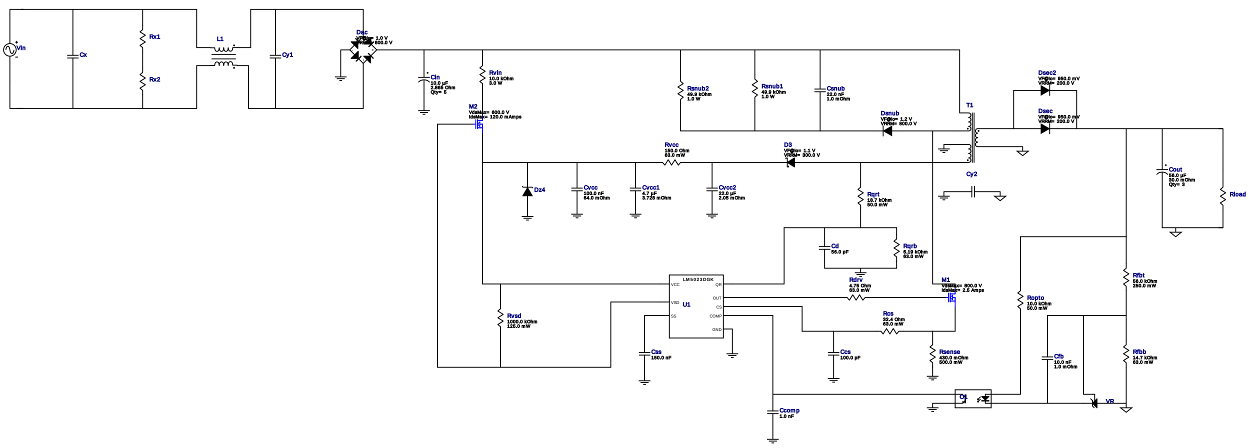
VinMin = 85.0V VinMax = 265.0V Vout = 12.0V Iout = 2.0A	Device = LM5023MMX-2/NOPB Topology = Flyback Created = 2023-09-12 13:31:03.103 BOM Cost = $9.03 BOM Count = 42 Total Pd = 4.78W

WEBENCH ® Design Report

Design : 1 LM5023MMX-2/NOPB
LM5023MMX-2/NOPB 85V-265V 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

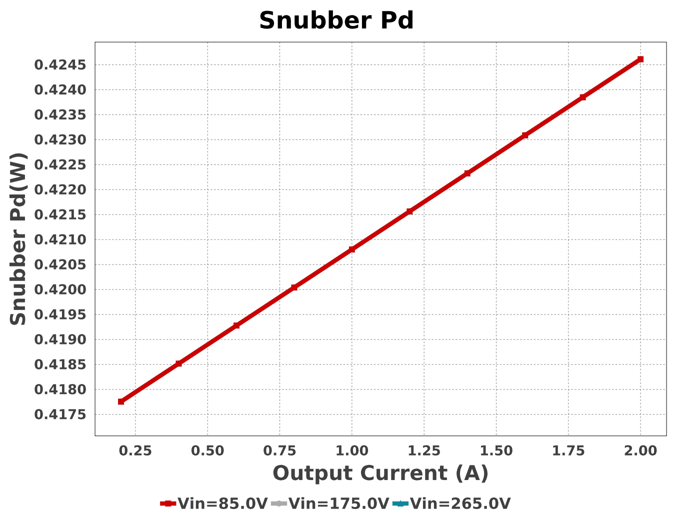
Click on the transformer symbol in the schematic and select "Explore Transformer Core/Bobbin Selection" to design using specific transformer cores and bobbin.

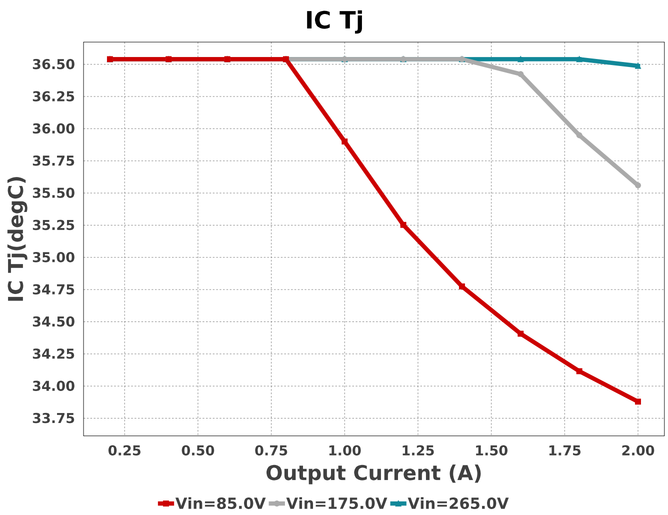
Electrical BOM

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	Samsung Electro-Mechanics	CL02C560JQ2ANNC Series= C0G/NP0	Cap= 56.0 pF VDC= 6.3 V IRMS= 0.0 A	1	$0.01	01005 2 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	Panasonic	EEUED2G100 Series= ED	Cap= 10.0 uF ESR= 2.8648 Ohm VDC= 400.0 V IRMS= 300.0 mA	5	$0.31	CAPPR5-10X20 144 mm^2
Cout	Panasonic	25SVPF56M Series= SVPF	Cap= 56.0 uF ESR= 30.0 mOhm VDC= 25.0 V IRMS= 2.8 A	3	$0.57	CAPSMT_62_F61 74 mm^2
Csnub	MuRata	GRM32QR72J223KW01L Series= X7R	Cap= 22.0 nF ESR= 1.0 mOhm VDC= 630.0 V IRMS= 0.0 A	1	$0.29	1210 15 mm^2
Css	Panasonic	ECPU1C154MA5 Series= ECPU(A)	Cap= 150.0 nF VDC= 16.0 V IRMS= 0.0 A	1	$0.23	1206 11 mm^2

