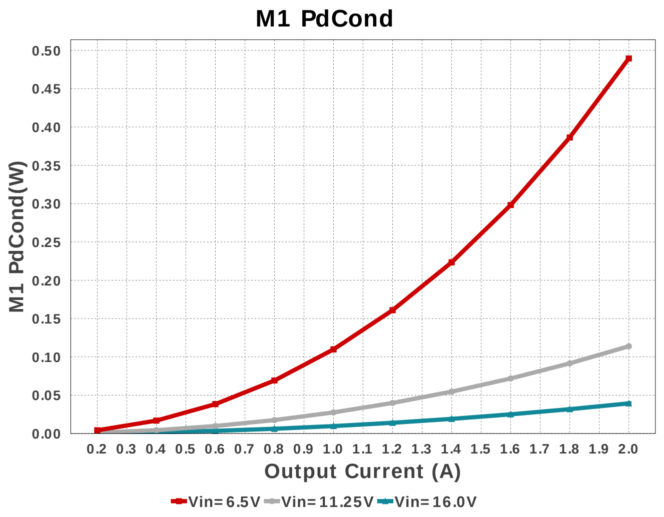

Efficiency
Efficiency(%)
95.5
95.0
94.5
94.0
93.5
93.0
92.5
92.0
91.5
91.0
90.5
90.0
89.5
89.0
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

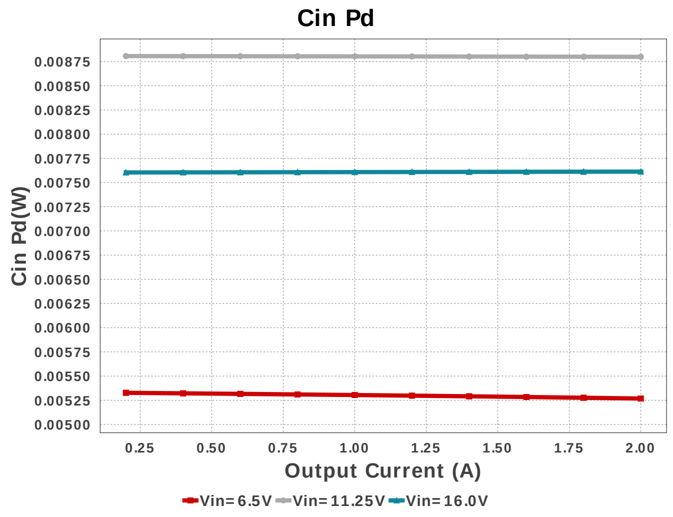

M1 TjOP
M1 TjOP(degC)
75
70
65
60
55
50
45
40
35
30
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

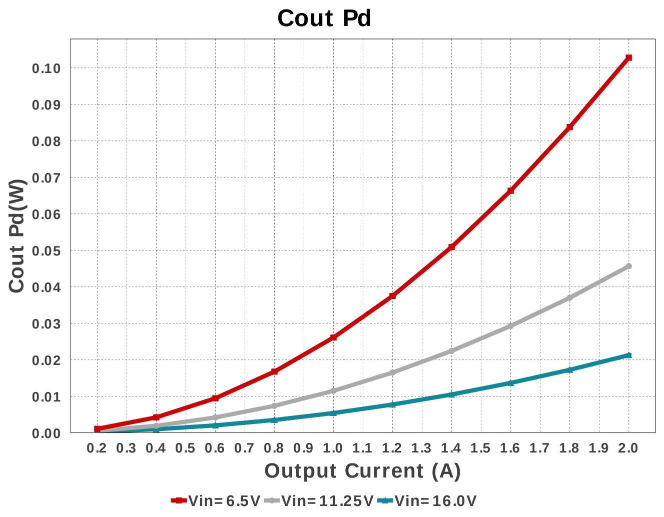

Vout p- p
Vout p- p(V)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Output Current (A)
Vin=6.5V
Vin=11.25V
Vin=16.0V

