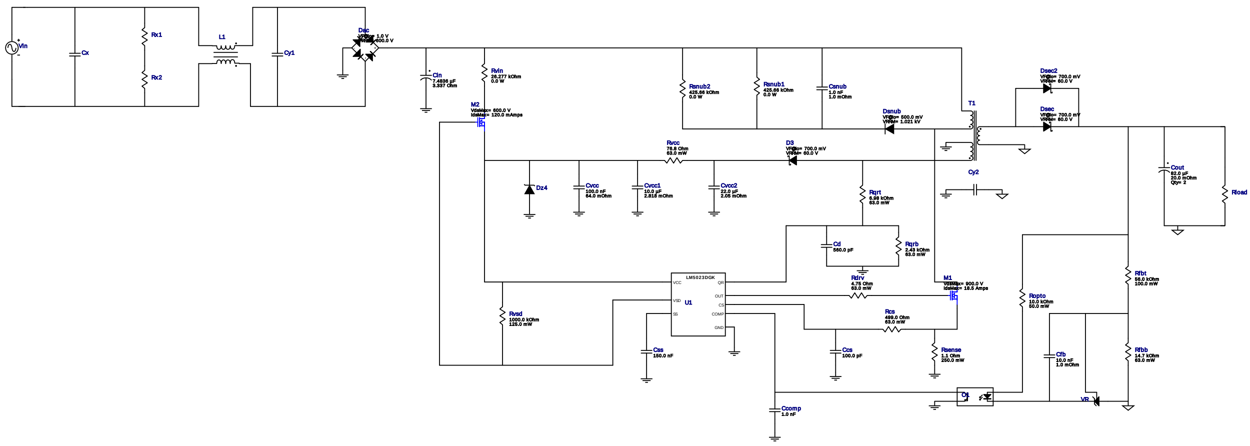
VinMin = 216.0V
VinMax = 244.0V
Vout = 12.0V
Iout = 2.0A

Device = LM5023MM-2/NOPB
Topology = Flyback
Created = 2020-06-11 23:47:51.220
BOM Cost = NA
BOM Count = 37
Total Pd = 2.34W

WEBENCH ® Design Report

Design : 13 LM5023MM-2/NOPB
LM5023MM-2/NOPB 216V-244V to 12.00V @ 2A



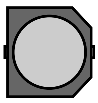
1. The EMI filter shown in the schematic is a placeholder. It has not yet been designed for the application.

Design Alerts

Component Selection Information

Click on the transformer symbol in the schematic and select "Explore Transformer Core/Bobbin Selection" to design using specific transformer cores and bobbin.

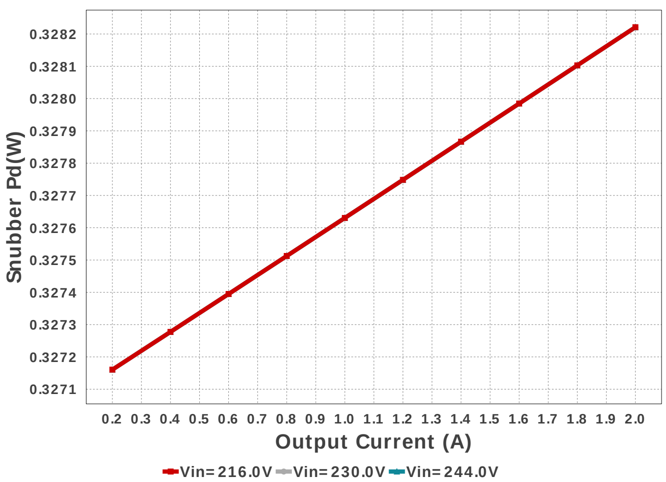
Electrical BOM

Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Ccomp	MuRata	GRM1555C1H102JA01J Series= C0G/NP0	Cap= 1.0 nF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Ccs	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
Cd	MuRata	GRM1555C1H561JA01J Series= C0G/NP0	Cap= 560.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Cfb	MuRata	GRM033R70J103KA01D Series= X7R	Cap= 10.0 nF ESR= 1.0 mOhm VDC= 6.3 V IRMS= 0.0 A	1	$0.01	0201 2 mm^2
Cin	CUSTOM	CUSTOM Series= ?	Cap= 7.4836 uF ESR= 3.3368 Ohm VDC= 362.32 V IRMS= 259.49 mA	1	NA	CUSTOM 0 mm^2
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 mm^2
Csnub	MuRata	GRM31A7U2J102JW31D Series= U2J	Cap= 1.0 nF ESR= 1.0 mOhm VDC= 630.0 V IRMS= 0.0 A	1	$0.09	1206 11 mm^2
Css	Panasonic	ECPU1C154MA5 Series= ECPU(A)	Cap= 150.0 nF VDC= 16.0 V IRMS= 0.0 A	1	$0.17	1206 11 mm^2

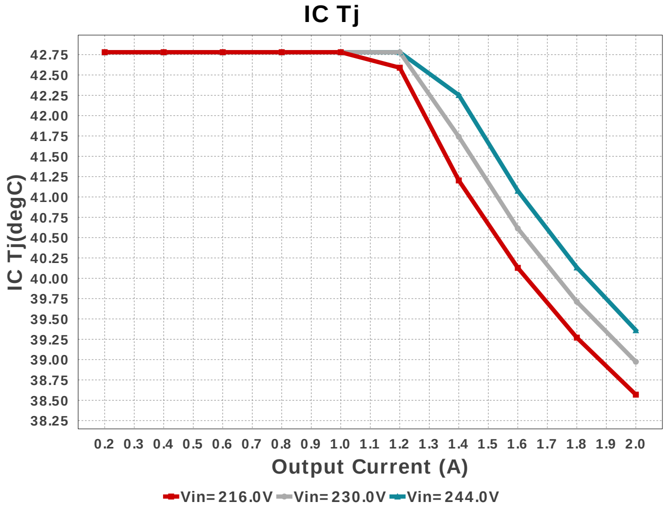
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cvcc	Kemet	C0805C104M5RACTU Series= X7R	Cap= 100.0 nF ESR= 64.0 mOhm VDC= 50.0 V IRMS= 1.64 A	1	$0.01	0805 7 mm^2
Cvcc1	TDK	C2012X5R1V106K085AC Series= X5R	Cap= 10.0 uF ESR= 2.818 mOhm VDC= 35.0 V IRMS= 3.8868 A	1	$0.17	0805 7 mm^2
Cvcc2	TDK	C2012X5R1V226M125AC Series= X5R	Cap= 22.0 uF ESR= 2.05 mOhm VDC= 35.0 V IRMS= 4.5559 A	1	$0.33	0805 7 mm^2
D3	Fairchild Semiconductor	SS26FL	VF@Io= 700.0 mV VRRM= 60.0 V	1	$0.07	SOD-123F 12 mm^2
Dac	Diodes Inc.	HD06-T	VF@Io= 1.0 V VRRM= 600.0 V	1	$0.13	MiniDIP 62 mm^2
Dsec	Diodes Inc.	B560C-13-F	VF@Io= 700.0 mV VRRM= 60.0 V	1	$0.17	SMC 83 mm^2
Dsec2	Diodes Inc.	B560C-13-F	VF@Io= 700.0 mV VRRM= 60.0 V	1	$0.17	SMC 83 mm^2
Dsnub	CUSTOM	CUSTOM	VF@Io= 500.0 mV VRRM= 1.021 kV	1	NA	CUSTOM 0 mm^2
Dz4	ON Semiconductor	MMBZ5244BLT1G	Zener	1	$0.02	SOT-23 14 mm^2
M1	STMicroelectronics	STW21N90K5	VdsMax= 900.0 V IdsMax= 18.5 Amps	1	$3.20	TO-247 123 mm^2
M2	Infineon Technologies	BSP135H6327XTSA1	VdsMax= 600.0 V IdsMax= 120.0 mAmps	1	$0.54	SOT-223 76 mm^2
O1	Fairchild Semiconductor	FOD817A	Optocoupler	1	$0.11	DIP-4 71 mm^2
Rcs	Vishay-Dale	CRCW0402499RFKED Series= CRCW..e3	Res= 499.0 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rdrv	Vishay-Dale	CRCW04024R75FKED Series= CRCW..e3	Res= 4.75 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbb	Vishay-Dale	CRCW040214K7FKED Series= CRCW..e3	Res= 14.7 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbt	Susumu Co Ltd	RR1220P-563-D Series= RR12	Res= 56.0 kOhm Power= 100.0 mW Tolerance= 0.5%	1	$0.01	0805 7 mm^2
Ropto	Yageo	RC0201FR-0710KL Series= ?	Res= 10.0 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm^2
Rqrb	Vishay-Dale	CRCW04022K43FKED Series= CRCW..e3	Res= 2.43 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rqrt	Vishay-Dale	CRCW04026K98FKED Series= CRCW..e3	Res= 6.98 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2