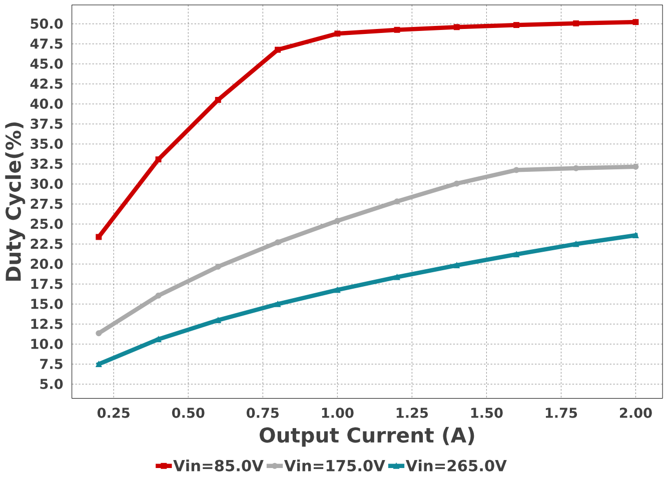
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cvcc	Kemet	C0805C104M5RACTU Series= X7R	Cap= 100.0 nF ESR= 64.0 mOhm VDC= 50.0 V IRMS= 1.64 A	1	$0.01	0805 7 mm²
Cvcc1	TDK	C1608X5R1V475K080AC Series= X5R	Cap= 4.7 uF ESR= 3.728 mOhm VDC= 35.0 V IRMS= 2.69359 A	1	$0.10	0603 5 mm²
Cvcc2	TDK	C2012X5R1V226M125AC Series= X5R	Cap= 22.0 uF ESR= 2.05 mOhm VDC= 35.0 V IRMS= 4.5559 A	1	$0.31	0805 7 mm²
D3	SMC Diode Solutions	ST1300ATR	VF@Io= 1.1 V VRRM= 300.0 V	1	$0.12	SMA 37 mm²
Dac	Diodes Inc.	HD06-T	VF@Io= 1.0 V VRRM= 600.0 V	1	$0.15	MiniDIP 62 mm²
Dsec	SMC Diode Solutions	SBRD10200TR	VF@Io= 950.0 mV VRRM= 200.0 V	1	$0.18	DPAK 102 mm²
Dsec2	SMC Diode Solutions	SBRD10200TR	VF@Io= 950.0 mV VRRM= 200.0 V	1	$0.18	DPAK 102 mm²
Dsnub	Microsemi	UFS180JE3/TR13	VF@Io= 1.2 V VRRM= 800.0 V	1	$0.95	DO-214BA 42 mm²
Dz4	ON Semiconductor	MMBZ5244BLT1G	Zener	1	$0.03	SOT-23 14 mm²
M1	STMicroelectronics	STD3NK80Z-1	VdsMax= 800.0 V IdsMax= 2.5 Amps	1	$1.11	IPAK 37 mm²
M2	Infineon Technologies	BSP135H6327XTSA1	VdsMax= 600.0 V IdsMax= 120.0 mAmps	1	$0.79	SOT-223 76 mm²
O1	Fairchild Semiconductor	FOD817A	Optocoupler	1	$0.11	DIP-4 71 mm²
Rcs	Vishay-Dale	CRCW040232R4FKED Series= CRCW..e3	Res= 32.4 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm²
Rdrv	Vishay-Dale	CRCW04024R75FKED Series= CRCW..e3	Res= 4.75 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm²
Rfbb	Vishay-Dale	CRCW040214K7FKED Series= CRCW..e3	Res= 14.7 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm²
Rfbt	Yageo	RC1206FR-0756KL Series= ?	Res= 56.0 kOhm Power= 250.0 mW Tolerance= 1.0%	1	$0.01	1206 11 mm²
Ropto	Yageo	RC0201FR-0710KL Series= ?	Res= 10.0 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm²
Rqrb	Vishay-Dale	CRCW04026K19FKED Series= CRCW..e3	Res= 6.19 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm²

Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Rqrt	Yageo	RC0201FR-0718K7L Series= ?	Res= 18.7 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm²
Rsense	Rohm	MCR25JZHFLR430 Series= MCR25	Res= 430.0 mOhm Power= 500.0 mW Tolerance= 1.0%	1	$0.03	1210 15 mm²
Rsnub1	Vishay-Dale	CRCW251249K9FKEG Series= CRCW..e3	Res= 49.9 kOhm Power= 1.0 W Tolerance= 1.0%	1	$0.05	2512 43 mm²
Rsnub2	Vishay-Dale	CRCW251249K9FKEG Series= CRCW..e3	Res= 49.9 kOhm Power= 1.0 W Tolerance= 1.0%	1	$0.05	2512 43 mm²
Rvcc	Vishay-Dale	CRCW0402150RFKED Series= CRCW..e3	Res= 150.0 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm²
Rvin	Vishay-Bccomponents	PR03000201002JAC00 Series= ?	Res= 10.0 kOhm Power= 3.0 W Tolerance= 5.0%	1	$0.18	PR03 197 mm²
Rvsd	Vishay-Dale	CRCW08051M00FKEA Series= CRCW..e3	Res= 1000.0 kOhm Power= 125.0 mW Tolerance= 1.0%	1	$0.01	0805 7 mm²
T1	Core=TDK , CoilFormer=TDK	Core=B66317G0000X187 , CoilFormer=B66208X1110T001	Lp= 1.056 mH Turns Ratio(Nas)= 8:9 Turns Ratio(Nps)= 85:9 Npri= 85.0 Naux= 8.0 Nsec= 9.0	1	$0.30	TDK_B66305 569 mm²
U1	Texas Instruments	LM5023MMX-2/NOPB	Switcher	1	$0.42	DGK0008A 24 mm²
VR	Texas Instruments	TL431IDBVR	Voltage References	1	$0.05	R-PDSO-G3 16 mm²

