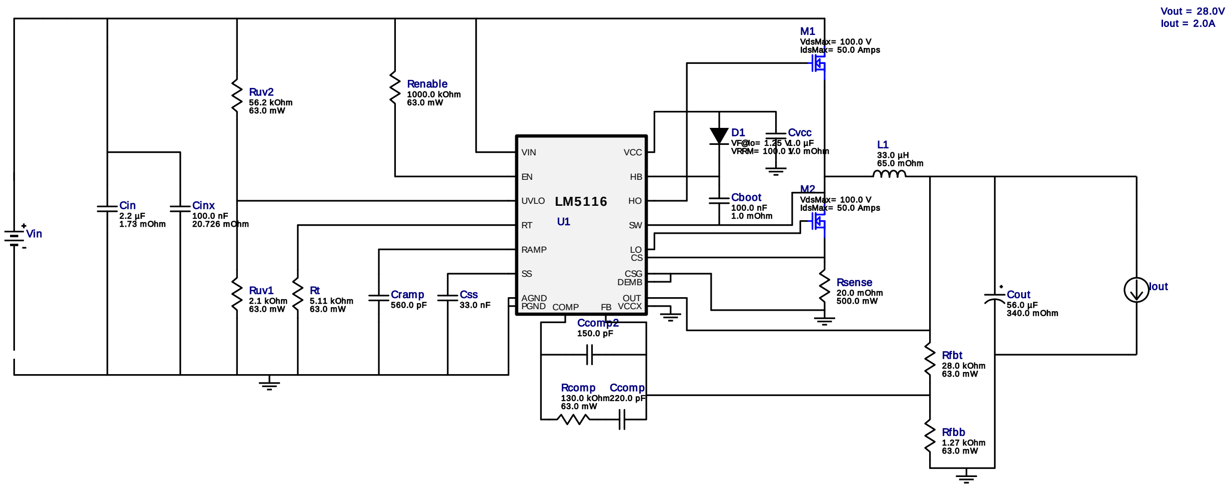
TEXAS INSTRUMENTS

WEBENCH ® Design Report

VinMin = 42.0V
VinMax = 52.0V
Vout = 28.0V
Iout = 2.0A

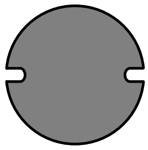
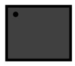
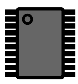
Device = LM5116MH/NOPB
Topology = Buck
Created = 2019-07-31 10:31:03.624
BOM Cost = $4.94
BOM Count = 23
Total Pd = 3.13W

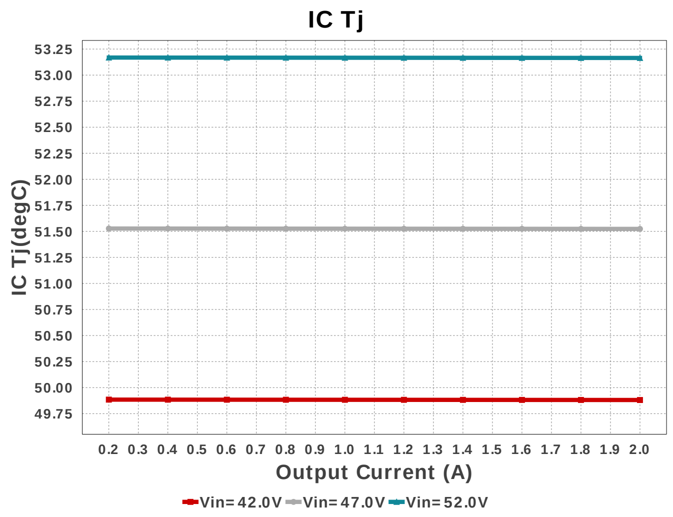
Design : 5 LM5116MH/NOPB
LM5116MH/NOPB 42V-52V to 28.00V @ 2A