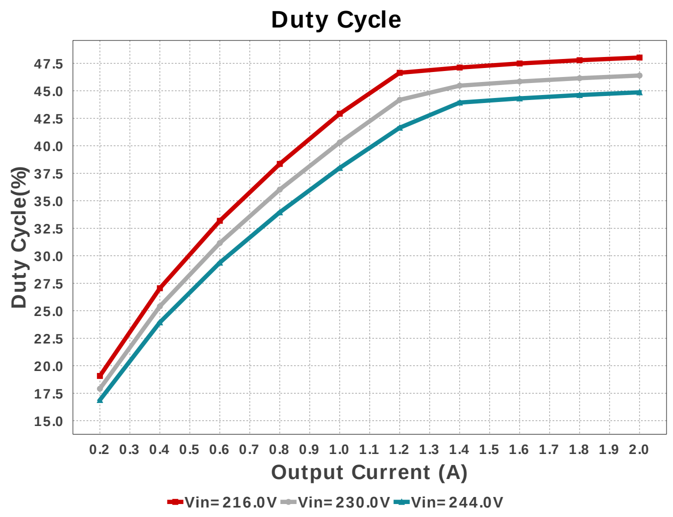
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Rsense	Vishay-Dale	CRCW12061R10FKEA Series= CRCW..e3	Res= 1.1 Ohm Power= 250.0 mW Tolerance= 1.0%	1	$0.01	1206 11 mm^2
Rsnub1	CUSTOM	CUSTOM Series= ?	Res= 425.66 kOhm Power= 0.0 W Tolerance= 0.0%	1	NA	CUSTOM 0 mm^2
Rsnub2	CUSTOM	CUSTOM Series= ?	Res= 425.66 kOhm Power= 0.0 W Tolerance= 0.0%	1	NA	CUSTOM 0 mm^2
Rvcc	Vishay-Dale	CRCW040276R8FKED Series= CRCW..e3	Res= 76.8 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rvin	CUSTOM	CUSTOM Series= ?	Res= 26.277 kOhm Power= 0.0 W Tolerance= 0.0%	1	NA	CUSTOM 0 mm^2
Rvsd	Vishay-Dale	CRCW08051M00FKEA Series= CRCW..e3	Res= 1000.0 kOhm Power= 125.0 mW Tolerance= 1.0%	1	$0.01	0805 7 mm^2
T1	Core=TDK , CoilFormer=TDK	Core=B66317G0000X187 , CoilFormer=B66208W1010T001	Lp= 4.814 mH Turns Ratio(Nas)= 6:7 Turns Ratio(Nps)= 171:7 Npri= 171.0 Naux= 6.0 Nsec= 7.0	1	$0.22	TDK_B66305 569 mm^2
U1	Texas Instruments	LM5023MM-2/NOPB	Switcher	1	$0.38	DGK0008A 24 mm^2
VR	Texas Instruments	TL431IDBVR	Voltage References	1	$0.06	R-PDSO-G3 16 mm^2