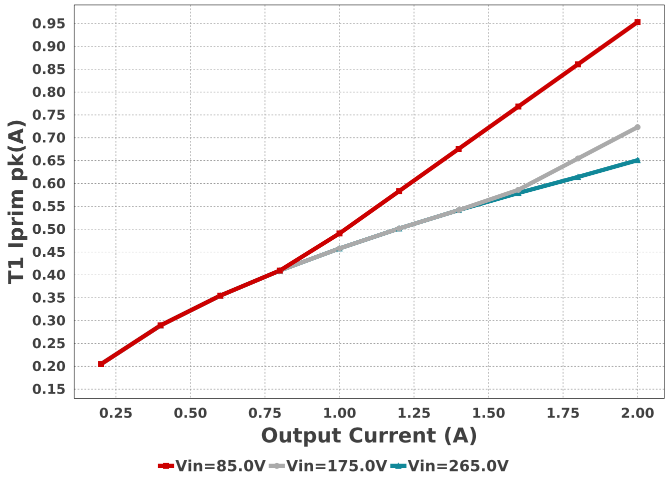




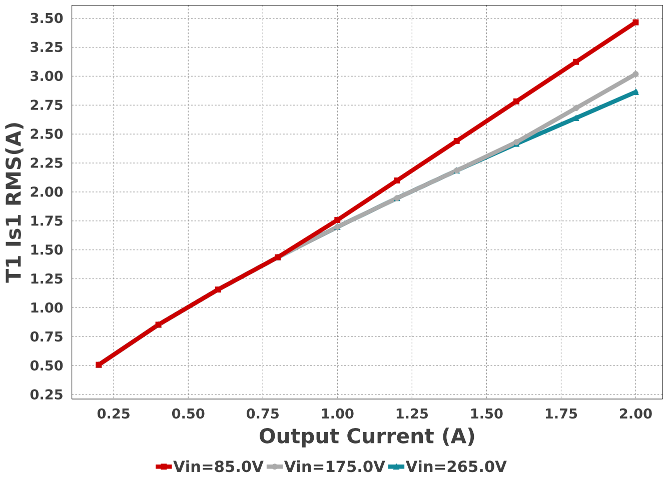
Duty Cycle



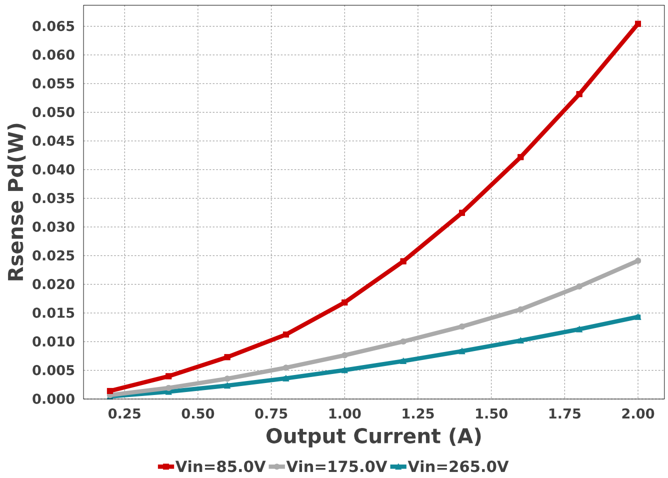
T1 Iprim pk



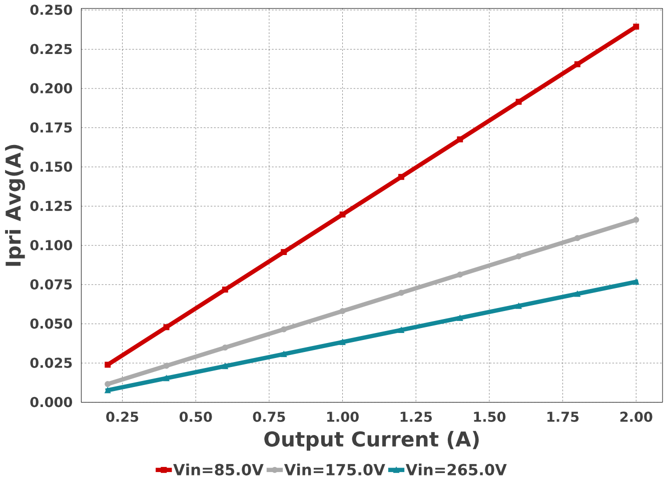
T1 Is1 RMS



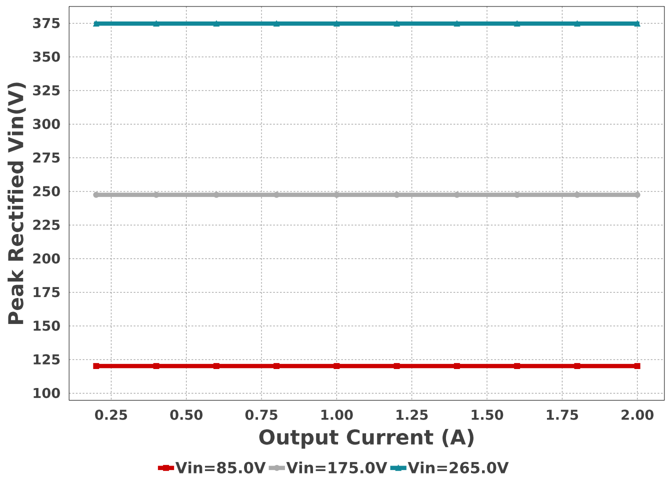
Rsense Pd

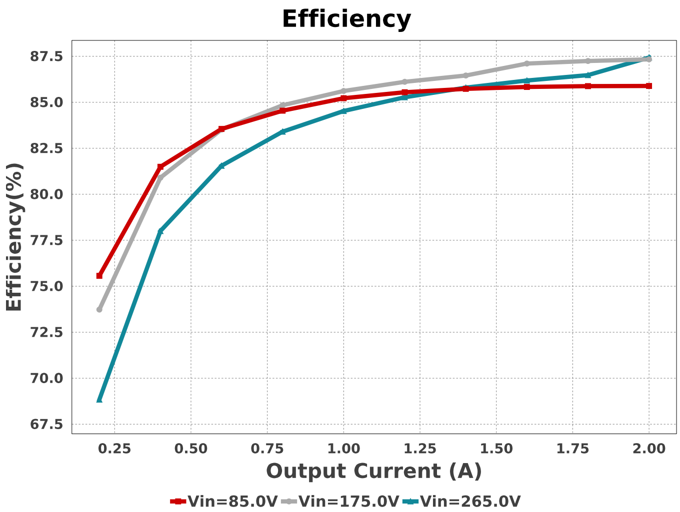


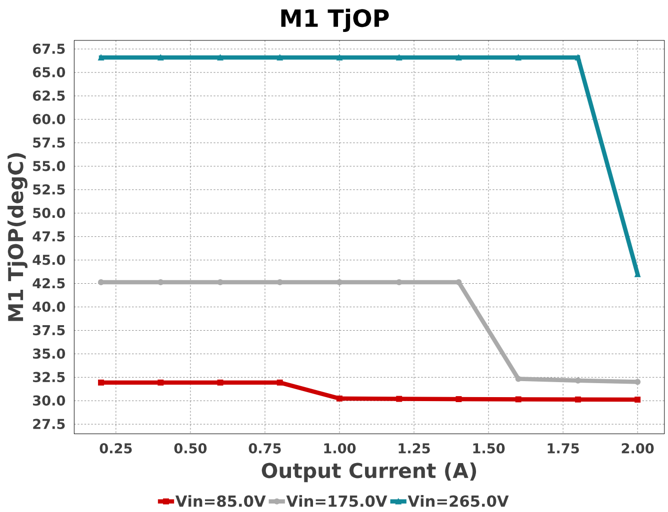