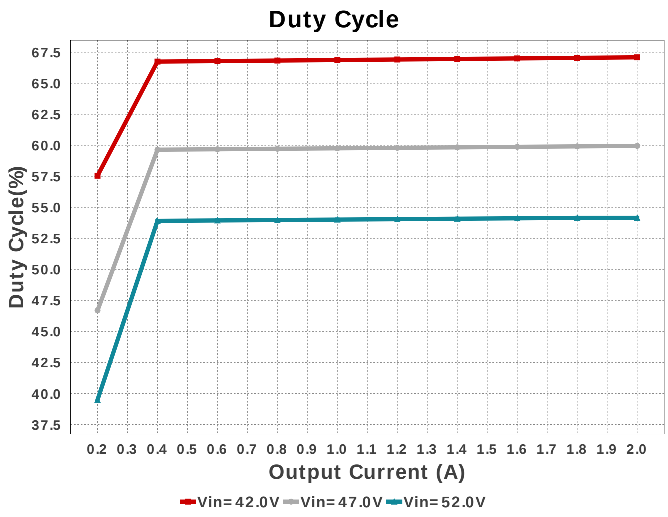


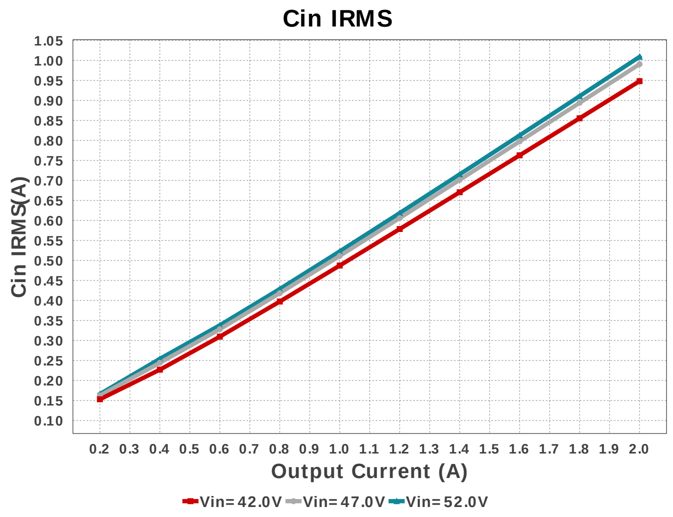
Electrical BOM

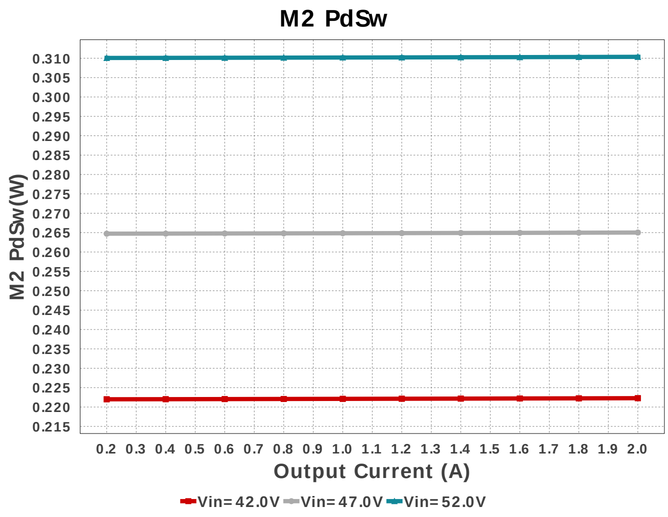
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cboot	Taiyo Yuden	HMK212B7104KG-T Series= X7R	Cap= 100.0 nF ESR= 1.0 mOhm VDC= 100.0 V IRMS= 0.0 A	1	$0.05	0805 7 mm^2
Ccomp	Samsung Electro-Mechanics	CL21C221JBANNNC Series= C0G/NP0	Cap= 220.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm^2
Ccomp2	Johanson Technology	250R07N151JV4T Series= C0G/NP0	Cap= 150.0 pF VDC= 25.0 V IRMS= 0.0 A	1	$0.02	0402 3 mm^2
Cin	TDK	C3225X7R2A225K230AB Series= X7R	Cap= 2.2 uF ESR= 1.73 mOhm VDC= 100.0 V IRMS= 5.5932 A	1	$0.22	1210_250 15 mm^2
Cinx	TDK	C2012X7R2A104K125AA Series= X7R	Cap= 100.0 nF ESR= 20.726 mOhm VDC= 100.0 V IRMS= 1.456 A	1	$0.03	0805 7 mm^2
Cout	Nichicon	UUD1H560MNL1GS Series= uD	Cap= 56.0 uF ESR= 340.0 mOhm VDC= 50.0 V IRMS= 300.0 mA	1	$0.21	SM_RADIAL_8MM 113 mm^2
Cramp	MuRata	GRM1555C1H561JA01J Series= C0G/NP0	Cap= 560.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Css	TDK	C2012C0G1H333J125AA Series= C0G/NP0	Cap= 33.0 nF VDC= 50.0 V IRMS= 0.0 A	1	$0.10	0805 7 mm^2
Cvcc	Taiyo Yuden	TMK212BJ105KG-T Series= X5R	Cap= 1.0 uF ESR= 1.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.03	0805 7 mm^2

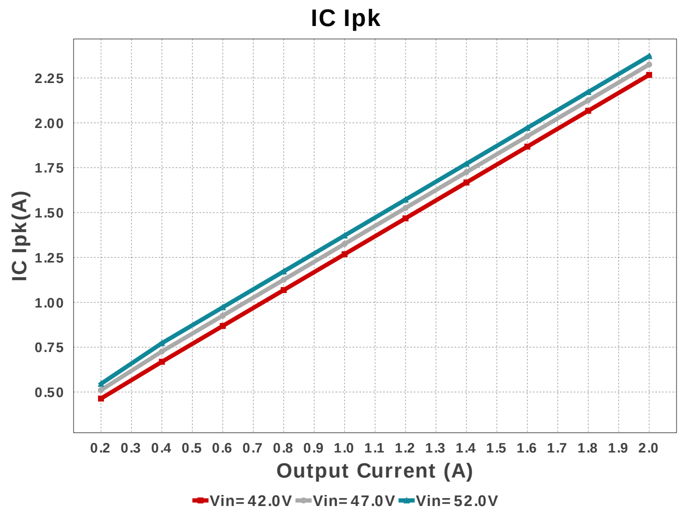
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
D1	Nexperia	BAS516,115	VF@Io= 1.25 V VRRM= 100.0 V	1	$0.04	SOD-523 5 mm^2
L1	Bourns	SDR1307-330KL	L= 33.0 µH 65.0 mOhm	1	$0.42	 SDR1307 226 mm^2
M1	Texas Instruments	CSD19534Q5A	VdsMax= 100.0 V IdsMax= 50.0 Amps	1	$0.36	 TRANS_NexFET_Q5A 55 mm^2
M2	Texas Instruments	CSD19534Q5A	VdsMax= 100.0 V IdsMax= 50.0 Amps	1	$0.36	 TRANS_NexFET_Q5A 55 mm^2
Rcomp	Vishay-Dale	CRCW0402130KFKED Series= CRCW..e3	Res= 130.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 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	CRCW04021K27FKED Series= CRCW..e3	Res= 1.27 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbt	Vishay-Dale	CRCW040228K0FKED Series= CRCW..e3	Res= 28.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rramp	Vishay-Dale	CRCW0402102KFKED Series= CRCW..e3	Res= 102.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rsense	Stackpole Electronics Inc	CSR1206FK20L0 Series= ?	Res= 20.0 mOhm Power= 500.0 mW Tolerance= 1.0%	1	$0.10	 1206 11 mm^2
Rt	Vishay-Dale	CRCW04025K11FKED Series= CRCW..e3	Res= 5.11 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Ruv1	Vishay-Dale	CRCW04022K10FKED Series= CRCW..e3	Res= 2.1 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Ruv2	Yageo	AC0402FR-0756K2L Series= ?	Res= 56.2 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
U1	Texas Instruments	LM5116MH/NOPB	Switcher	1	$2.90	 MXA20A 71 mm^2