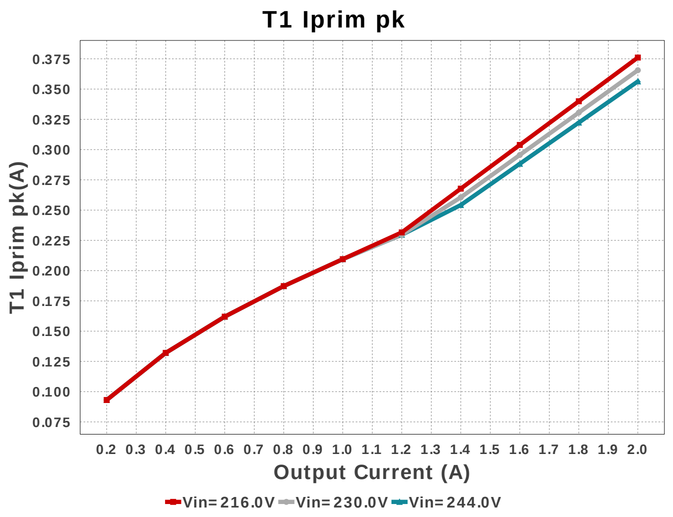
Snubber Pd

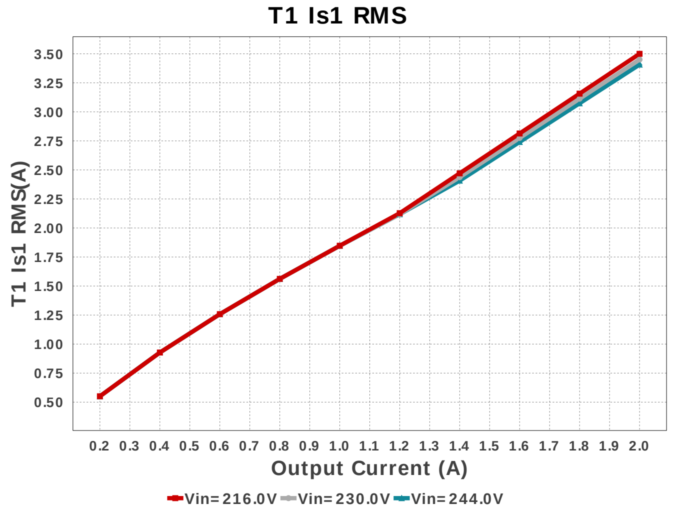


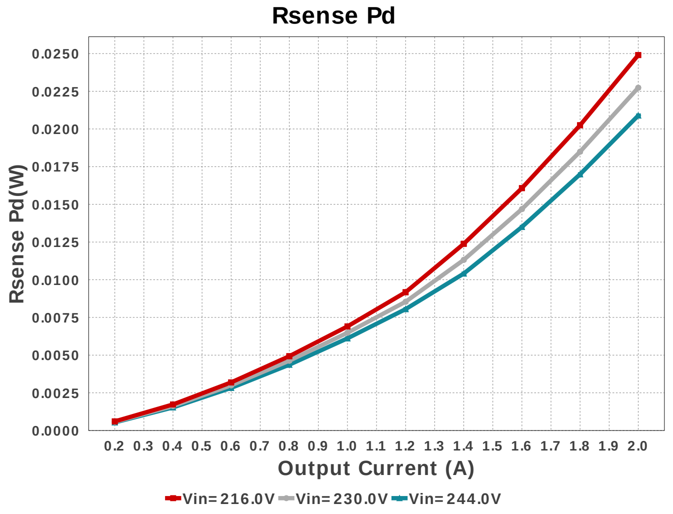
IC Tj

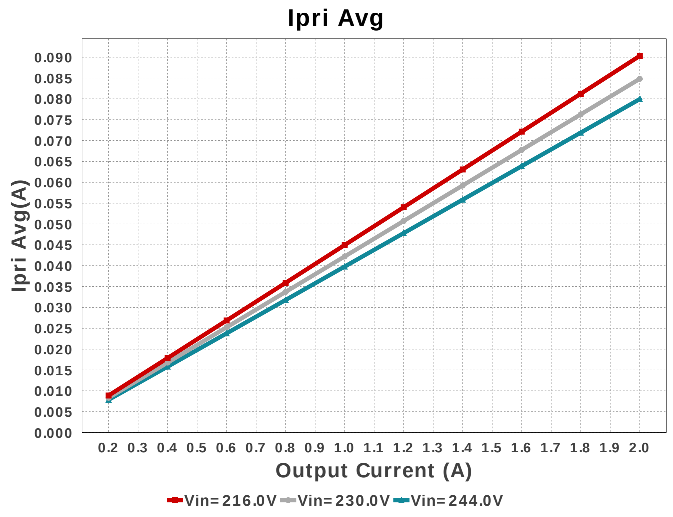


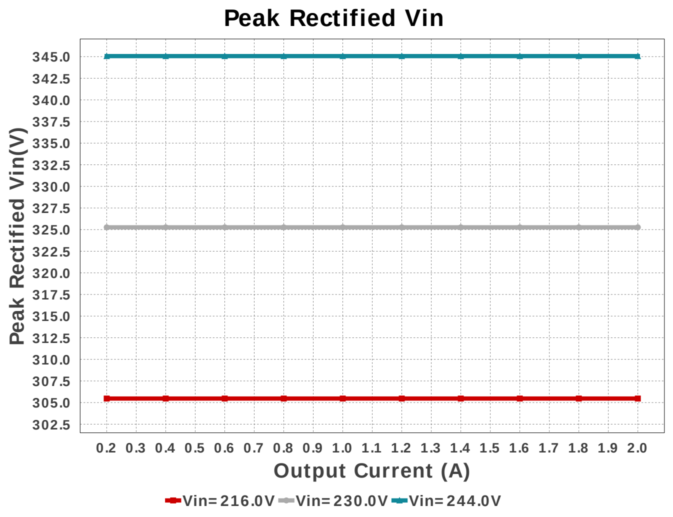

Duty Cycle
Duty Cycle(%)
Output Current (A)
Vin= 216.0V
Vin= 230.0V
Vin= 244.0V

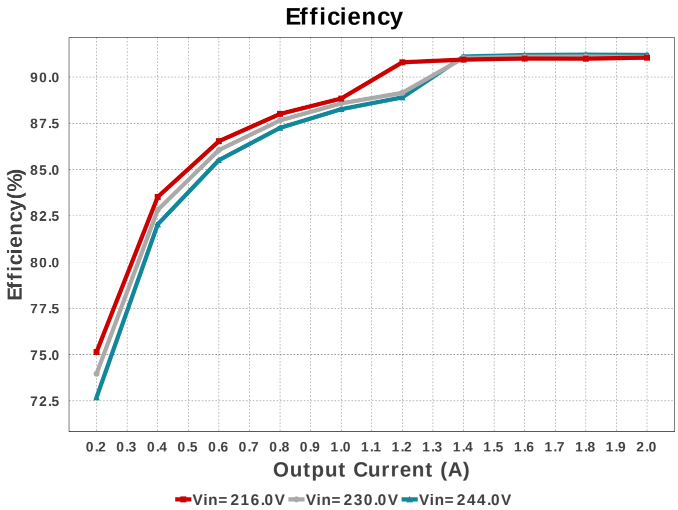

T1 Iprim pk
T1 Iprim pk(A)
Output Current (A)
Vin= 216.0V
Vin= 230.0V
Vin= 244.0V