Ipri Avg

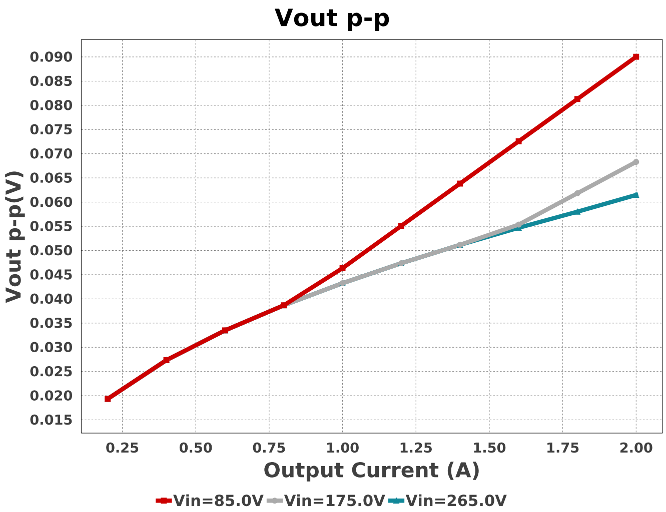


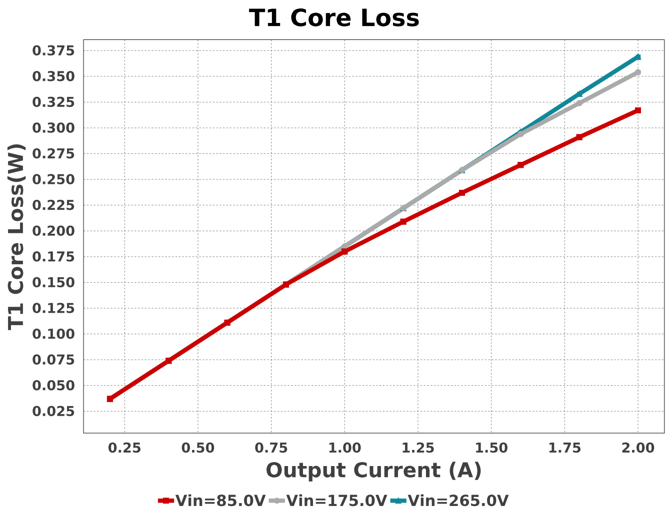
Peak Rectified Vin

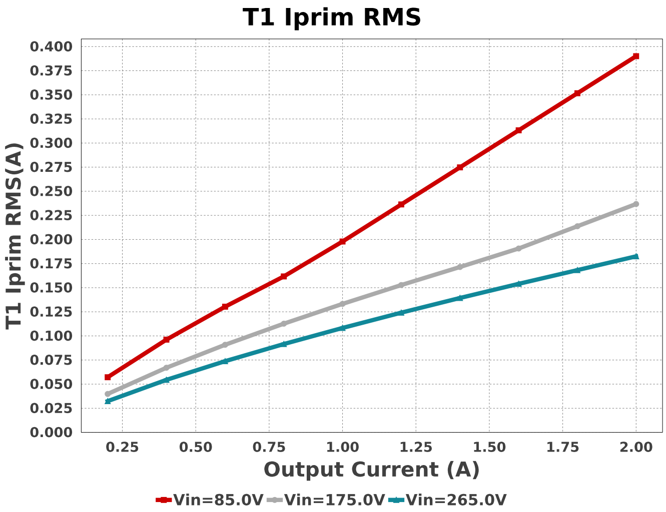


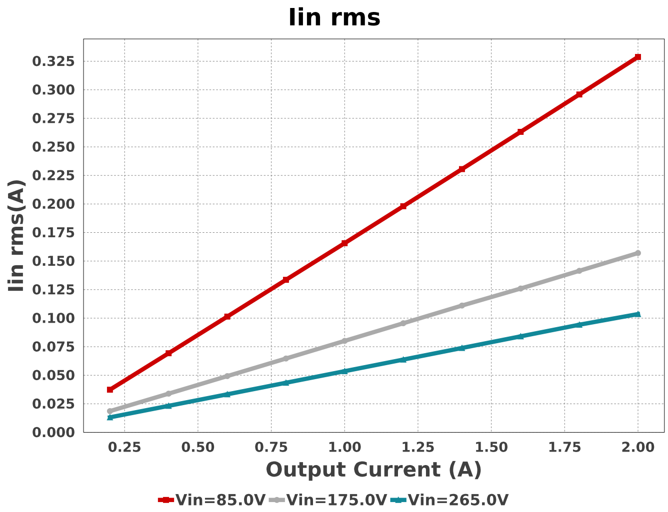

Efficiency
Efficiency(%)
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V


M1 TjOP
M1 TjOP(degC)
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