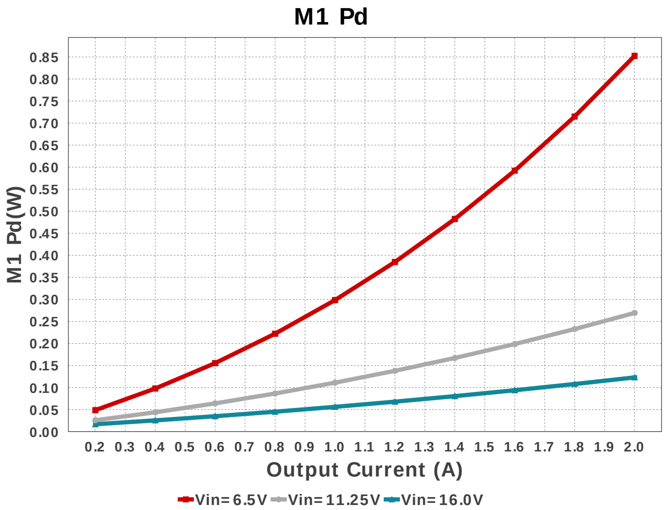

Coutx IRMS
Coutx IRMS(A)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.11
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Output Current (A)
Vin=6.5V
Vin=11.25V
Vin=16.0V

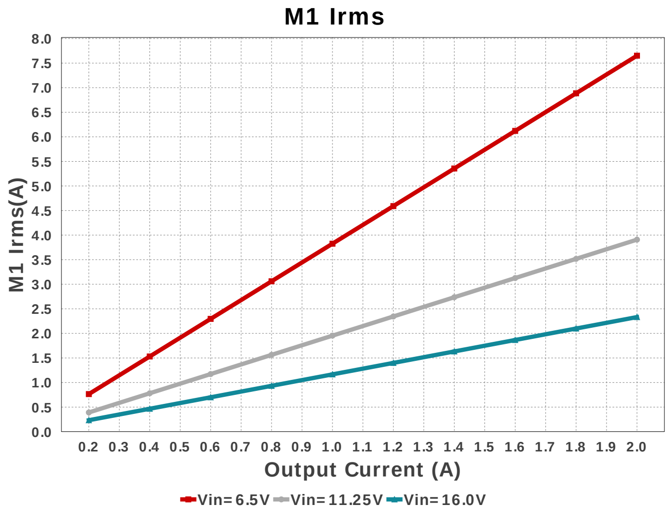

Coutx Pd
Coutx Pd(W)
0.000000
0.000005
0.000010
0.000015
0.000020
0.000025
0.000030
0.000035
0.000040
0.000045
0.000050
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Output Current (A)
Vin=6.5V
Vin=11.25V
Vin=16.0V

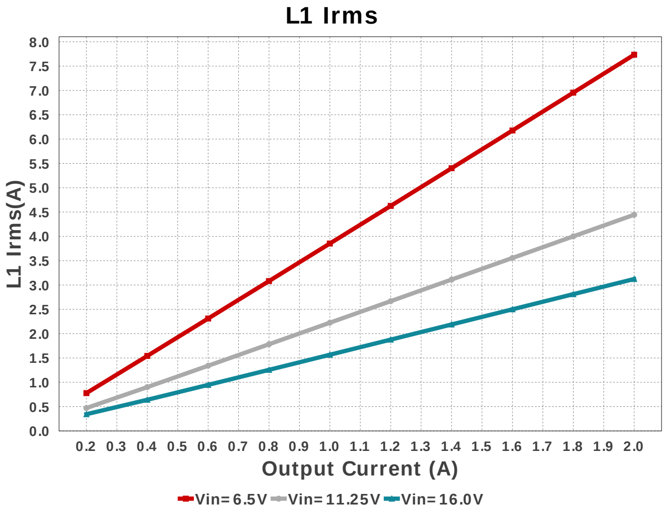

M1 PdCond
M1 PdCond(W)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Output Current (A)
Vin=6.5V
Vin=11.25V
Vin=16.0V