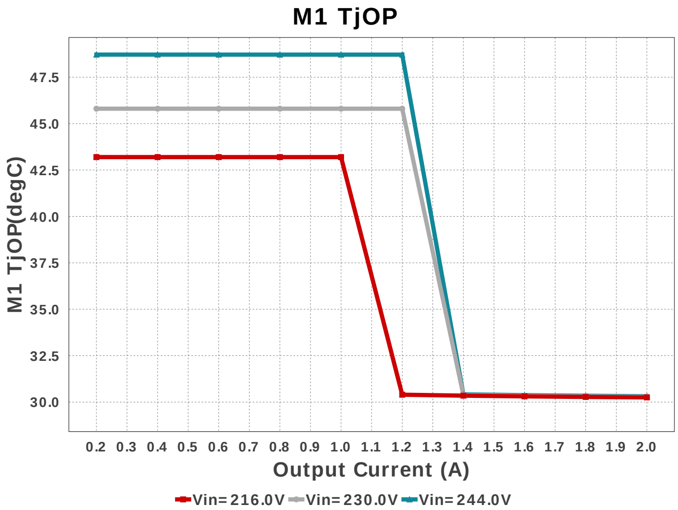

T1 Is1 RMS
T1 Is1 RMS(A)
Output Current (A)
Vin= 216.0V
Vin= 230.0V
Vin= 244.0V

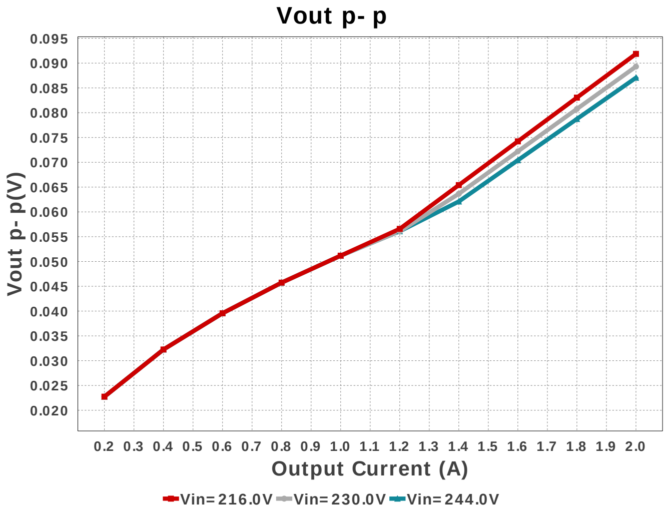

Rsense Pd
Rsense Pd(W)
Output Current (A)
Vin= 216.0V
Vin= 230.0V
Vin= 244.0V

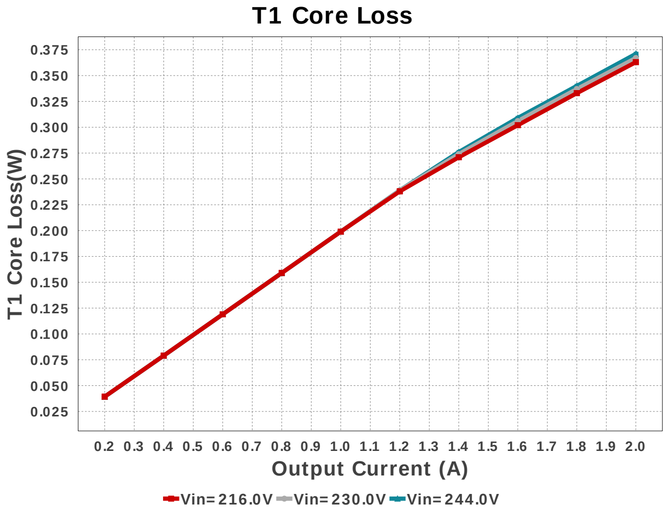

Ipri Avg
Ipri Avg(A)
Output Current (A)
Vin= 216.0V
Vin= 230.0V
Vin= 244.0V

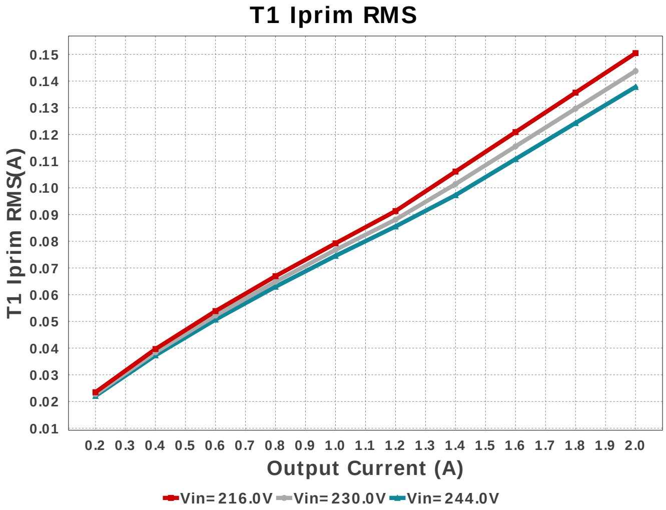

Peak Rectified Vin
Peak Rectified Vin(V)
Output Current (A)
Vin= 216.0V
Vin= 230.0V
Vin= 244.0V

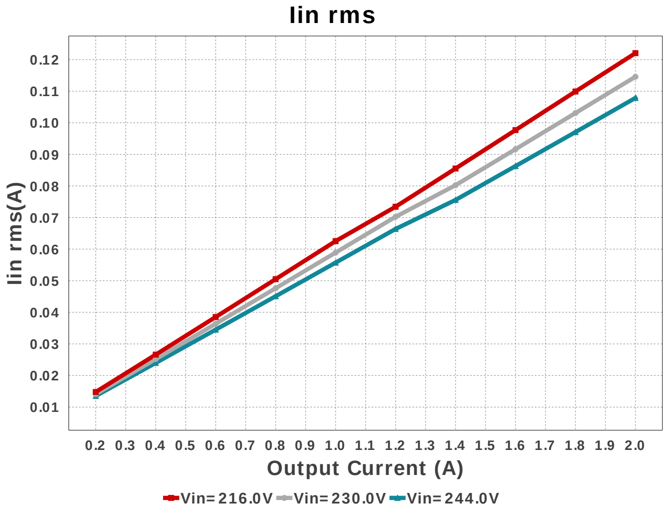

Efficiency
Efficiency(%)
Output Current (A)
Vin= 216.0V Vin= 230.0V Vin= 244.0V

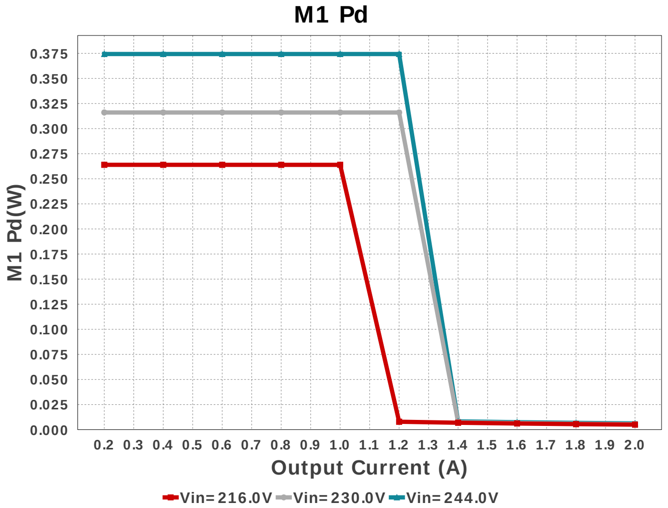

M1 TjOP
M1 TjOP(degC)
Output Current (A)
Vin= 216.0V Vin= 230.0V Vin= 244.0V

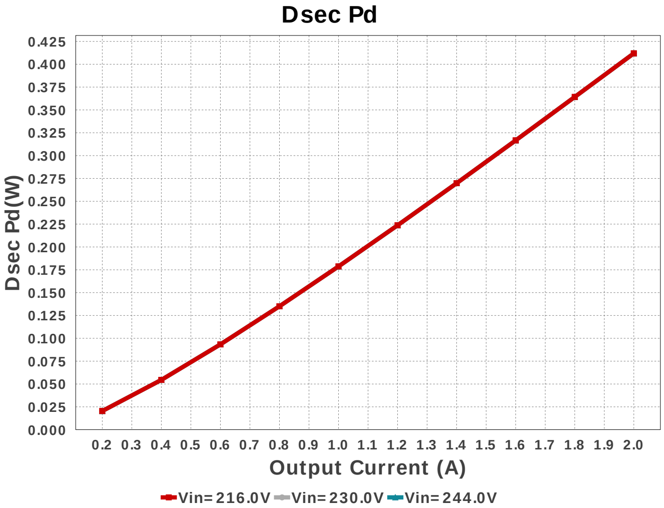

Vout p- p
Vout p- p(V)
Output Current (A)
Vin= 216.0V Vin= 230.0V Vin= 244.0V

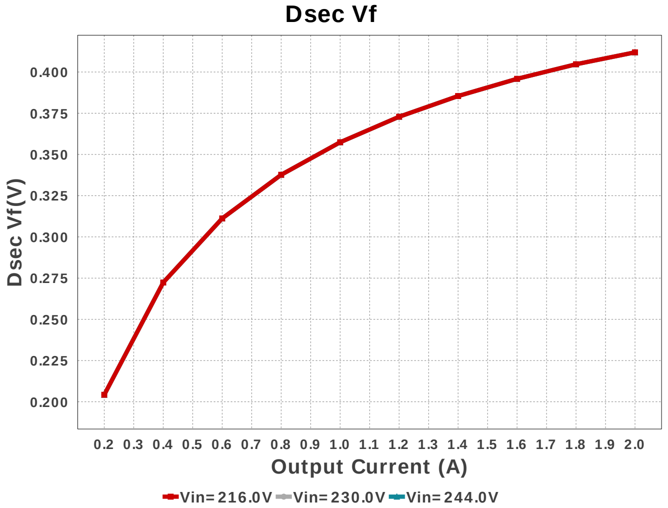

T1 Core Loss
T1 Core Loss(W)
Output Current (A)
Vin= 216.0V Vin= 230.0V Vin= 244.0V