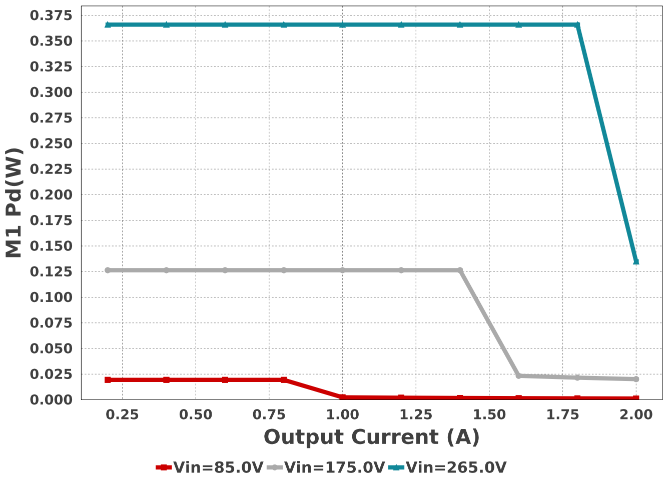

Vout p-p
Vout p-p(V)
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V


T1 Core Loss
T1 Core Loss(W)
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

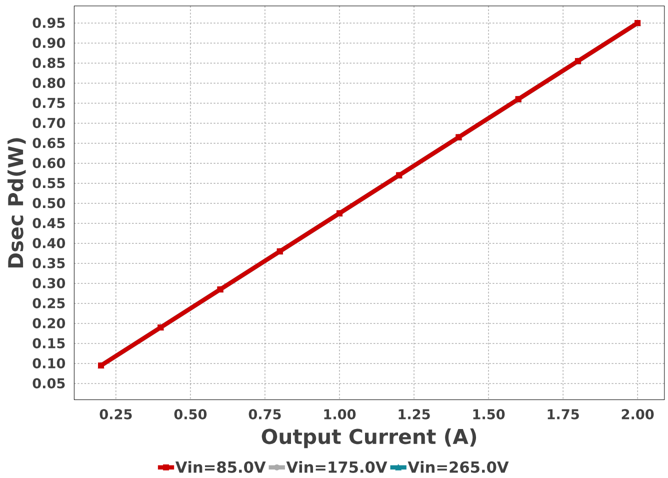

T1 Iprim RMS
T1 Iprim RMS(A)
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V