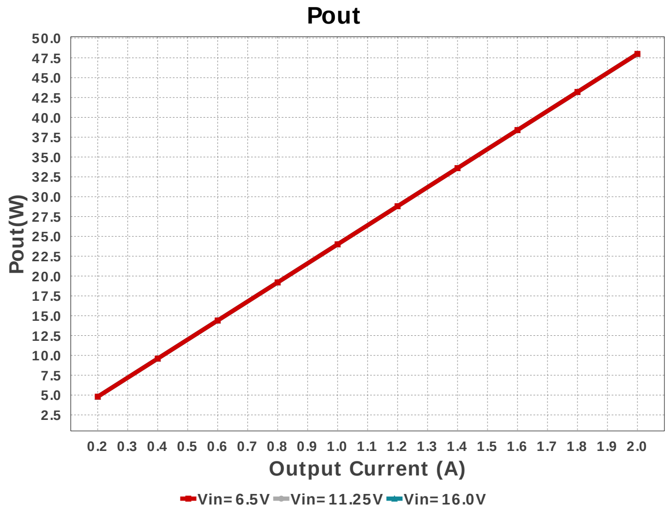

Cin Pd
Cin Pd(W)
0.00500
0.00525
0.00550
0.00575
0.00600
0.00625
0.00650
0.00675
0.00700
0.00725
0.00750
0.00775
0.00800
0.00825
0.00850
0.00875
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Output Current (A)
Vin=6.5V
Vin=11.25V
Vin=16.0V

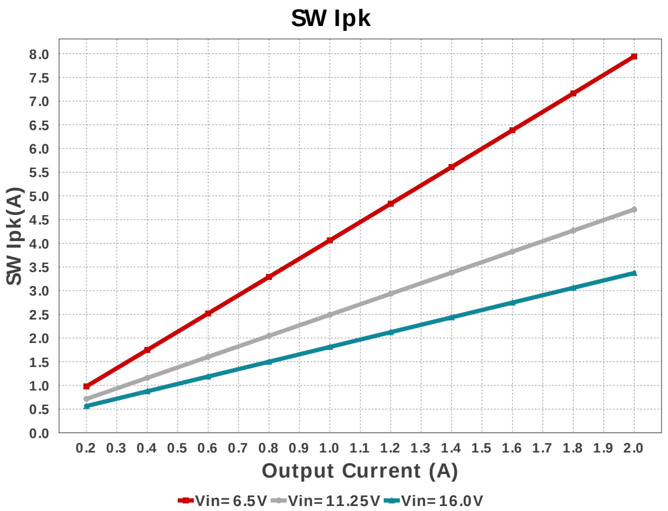

Cout Pd
Cout Pd(W)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Output Current (A)
Vin=6.5V
Vin=11.25V
Vin=16.0V