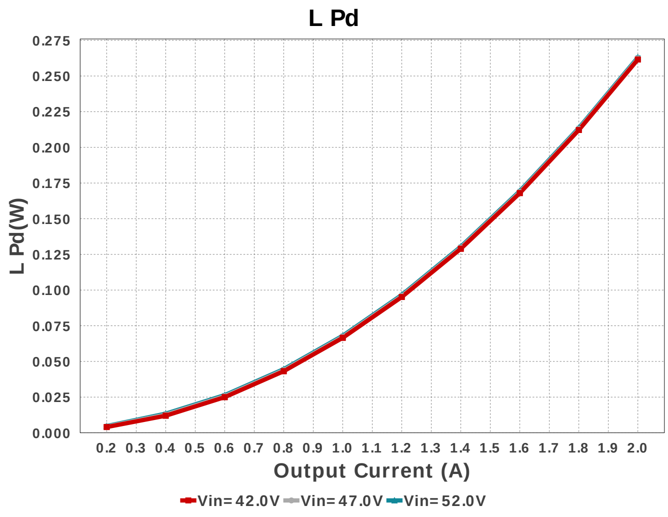

IC Tj
IC Tj(degC)
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V

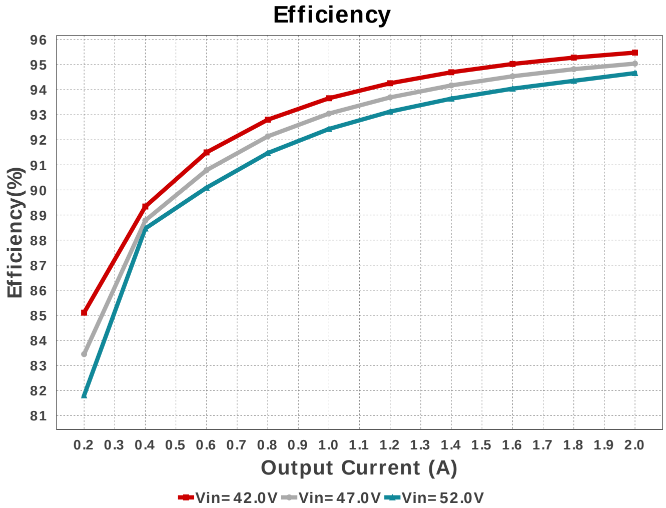

Duty Cycle
Duty Cycle(%)
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V

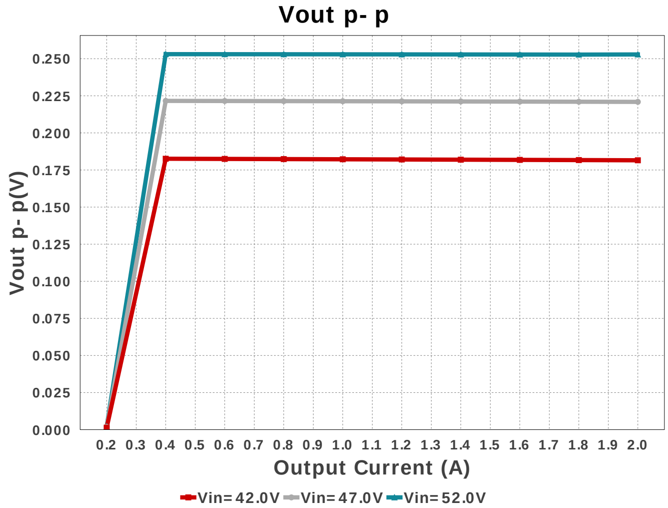

Cin IRMS
Cin IRMS(A)
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V

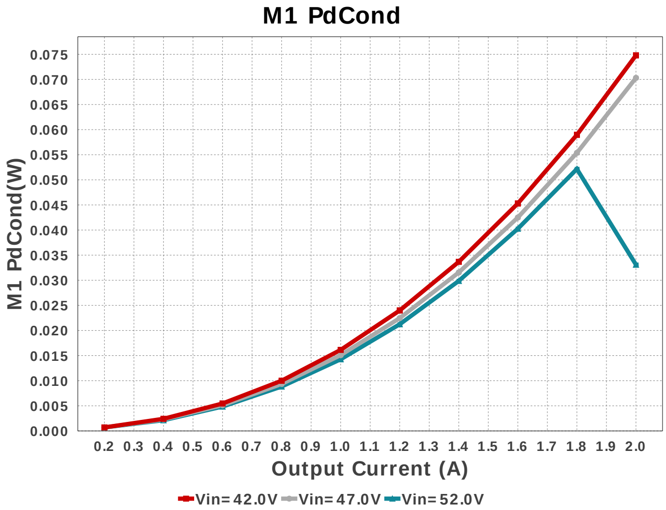

M2 PdSw
M2 PdSw(W)
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V