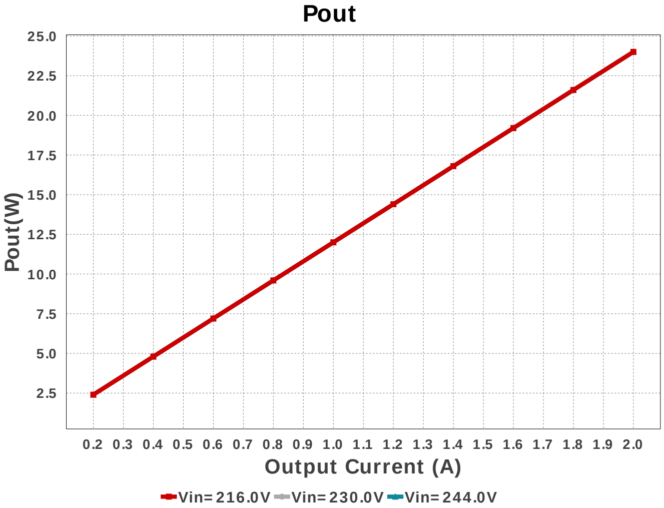

T1 Iprim RMS
T1 Iprim RMS(A)
Output Current (A)
Vin= 216.0V Vin= 230.0V Vin= 244.0V