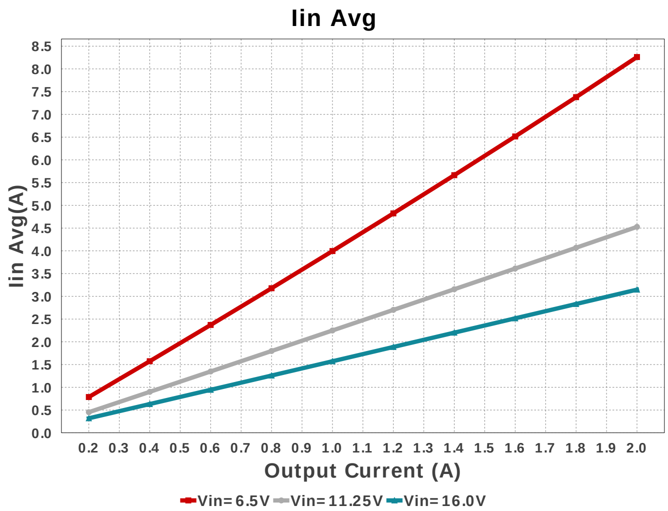

M1 Pd
M1 Pd(W)
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

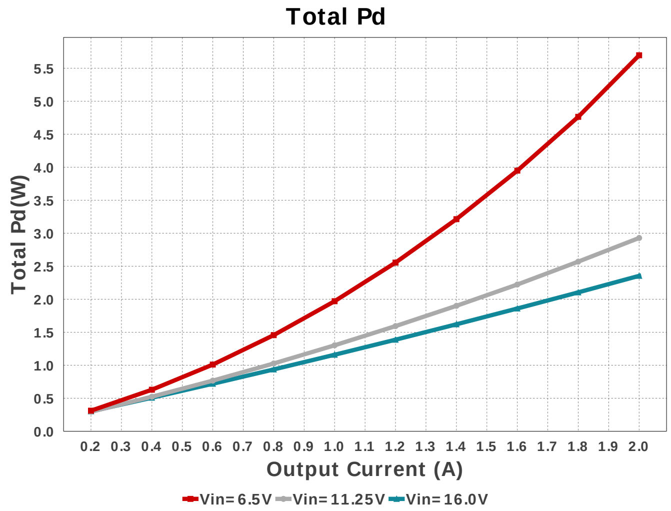

M1 Irms
M1 Irms(A)
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

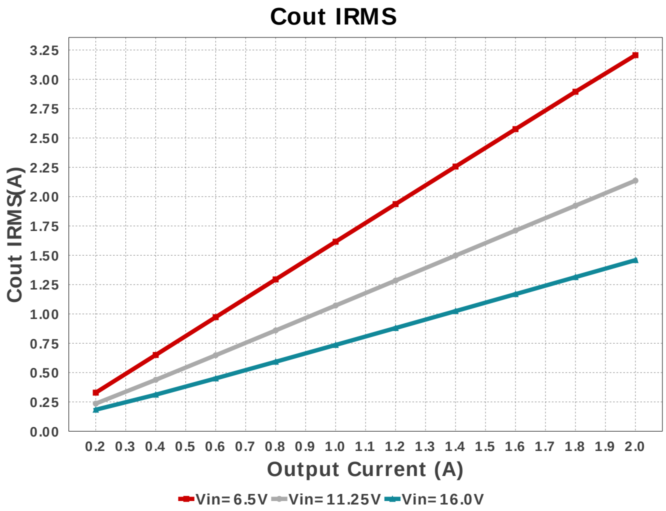

L1 Irms
L1 Irms(A)
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

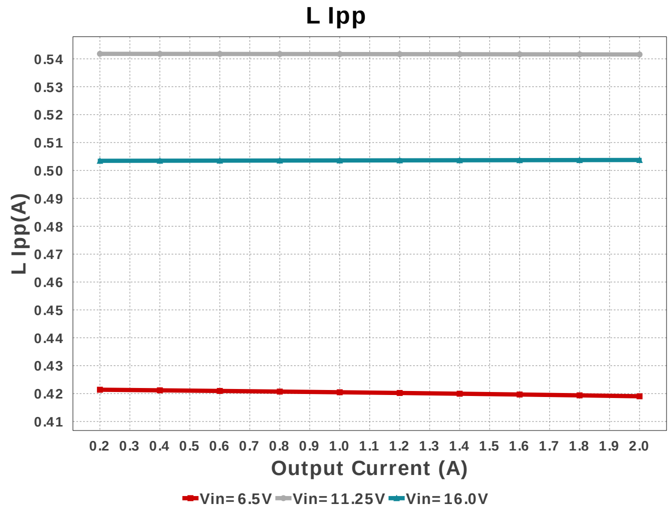

Pout
Pout(W)
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

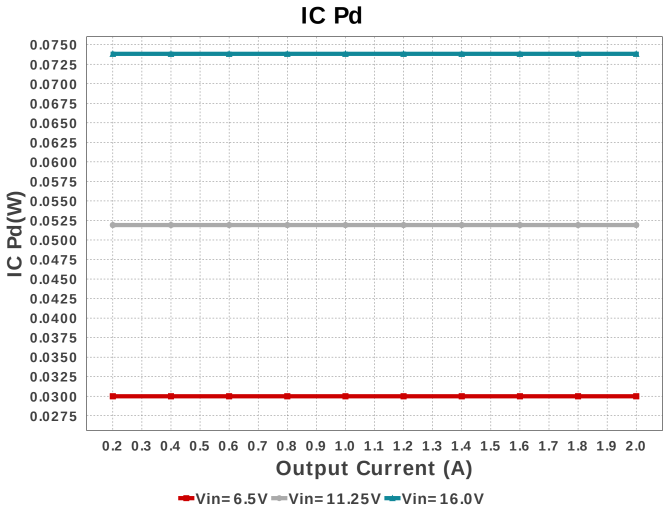

SW Ipk
SW Ipk(A)
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

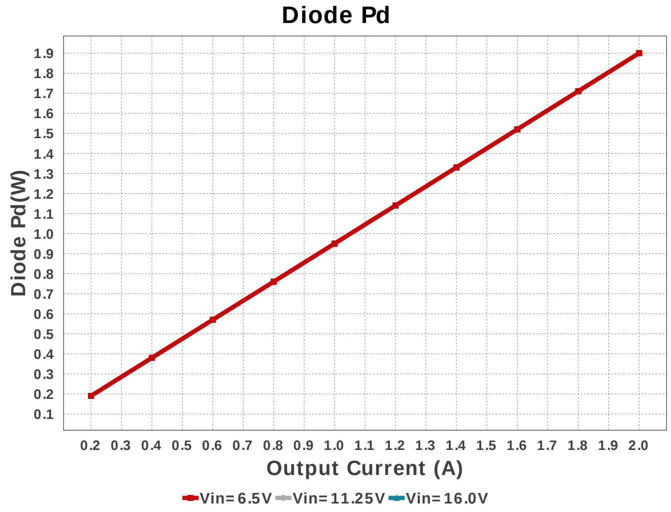

Iin Avg
Iin Avg(A)
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

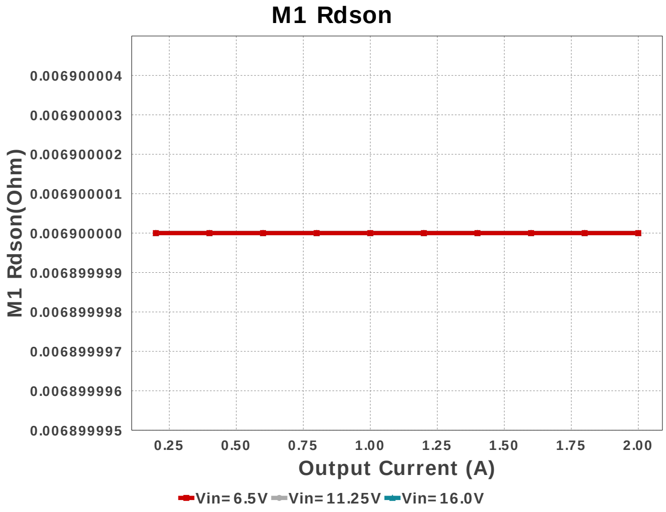

Total Pd
Total Pd(W)
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

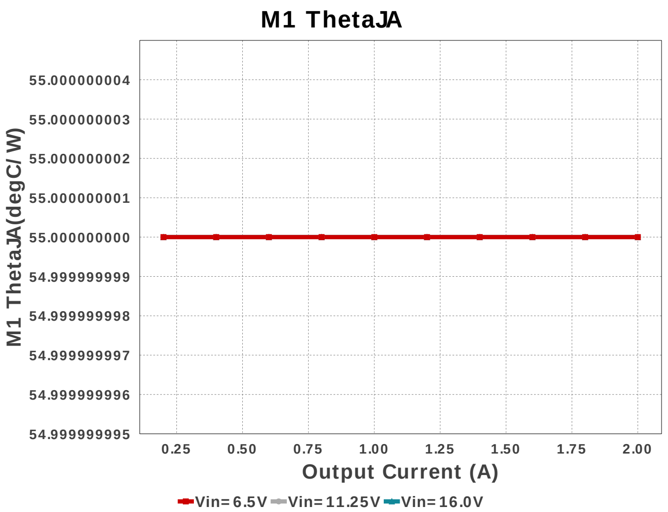

Cout IRMS
Cout IRMS(A)
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

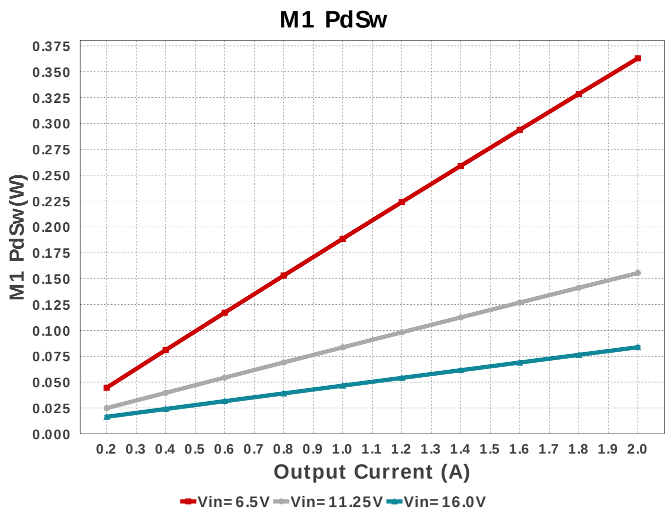

L Ipp
L Ipp(A)
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V

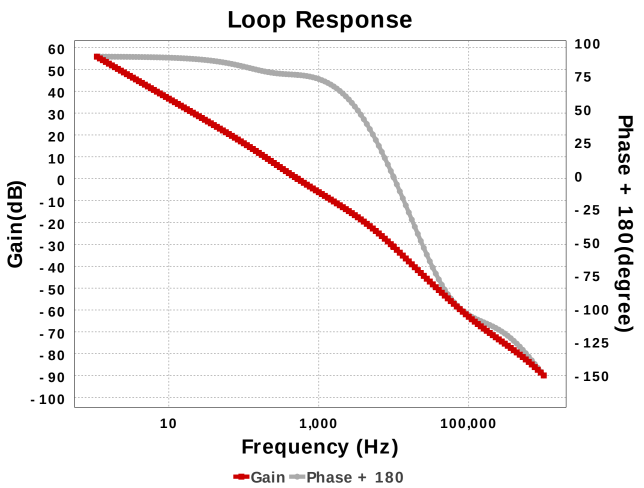