Iin rms
Iin rms(A)
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

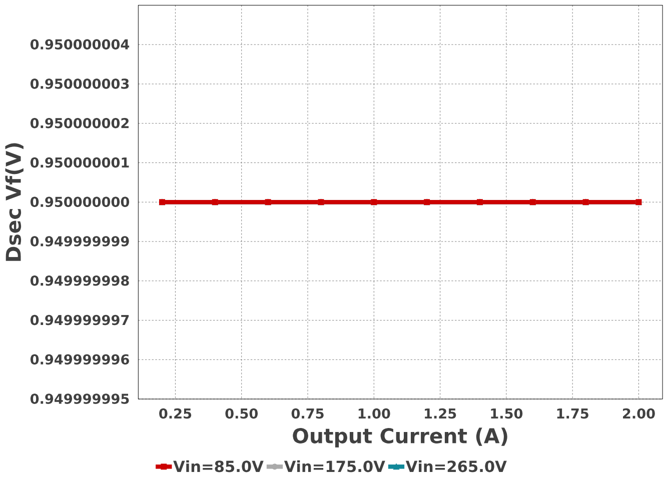
M1 Pd



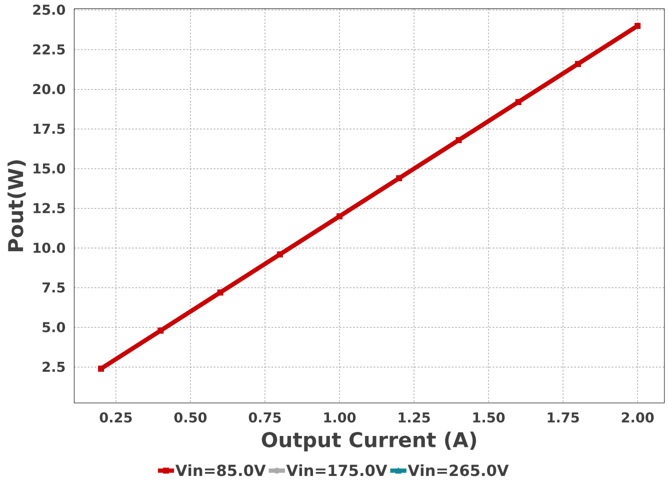
Dsec Pd



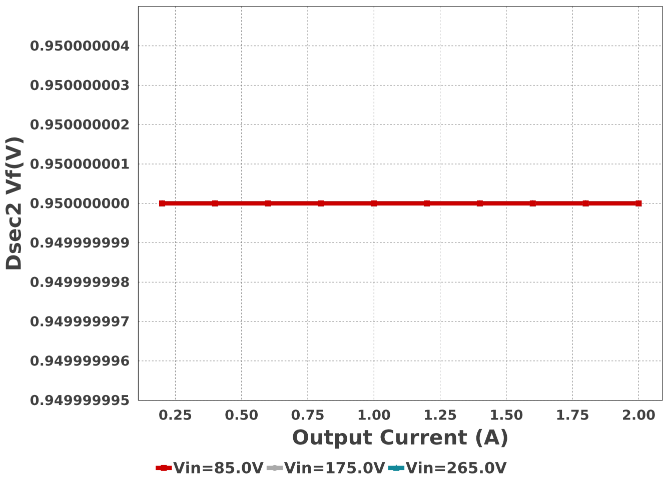
Dsec Vf



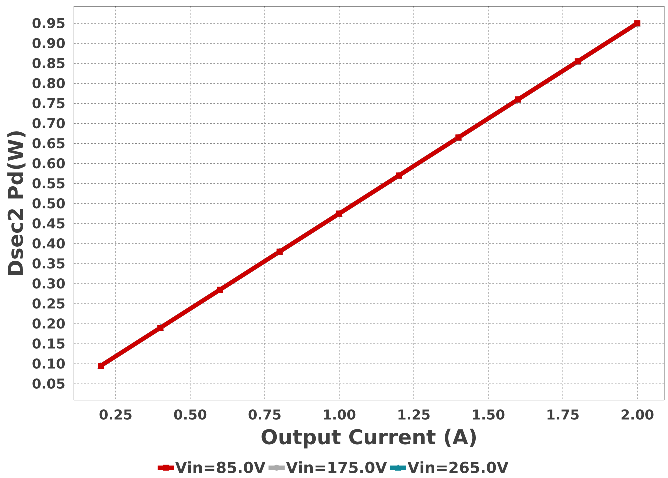
Pout

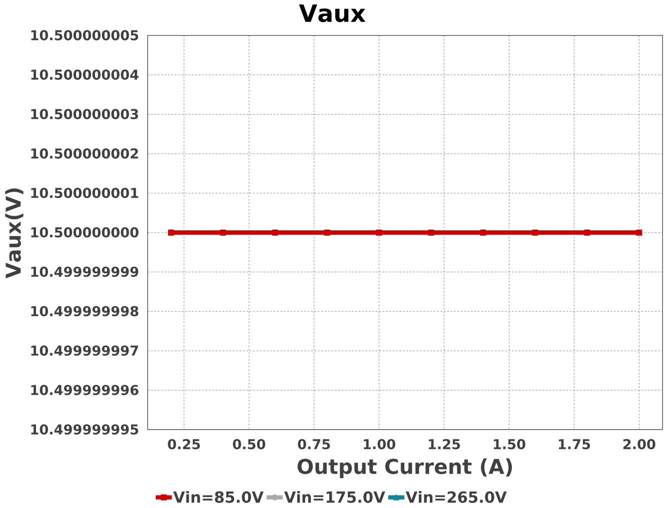


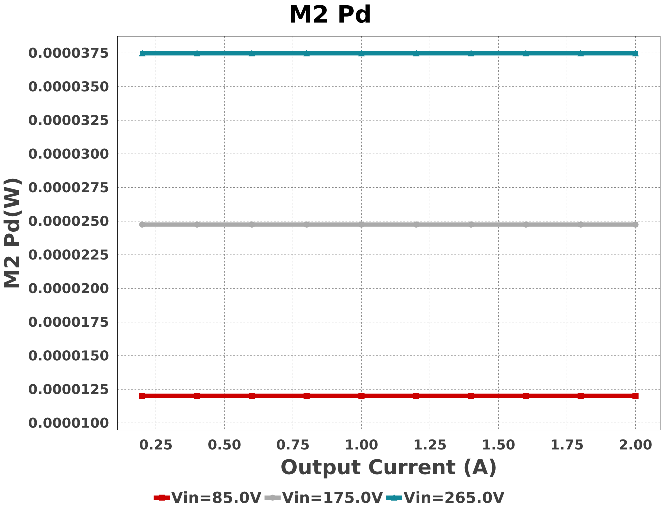
Dsec2 Vf

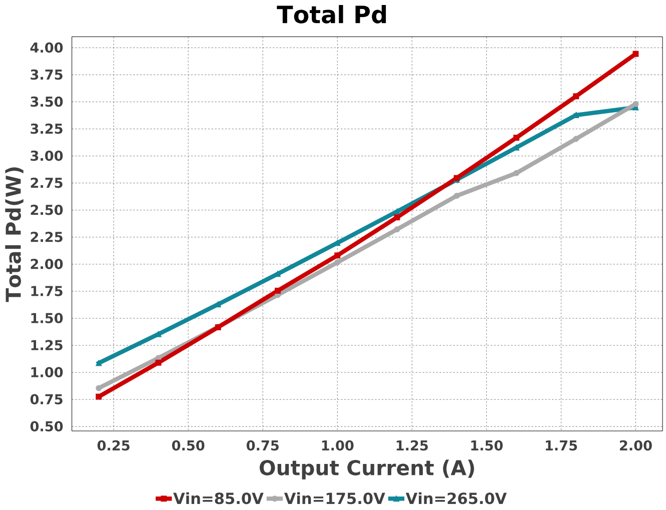


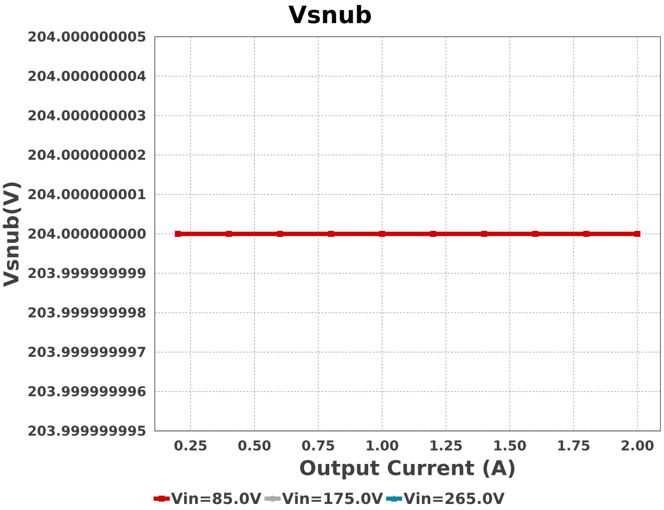
Dsec2 Pd

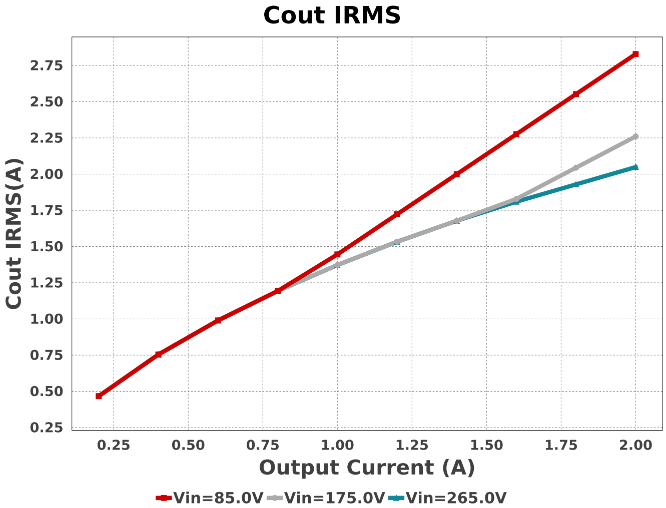