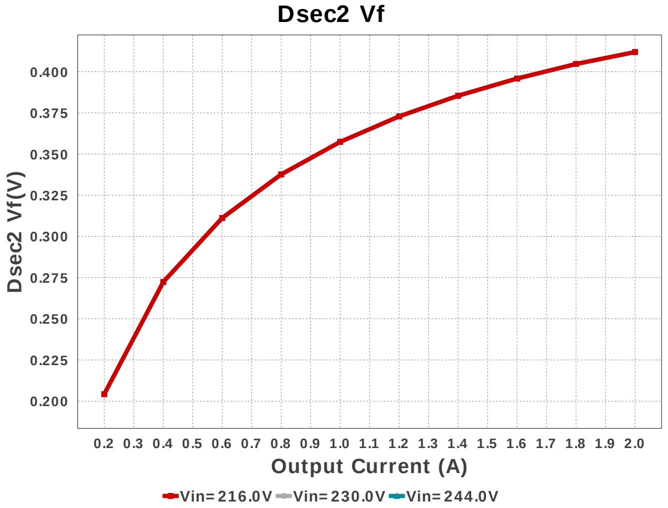

Iin rms
Iin rms(A)
Output Current (A)
Vin= 216.0V Vin= 230.0V Vin= 244.0V

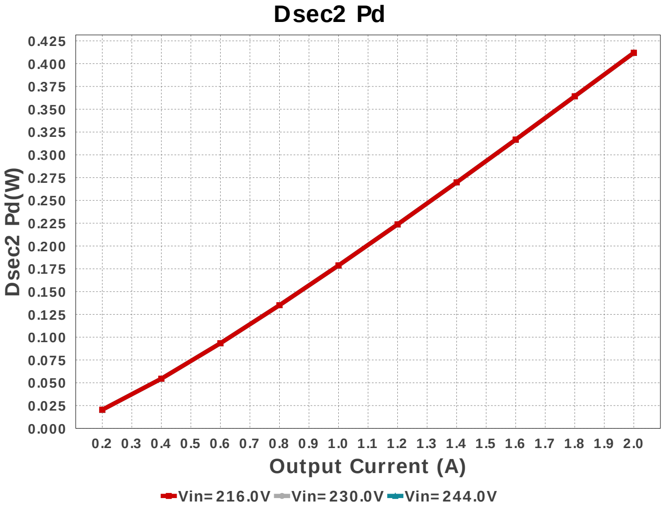

M1 Pd
M1 Pd(W)
Output Current (A)
Vin=216.0V Vin=230.0V Vin=244.0V

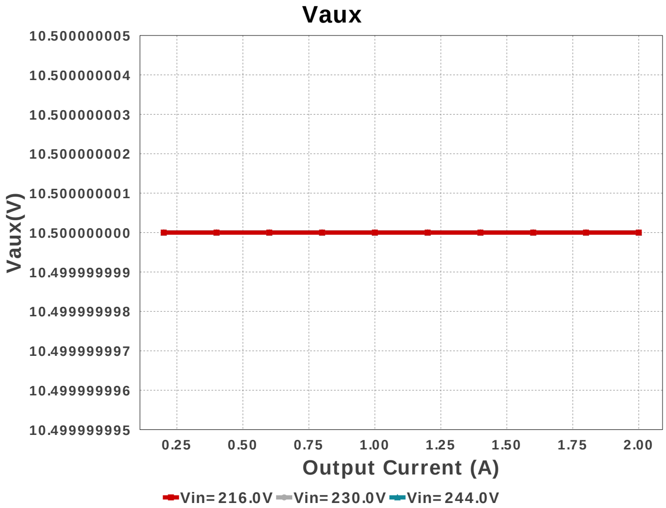

Dsec Pd
Dsec Pd(W)
Output Current (A)
Vin=216.0V Vin=230.0V Vin=244.0V

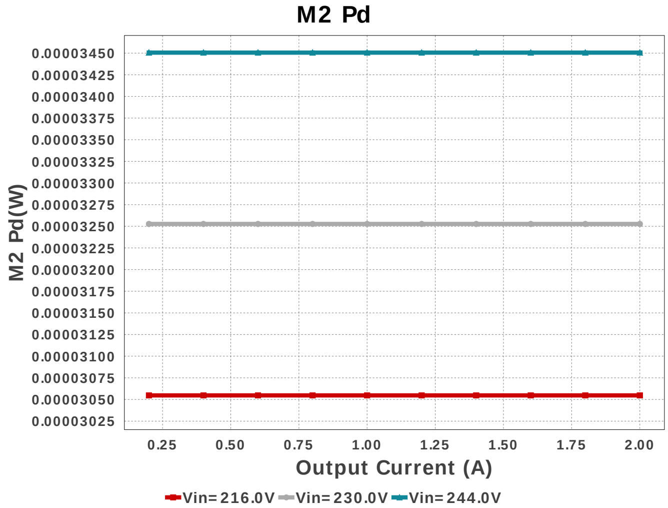

Dsec Vf
Dsec Vf(V)
Output Current (A)
Vin=216.0V Vin=230.0V Vin=244.0V

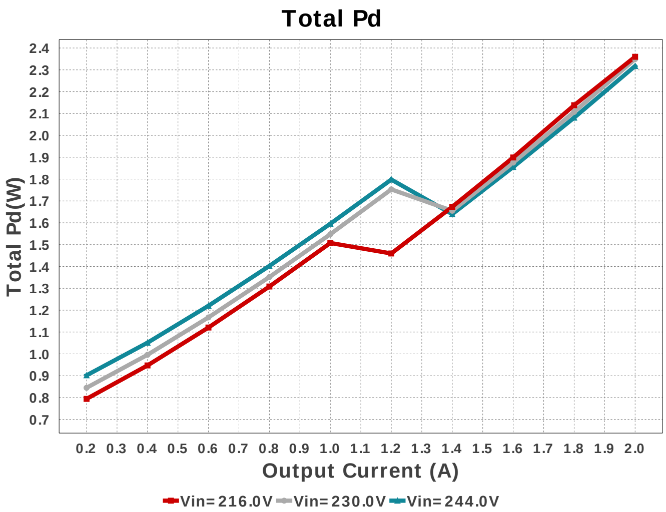

Pout
Pout(W)
Output Current (A)
Vin=216.0V Vin=230.0V Vin=244.0V

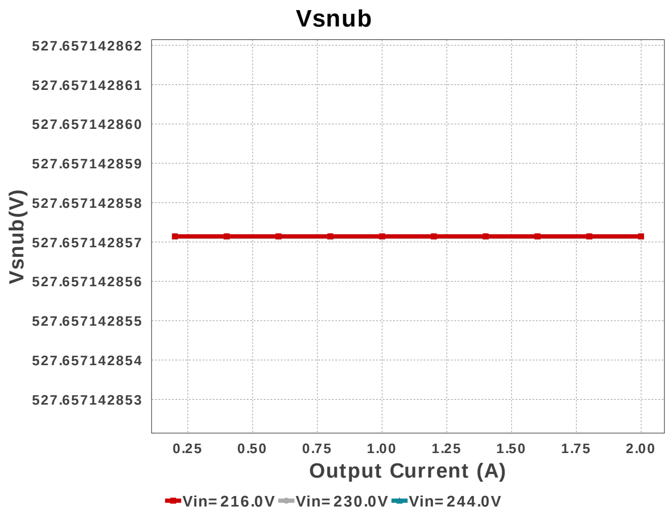

Dsec2 Vf
Dsec2 Vf(V)
Output Current (A)
Vin=216.0V Vin=230.0V Vin=244.0V

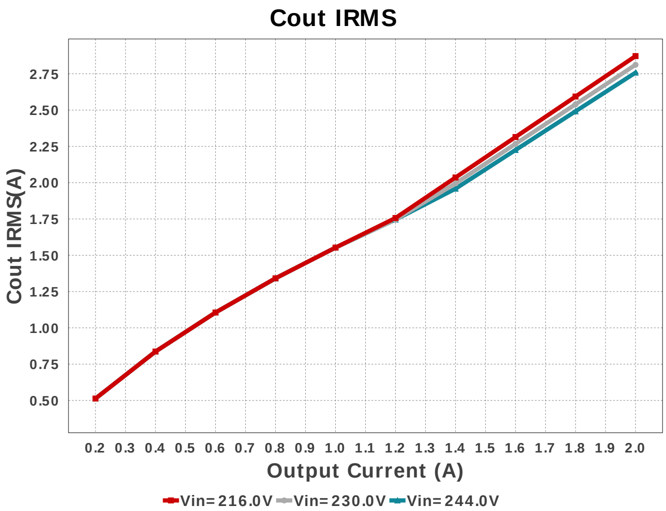

Dsec2 Pd
Dsec2 Pd(W)
Output Current (A)
Vin=216.0V Vin=230.0V Vin=244.0V

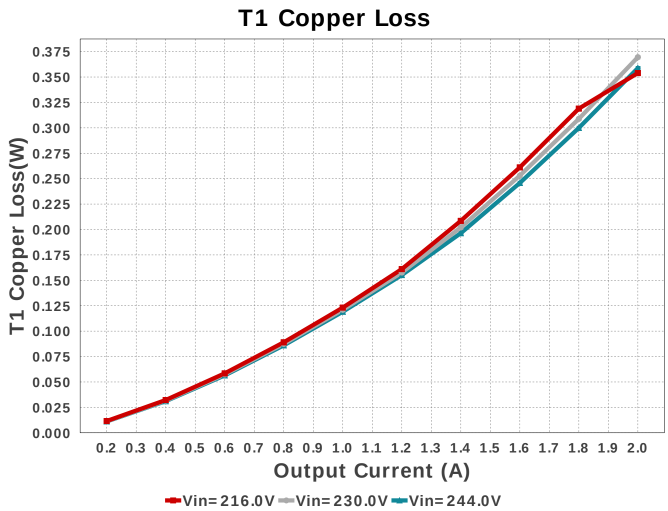

Vaux
Vaux(V)
10.500000005
10.500000004
10.500000003
10.500000002
10.500000001
10.500000000
10.499999999
10.499999998
10.499999997
10.499999996
10.499999995
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Output Current (A)
Vin=216.0V Vin=230.0V Vin=244.0V

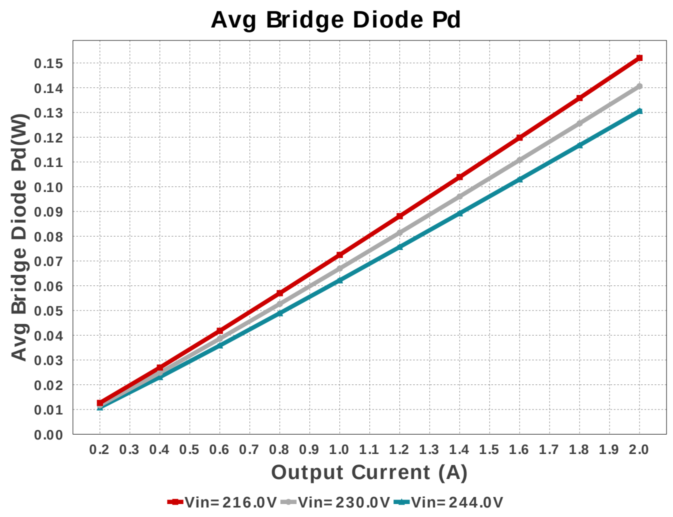

M2 Pd
M2 Pd(W)
0.00003450
0.00003425
0.00003400
0.00003375
0.00003350
0.00003325
0.00003300
0.00003275
0.00003250
0.00003225
0.00003200
0.00003175
0.00003150
0.00003125
0.00003100
0.00003075
0.00003050
0.00003025
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Output Current (A)
Vin=216.0V Vin=230.0V Vin=244.0V

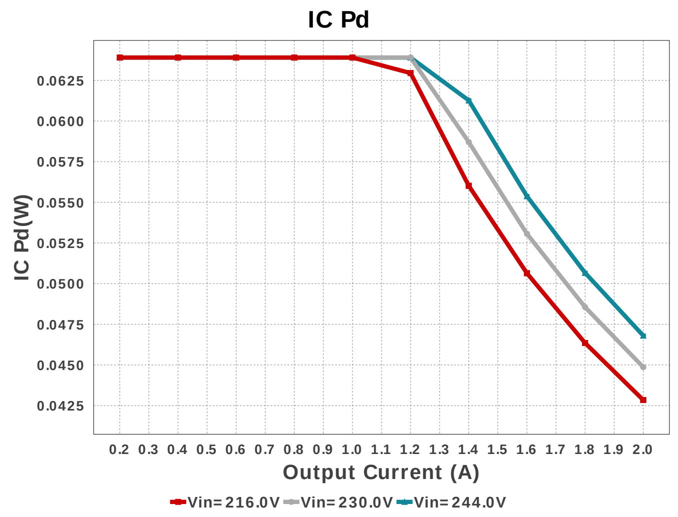

Total Pd
Total Pd(W)
2.4 2.3 2.2 2.1 2.0 1.9 1.8 1.7 1.6 1.5 1.4 1.3 1.2 1.1 1.0 0.9 0.8 0.7
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Output Current (A)
Vin=216.0V Vin=230.0V Vin=244.0V

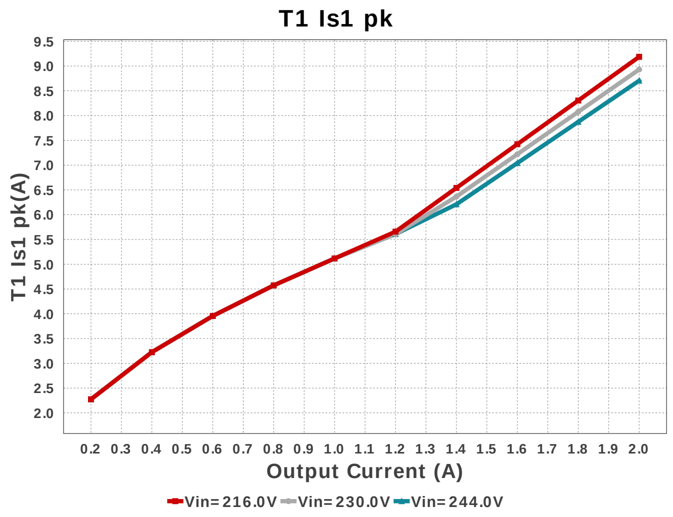

Vsnub
Vsnub(V)
527.657142862
527.657142861
527.657142860
527.657142859
527.657142858
527.657142857
527.657142856
527.657142855
527.657142854
527.657142853
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Output Current (A)
Vin=216.0V Vin=230.0V Vin=244.0V