IC Pd
IC Pd(W)
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V


Diode Pd
Diode Pd(W)
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V


M1 Rdson
M1 Rdson(Ohm)
Output Current (A)
Vin=6.5V Vin=11.25V Vin=16.0V







Operating Values

#	Name	Value	Category	Description
1.	BOM Count	22		Total Design BOM count
2.	Total BOM	$10.816		Total BOM Cost
3.	Cin IRMS	120.966 mA	Capacitor	Input capacitor RMS ripple current
4.	Cin Pd	5.268 mW	Capacitor	Input capacitor power dissipation
5.	Cout IRMS	3.206 A	Capacitor	Output capacitor RMS ripple current
6.	Cout Pd	102.79 mW	Capacitor	Output capacitor power dissipation
7.	Coutx IRMS	107.844 mA	Capacitor	Output capacitor_x RMS ripple current
8.	Coutx Pd	51.731 µW	Capacitor	Output capacitor_x power loss
9.	D1 Tj	30.0 degC	Diode	D1 junction temperature
10.	Diode Pd	1.9 W	Diode	Diode power dissipation
11.	IC Pd	29.993 mW	IC	IC power dissipation
12.	IC Tj	31.731 degC	IC	IC junction temperature
13.	IC Tolerance	14.0 mV	IC	IC Feedback Tolerance
14.	ICThetaJA	57.7 degC/W	IC	IC junction-to-ambient thermal resistance