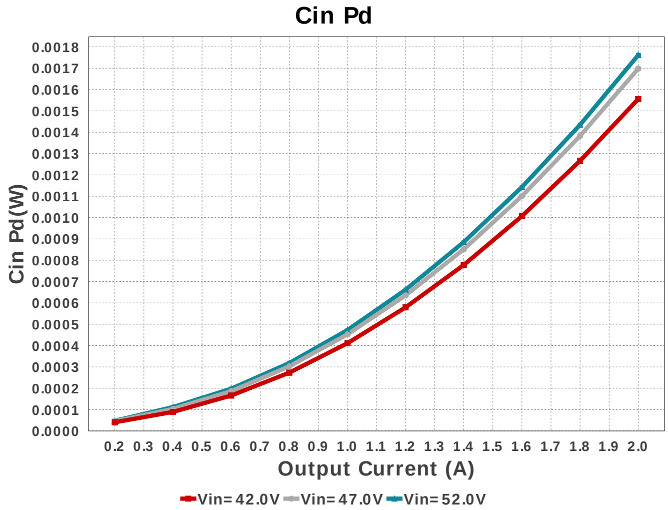

IC Ipk
IC Ipk(A)
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V

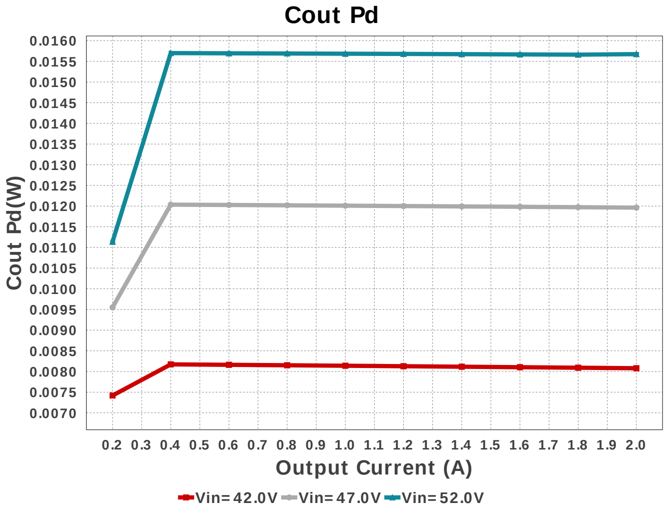

L Pd
L Pd(W)
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V

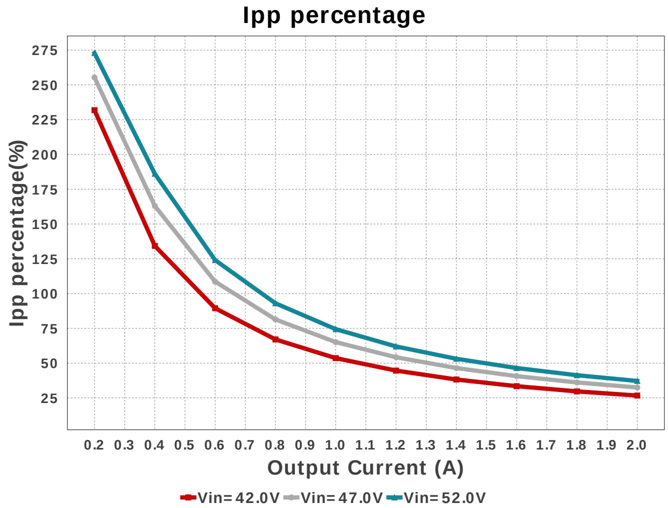

Efficiency
Efficiency(%)
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V

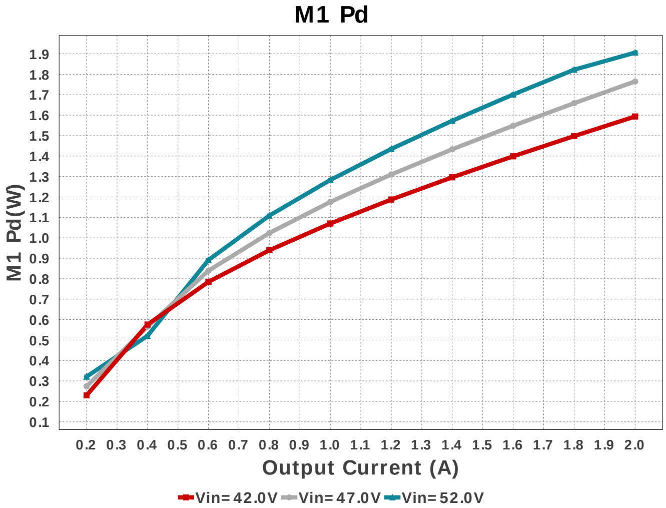

Vout p-p
Vout p-p(V)
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V