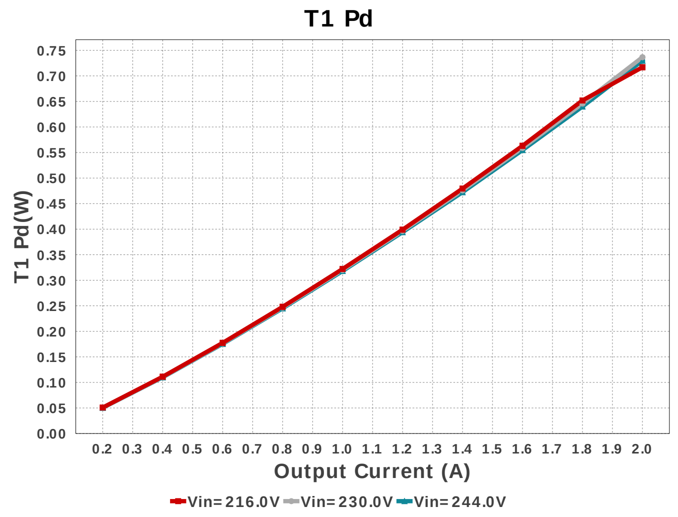

Cout IRMS
Cout IRMS(A)
2.75 2.50 2.25 2.00 1.75 1.50 1.25 1.00 0.75 0.50
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Output Current (A)
Vin=216.0V Vin=230.0V Vin=244.0V

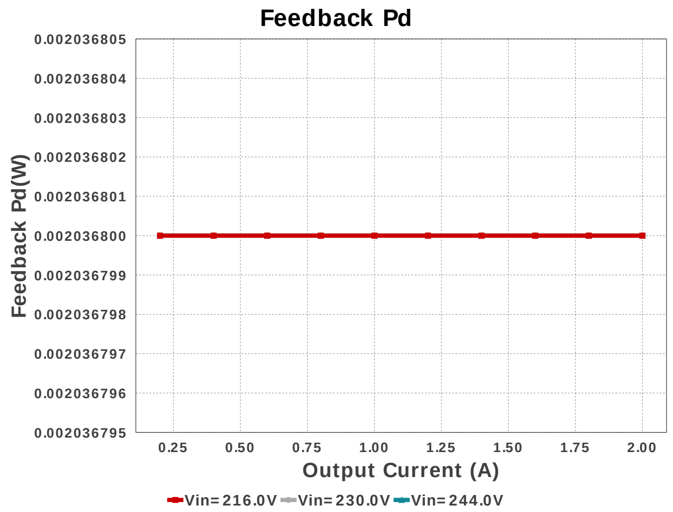

T1 Copper Loss
T1 Copper Loss(W)
0.375 0.350 0.325 0.300 0.275 0.250 0.225 0.200 0.175 0.150 0.125 0.100 0.075 0.050 0.025 0.000
0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0
Output Current (A)
Vin=216.0V Vin=230.0V Vin=244.0V











Operating Values

#	Name	Value	Category	Description
1.	Cout IRMS	2.872 A	Capacitor	Output capacitor RMS ripple current
2.	Avg Bridge Diode Pd	152.04 mW	Diode	Average Power Dissipation in the Bridge Diode over the AC Line Period
3.	Daux trr	8.26 ns	Diode	Auxiliary Diode Reverse Recovery Time
4.	Dsec Pd	411.93 mW	Diode	Secondary Diode Power Dissipation
5.	Dsec Vf	411.934 mV	Diode	Effective Forward Voltage Drop at the Operating Current
6.	Dsec trr	0.0 ns	Diode	Output Diode Reverse Recovery Time
7.	Dsec2 Pd	411.93 mW	Diode	Secondary Diode Power Dissipation
8.	Dsec2 Vf	411.934 mV	Diode	Effective Forward Voltage Drop at the Operating Current
9.	Dsnub trr	0.0 ns	Diode	Snubber Diode Reverse Recovery Time
10.	IC Pd	42.845 mW	IC	IC power dissipation
11.	IC Tj	38.569 degC	IC	IC junction temperature

#	Name	Value	Category	Description
12.	ICThetaJA	200.0 degC/W	IC	IC junction-to-ambient thermal resistance
13.	M1 Pd	13.973 mW	Mosfet	M1 MOSFET total power dissipation
14.	M1 TjOP	30.73 degC	Mosfet	M1 MOSFET junction temperature
15.	M2 Pd	30.547 µW	Mosfet	M2 MOSFET total power dissipation
16.	Avg Bridge Diode Pd	152.04 mW	Power	Average Power Dissipation in the Bridge Diode over the AC Line Period
17.	Dsec Pd	411.93 mW	Power	Secondary Diode Power Dissipation
18.	Dsec2 Pd	411.93 mW	Power	Secondary Diode Power Dissipation
19.	Feedback Pd	2.037 mW	Power	Power Dissipation in Feedback Resistors
20.	IC Pd	42.845 mW	Power	IC power dissipation
21.	M1 Pd	13.973 mW	Power	M1 MOSFET total power dissipation
22.	M2 Pd	30.547 µW	Power	M2 MOSFET total power dissipation
23.	Rsense Pd	24.9 mW	Power	LED Current Rsns Power Dissipation
24.	Snubber Pd	328.221 mW	Power	Snubber Power Dissipation
25.	T1 Copper Loss	345.86 mW	Power	Transformer Copper Loss Power Dissipation
26.	T1 Core Loss	345.86 mW	Power	Transformer Core Loss Power Dissipation
27.	T1 Pd	691.72 mW	Power	Estimated Losses in Transformer
28.	Total Pd	2.344 W	Power	Total Power Dissipation
29.	Feedback Pd	2.037 mW	Resistor	Power Dissipation in Feedback Resistors
30.	Rsense Pd	24.9 mW	Resistor	LED Current Rsns Power Dissipation
31.	BOM Count	37	System Information	Total Design BOM count
32.	Duty Cycle	48.023 %	System Information	Duty cycle
33.	Efficiency	91.101 %	System Information	Steady state efficiency
34.	FootPrint	1.502 k mm^2	System Information	Total Foot Print Area of BOM components
35.	Frequency	81.035 kHz	System Information	Switching frequency
36.	Iin rms	121.97 mA	System Information	RMS Input Current
37.	Iout	2.0 A	System Information	Iout operating point
38.	Mode	TM	System Information	Conduction Mode
39.	Peak Rectified Vin	305.467 V	System Information	Peak voltage seen at rectified input
40.	Pout	24.0 W	System Information	Total output power
41.	Total BOM	NA	System Information	Total BOM Cost
42.	Vin_RMS	216.0 V	System Information	Vin operating point
43.	Vout	12.0 V	System Information	Operational Output Voltage
44.	Vout Actual	12.0 V	System Information	Vout Actual calculated based on selected voltage divider resistors
45.	Vout Tolerance	1.525 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
46.	Vout p-p	91.862 mV	System Information	Peak-to-peak output ripple voltage
47.	Vsnub	527.657 V	System Information	Voltage Across the Snubber
48.	Ipri Avg	90.295 mA	Transformer	Average Current in Primary Winding over the complete Switching Period
49.	T1 Copper Loss	345.86 mW	Transformer	Transformer Copper Loss Power Dissipation
50.	T1 Core Loss	345.86 mW	Transformer	Transformer Core Loss Power Dissipation
51.	T1 Iprim RMS	150.455 mA	Transformer	Transformer Primary RMS Current
52.	T1 Iprim pk	376.045 mA	Transformer	Transformer Primary Peak Current
53.	T1 Is1 RMS	3.5 A	Transformer	Transformer Secondary1 RMS Current
54.	T1 Is1 pk	9.186 A	Transformer	Transformer Secondary1 Peak Current
55.	T1 Pd	691.72 mW	Transformer	Estimated Losses in Transformer
56.	Vaux	10.5 V	Transformer	Auxiliary Voltage