15.	Iin Avg	8.261 A	IC	Average input current
16.	L Ipp	419.039 mA	Inductor	Peak-to-peak inductor ripple current
17.	L Pd	211.76 mW	Inductor	Inductor power dissipation
18.	L1 Irms	7.734 A	Inductor	Inductor ripple current
19.	M1 Irms	7.651 A	Mosfet	M1 MOSFET Irms
20.	M1 Pd	852.42 mW	Mosfet	M1 MOSFET total power dissipation
21.	M1 PdCond	489.41 mW	Mosfet	M1 MOSFET conduction losses
22.	M1 PdSw	363.01 mW	Mosfet	M1 MOSFET switching losses
23.	M1 Rdson	6.9 mOhm	Mosfet	Drain-Source On-resistance
24.	M1 ThetaJA	55.0 degC/W	Mosfet	MOSFET junction-to-ambient thermal resistance
25.	M1 TjOP	76.883 degC	Mosfet	M1 MOSFET junction temperature
26.	Cin Pd	5.268 mW	Power	Input capacitor power dissipation
27.	Cout Pd	102.79 mW	Power	Output capacitor power dissipation
28.	Coutx Pd	51.731 µW	Power	Output capacitor_x power loss
29.	Diode Pd	1.9 W	Power	Diode power dissipation
30.	IC Pd	29.993 mW	Power	IC power dissipation
31.	L Pd	211.76 mW	Power	Inductor power dissipation
32.	M1 Pd	852.42 mW	Power	M1 MOSFET total power dissipation