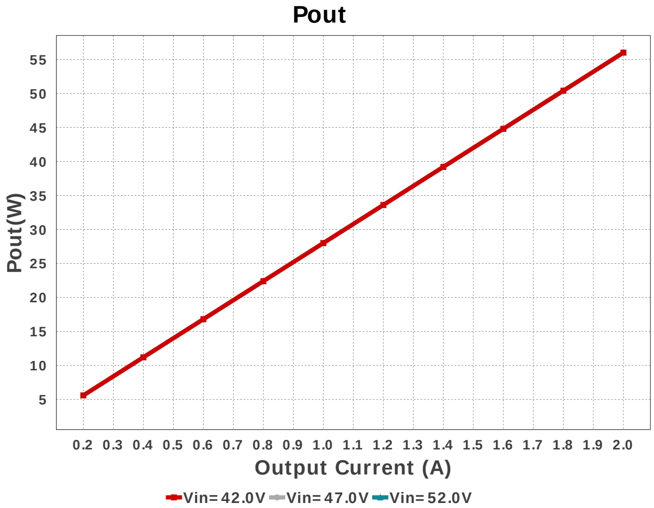

M1 PdCond
M1 PdCond(W)
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V

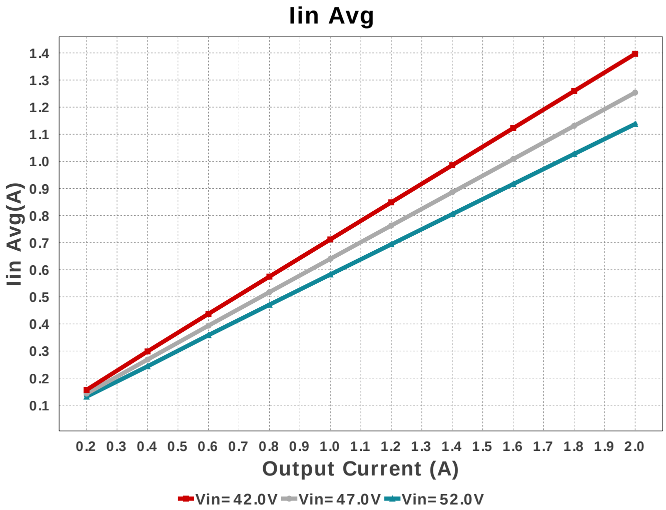

Cin Pd
Cin Pd(W)
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V

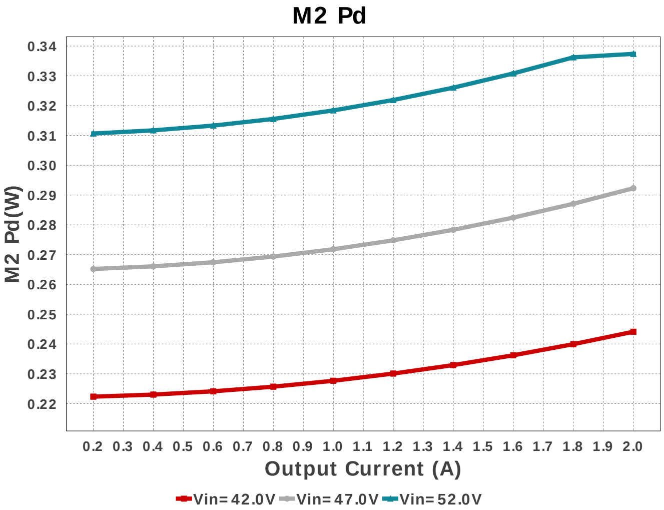

Cout Pd
Cout Pd(W)
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V

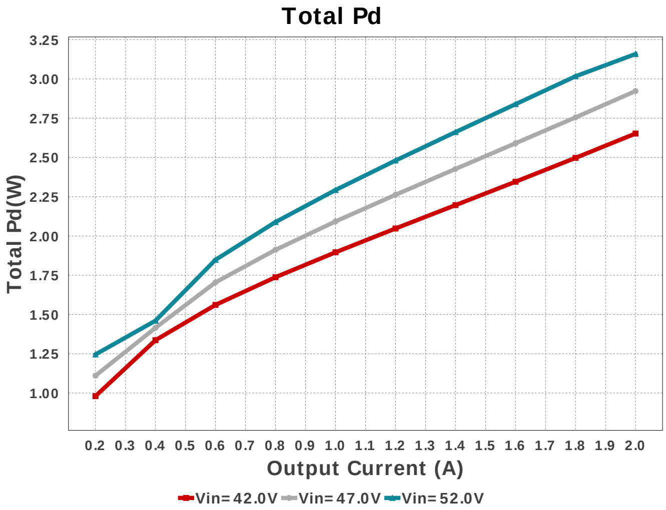

Ipp percentage
Ipp percentage(%)
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V