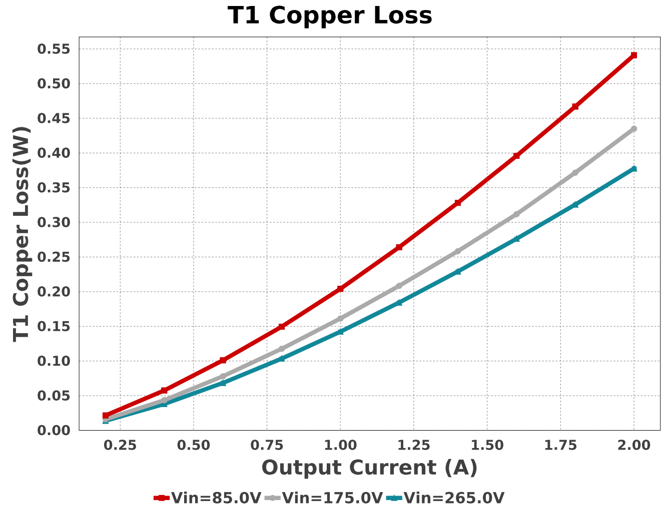

Vaux
Vaux(V)
10.500000005
10.500000004
10.500000003
10.500000002
10.500000001
10.500000000
10.499999999
10.499999998
10.499999997
10.499999996
10.499999995
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

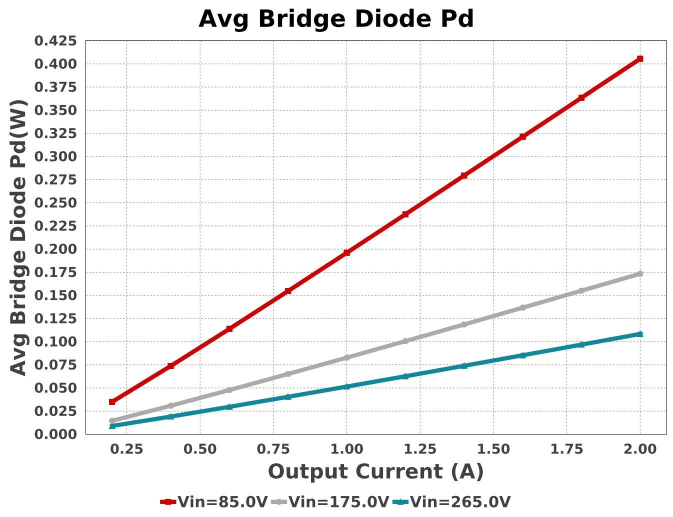

M2 Pd
M2 Pd(W)
0.0000375
0.0000350
0.0000325
0.0000300
0.0000275
0.0000250
0.0000225
0.0000200
0.0000175
0.0000150
0.0000125
0.0000100
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