#	Name	Value	Category	Description
33.	M1 PdCond	489.41 mW	Power	M1 MOSFET conduction losses
34.	M1 PdSw	363.01 mW	Power	M1 MOSFET switching losses
35.	Rfb Pd	11.206 mW	Power	Rfb Power Dissipation
36.	Total Pd	5.696 W	Power	Total Power Dissipation
37.	Rfb Pd	11.206 mW	Resistor	Rfb Power Dissipation
38.	Cross Freq	249.908 Hz	System Information	Bode plot crossover frequency
39.	Duty Cycle	75.775 %	System Information	Duty cycle
40.	Efficiency	89.392 %	System Information	Steady state efficiency
41.	FootPrint	2.217 k mm^2	System Information	Total Foot Print Area of BOM components
42.	Frequency	345.484 kHz	System Information	Switching frequency
43.	Gain Marg	-24.993 dB	System Information	Bode Plot Gain Margin
44.	Iout	2.0 A	System Information	Iout operating point
45.	Low Freq Gain	50.244 dB	System Information	Gain at 1Hz
46.	Mode	CCM	System Information	Conduction Mode
47.	Phase Marg	65.919 deg	System Information	Bode Plot Phase Margin
48.	Pout	48.0 W	System Information	Total output power
49.	SW Ipk	7.943 A	System Information	Peak switch current
50.	Vin	6.5 V	System Information	Vin operating point
51.	Vout	24.0 V	System Information	Operational Output Voltage
52.	Vout Actual	23.987 V	System Information	Vout Actual calculated based on selected voltage divider resistors
53.	Vout Tolerance	4.0 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
54.	Vout p-p	103.721 mV	System Information	Peak-to-peak output ripple voltage

Design Inputs

Name	Value	Description
Iout	2.0	Maximum Output Current
VinMax	16.0	Maximum input voltage
VinMin	6.5	Minimum input voltage
Vout	24.0	Output Voltage
base_pn	TPS40210	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

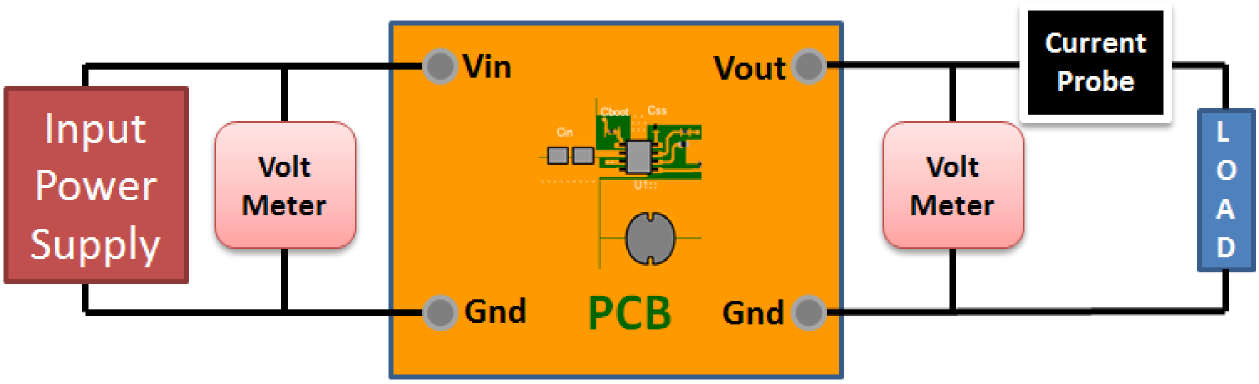
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. 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 6.5V 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 : 2BD3F413F9954482[v1]

2. **TPS40210** Product Folder : http://www.ti.com/product/TPS40210 : contains the data sheet and other resources.