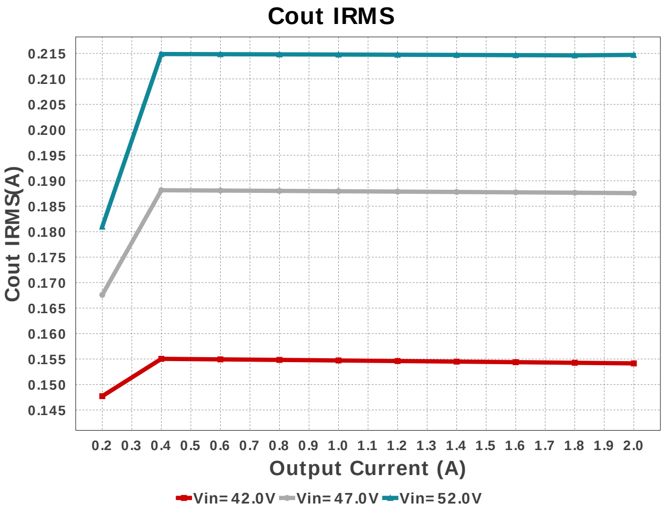

M1 Pd
M1 Pd(W)
Output Current (A)
Vin= 42.0V
Vin= 47.0V
Vin= 52.0V

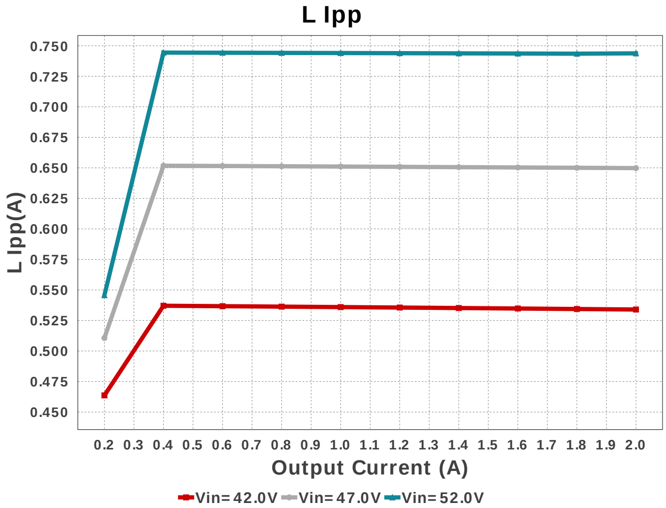

Pout
Pout(W)
Output Current (A)
Vin= 42.0V
Vin= 47.0V
Vin= 52.0V

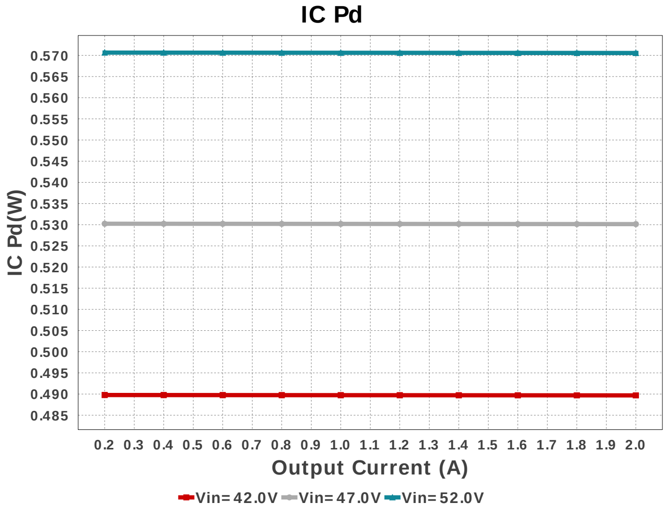

Iin Avg
Iin Avg(A)
Output Current (A)
Vin= 42.0V
Vin= 47.0V
Vin= 52.0V

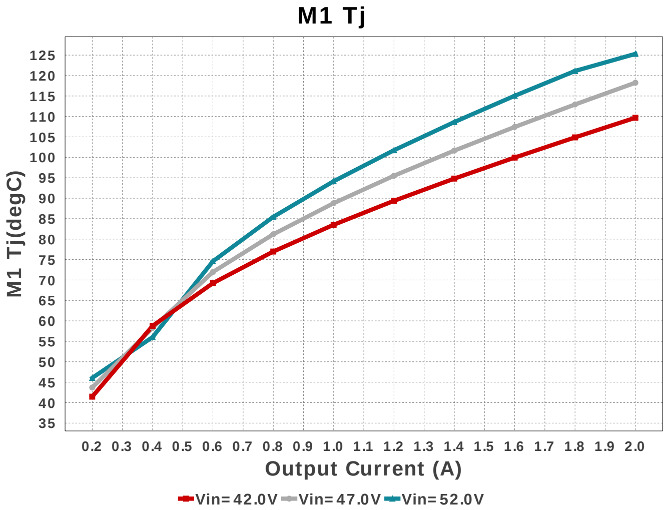

M2 Pd
M2 Pd(W)
Output Current (A)
Vin= 42.0V
Vin= 47.0V
Vin= 52.0V

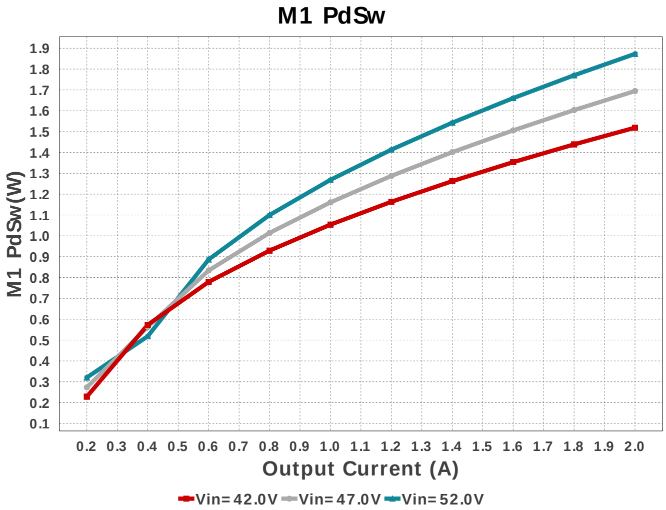

Total Pd
Total Pd(W)
Output Current (A)
Vin= 42.0V
Vin= 47.0V
Vin= 52.0V

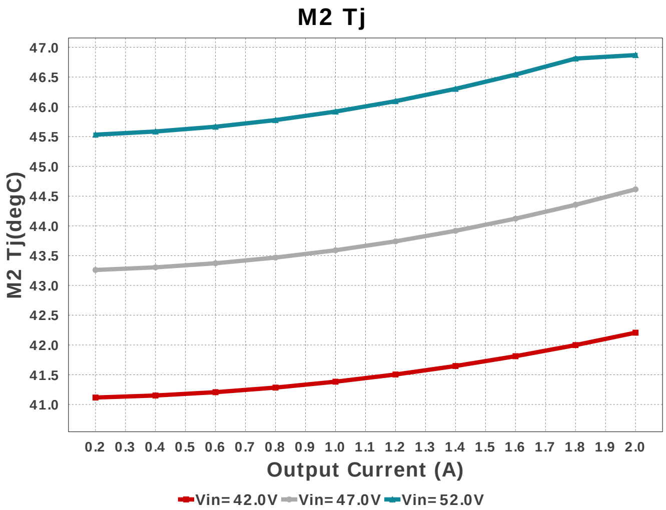

Cout IRMS
Cout IRMS(A)
Output Current (A)
Vin= 42.0V
Vin= 47.0V
Vin= 52.0V

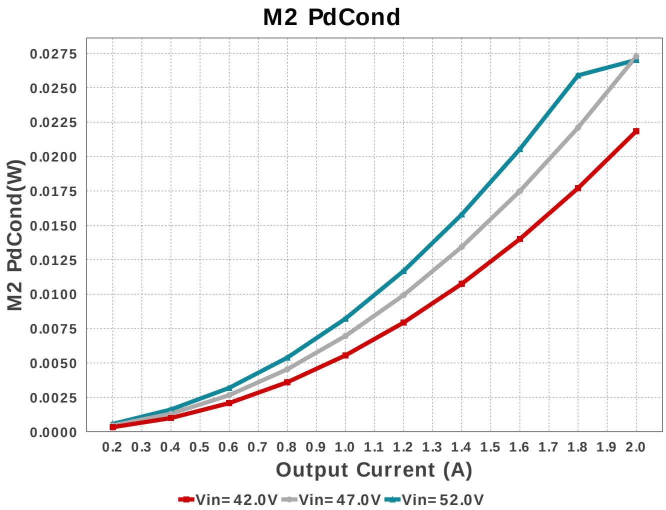

L Ipp
L Ipp(A)
0.750
0.725
0.700
0.675
0.650
0.625
0.600
0.575
0.550
0.525
0.500
0.475
0.450
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V

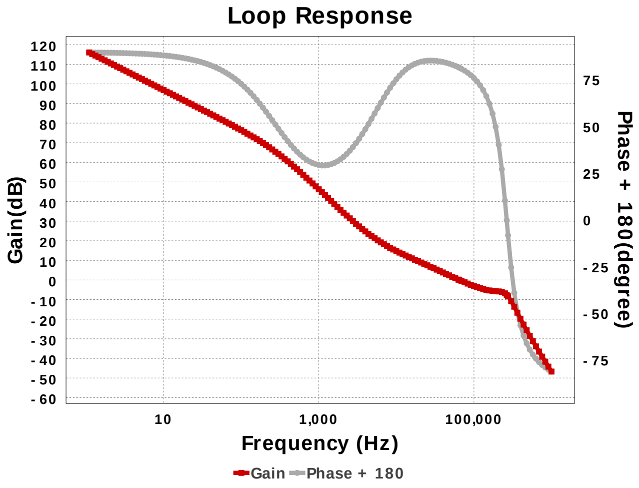

IC Pd
IC Pd(W)
0.570
0.565
0.560
0.555
0.550
0.545
0.540
0.535
0.530
0.525
0.520
0.515
0.510
0.505
0.500
0.495
0.490
0.485
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Output Current (A)
Vin=42.0V Vin=47.0V Vin=52.0V


M1 Tj
M1 Tj(degC)
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
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=42.0V Vin=47.0V Vin=52.0V


M1 PdSw
M1 PdSw(W)
1.9
1.8
1.7
1.6
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
0.2 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=42.0V Vin=47.0V Vin=52.0V


M2 Tj
M2 Tj(degC)
47.0
46.5
46.0
45.5
45.0
44.5
44.0
43.5
43.0
42.5
42.0
41.5
41.0
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=42.0V Vin=47.0V Vin=52.0V


M2 PdCond
M2 PdCond(W)
0.0275
0.0250
0.0225
0.0200
0.0175
0.0150
0.0125
0.0100
0.0075
0.0050
0.0025
0.0000
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=42.0V Vin=47.0V Vin=52.0V