Design Inputs

Name	Value	Description
Iout	2.0	Maximum Output Current
VinMax	244.0	Maximum input voltage
VinMin	216.0	Minimum input voltage
Vout	12.0	Output Voltage
acFrequency	50.0	AC Frequency
base_pn	LM5023	Base Product Number
source	AC	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

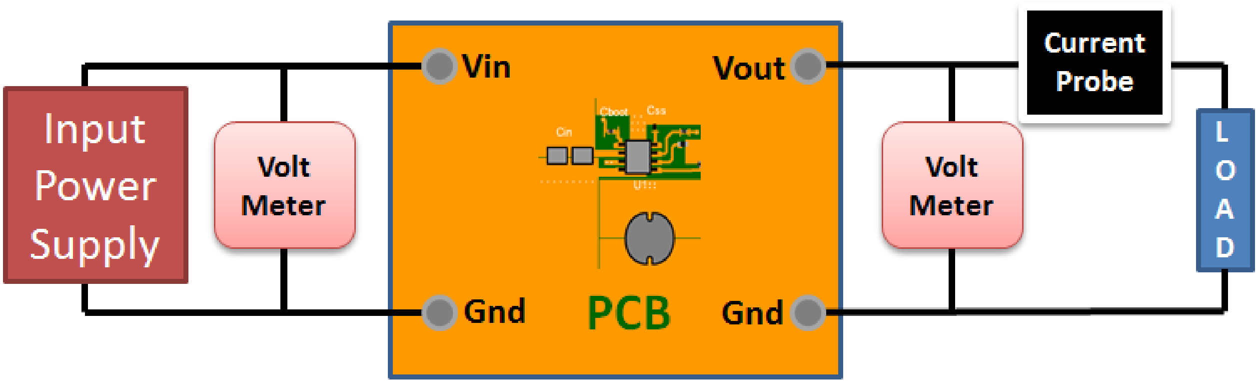
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. 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 216.0V 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.



WEBENCH® Transformer Report

#	Name	Value
1.	Core Part Number	B66317G0000X187
2.	Core Manufacturer	TDK
3.	Coil Former Part Number	B66208W1010T001
4.	Coil Former Manufacturer	TDK

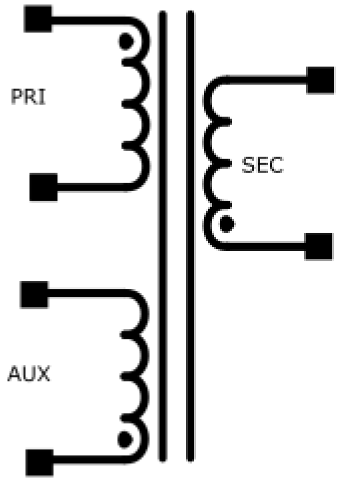
Transformer Electrical Diagram

Primary

Turns	171.0
AWG	32.0
Layers	3.0
Strands	1.0
Insulation Type	Heavy Insulated Magnet Wire

Auxiliary

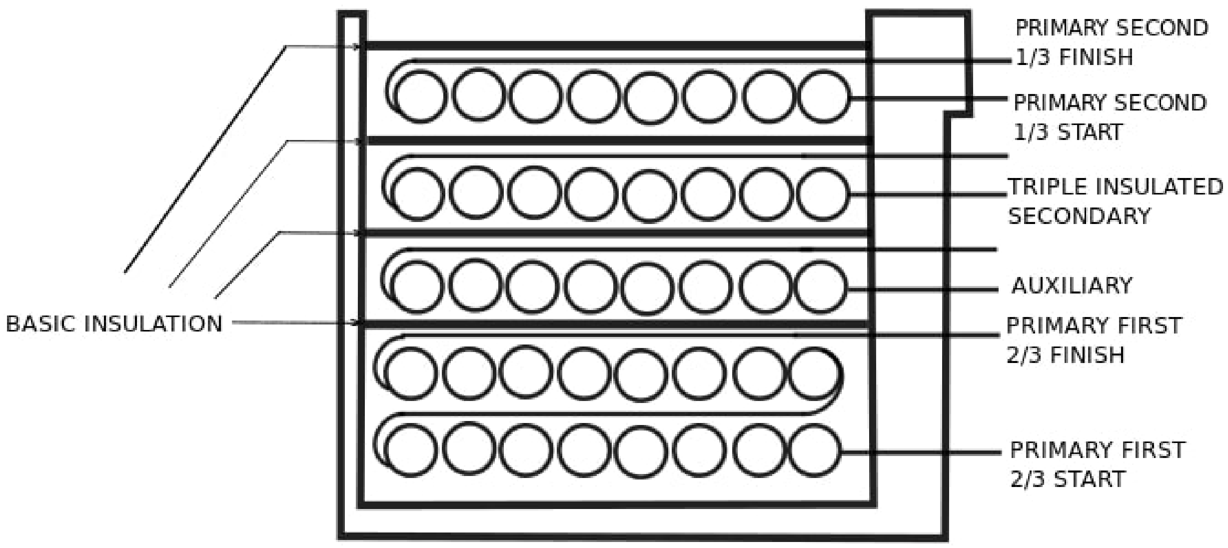
Turns	6.0
AWG	28.0
Layers	1.0
Strands	4.0
Insulation Type	Heavy Insulated Magnet Wire



Secondary

Turns	7.0
AWG	27.0
Layers	1.0
Strands	3.0
Insulation Type	Triple Insulated

Transformer Construction Diagram



Winding Instruction

Winding	AWG	Turns	Winding Orientation
Primary First 2/3.0	32.0	114	Clockwise
Auxiliary	28.0	6.0	Counter Clockwise
Triple Insulated Secondary	27.0	7.0	Counter Clockwise
Primary Second 1/3.0	32.0	57	Clockwise

Transformer Parameters

#	Name	Value
1.	Lpri	0.00481H
2.	Inductance Factor(Al)	165.0nH
3.	Npri	171.0
4.	Nsec	7.0
5.	Naux	6.0
6.	Core Type	E25/13/7
7.	Core Material	N87
8.	Bmax	0.20T
9.	Switching Frequency	80.00kHz
10.	DMax	0.45
11.	Ipk(Primary)	0.37A
12.	Irms(Primary)	0.14A
13.	Ipk(Secondary)	9.09A
14.	Irms(Secondary)	3.47A

Design Assistance

1. Master key : 84E05F9E8AACC473[v1]
2. **LM5023** Product Folder : http://www.ti.com/product/LM5023 : contains the data sheet and other resources.