Operating Values

#	Name	Value	Category	Description
1.	Cin IRMS	1.009 A	Capacitor	Input capacitor RMS ripple current
2.	Cin Pd	1.761 mW	Capacitor	Input capacitor power dissipation
3.	Cout IRMS	214.71 mA	Capacitor	Output capacitor RMS ripple current
4.	Cout Pd	15.674 mW	Capacitor	Output capacitor power dissipation
5.	IC Ipk	2.372 A	IC	Peak switch current in IC
6.	IC Pd	570.56 mW	IC	IC power dissipation
7.	IC Tj	52.822 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	1.137 A	IC	Average input current
11.	Ipp percentage	37.189 %	Inductor	Inductor ripple current percentage (with respect to average inductor current)
12.	L Ipp	743.78 mA	Inductor	Peak-to-peak inductor ripple current
13.	L Pd	263.0 mW	Inductor	Inductor power dissipation
14.	M1 Pd	1.906 W	Mosfet	M1 MOSFET total power dissipation
15.	M1 PdCond	33.111 mW	Mosfet	M1 MOSFET conduction losses
16.	M1 PdSw	1.873 W	Mosfet	M1 MOSFET switching losses
17.	M1 Tj	125.3 degC	Mosfet	M1 MOSFET junction temperature
18.	M2 Pd	337.37 mW	Mosfet	M2 MOSFET total power dissipation
19.	M2 PdCond	27.016 mW	Mosfet	M2 MOSFET conduction losses
20.	M2 PdSw	310.36 mW	Mosfet	M2 MOSFET switching losses
21.	M2 Tj	46.869 degC	Mosfet	M2 MOSFET junction temperature
22.	Cin Pd	1.761 mW	Power	Input capacitor power dissipation
23.	Cout Pd	15.674 mW	Power	Output capacitor power dissipation
24.	IC Pd	570.56 mW	Power	IC power dissipation
25.	L Pd	263.0 mW	Power	Inductor power dissipation
26.	M1 Pd	1.906 W	Power	M1 MOSFET total power dissipation
27.	M1 PdCond	33.111 mW	Power	M1 MOSFET conduction losses
28.	M1 PdSw	1.873 W	Power	M1 MOSFET switching losses
29.	M2 Pd	337.37 mW	Power	M2 MOSFET total power dissipation
30.	M2 PdCond	27.016 mW	Power	M2 MOSFET conduction losses
31.	M2 PdSw	310.36 mW	Power	M2 MOSFET switching losses
32.	Total Pd	3.131 W	Power	Total Power Dissipation
33.	BOM Count	23	System Information	Total Design BOM count
34.	Cross Freq	64.767 kHz	System Information	Bode plot crossover frequency
35.	Duty Cycle	54.158 %	System Information	Duty cycle
36.	Efficiency	94.705 %	System Information	Steady state efficiency
37.	FootPrint	616.0 mm^2	System Information	Total Foot Print Area of BOM components
38.	Frequency	525.973 kHz	System Information	Switching frequency
39.	Gain Marg	-7.597 dB	System Information	Bode Plot Gain Margin
40.	Iout	2.0 A	System Information	Iout operating point
41.	Low Freq Gain	116.034 dB	System Information	Gain at 1Hz

#	Name	Value	Category	Description
42.	Mode	CCM	System Information	Conduction Mode
43.	Phase Marg	81.659 deg	System Information	Bode Plot Phase Margin
44.	Pout	56.005 W	System Information	Total output power
45.	Total BOM	$4.94	System Information	Total BOM Cost
46.	Vin	52.0 V	System Information	Vin operating point
47.	Vout	28.002 V	System Information	Operational Output Voltage
48.	Vout Actual	28.002 V	System Information	Vout Actual calculated based on selected voltage divider resistors
49.	Vout Tolerance	3.275 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
50.	Vout p-p	252.885 mV	System Information	Peak-to-peak output ripple voltage

Design Inputs

Name	Value	Description
Iout	2.0	Maximum Output Current
VinMax	52.0	Maximum input voltage
VinMin	42.0	Minimum input voltage
Vout	28.0	Output Voltage
base_pn	LM5116	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

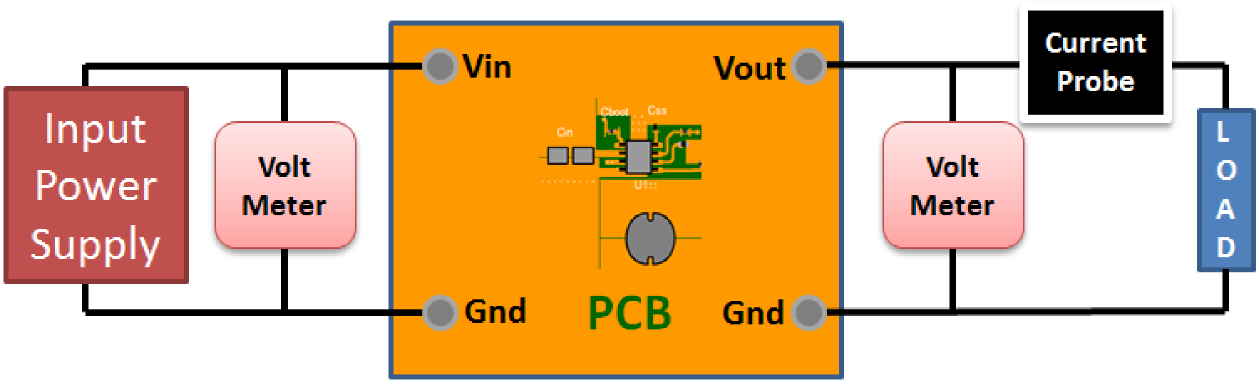
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. 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 42.0V 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 : A03639B951AB0554[v1]

2. **LM5116** Product Folder : http://www.ti.com/product/LM5116 : contains the data sheet and other resources.