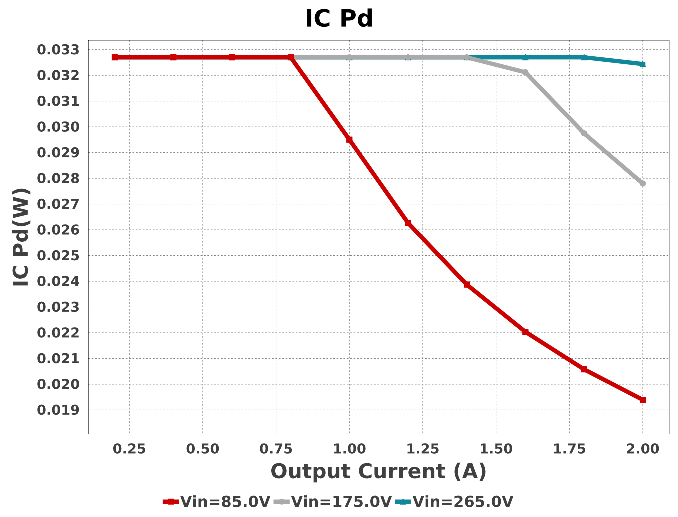

Total Pd
Total Pd(W)
4.00 3.75 3.50 3.25 3.00 2.75 2.50 2.25 2.00 1.75 1.50 1.25 1.00 0.75 0.50
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

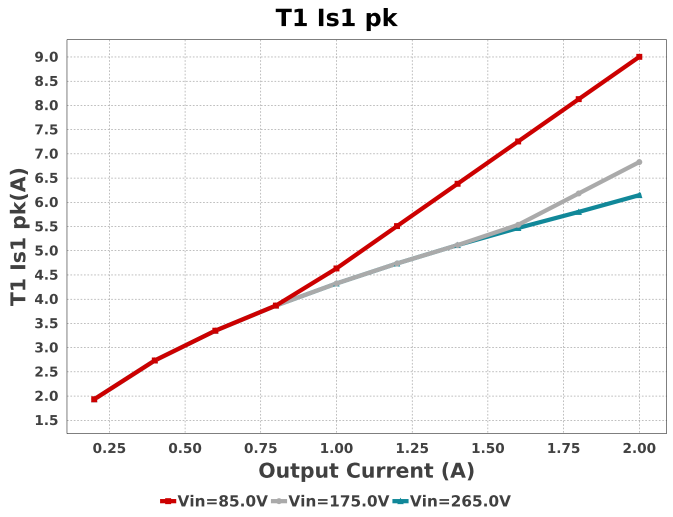

Vsnub
Vsnub(V)
204.000000005
204.000000004
204.000000003
204.000000002
204.000000001
204.000000000
203.999999999
203.999999998
203.999999997
203.999999996
203.999999995
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

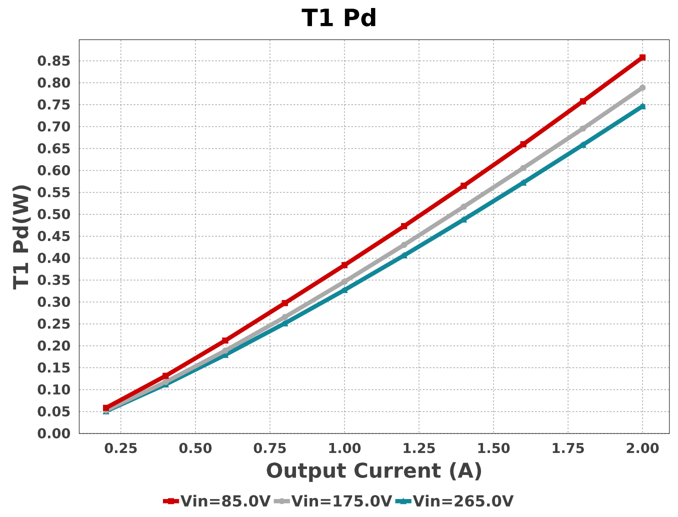

Cout IRMS
Cout IRMS(A)
2.75 2.50 2.25 2.00 1.75 1.50 1.25 1.00 0.75 0.50 0.25
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

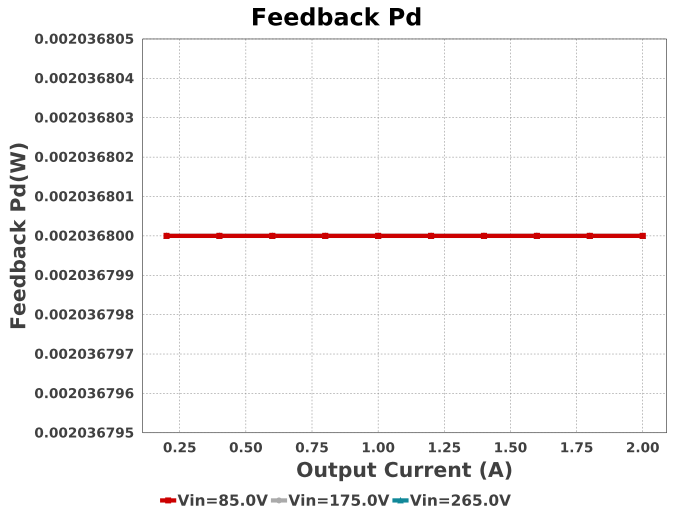

T1 Copper Loss
T1 Copper Loss(W)
0.55 0.50 0.45 0.40 0.35 0.30 0.25 0.20 0.15 0.10 0.05 0.00
0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V











Operating Values

#	Name	Value	Category	Description
1.	Cout IRMS	2.829 A	Capacitor	Output capacitor RMS ripple current
2.	Avg Bridge Diode Pd	405.52 mW	Diode	Average Power Dissipation in the Bridge Diode over the AC Line Period
3.	Daux trr	35.0 ns	Diode	Auxiliary Diode Reverse Recovery Time
4.	Dsec Pd	950.0 mW	Diode	Secondary Diode Power Dissipation
5.	Dsec Vf	950.0 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	950.0 mW	Diode	Secondary Diode Power Dissipation
8.	Dsec2 Vf	950.0 mV	Diode	Effective Forward Voltage Drop at the Operating Current
9.	Dsnub trr	60.0 ns	Diode	Snubber Diode Reverse Recovery Time
10.	IC Pd	19.396 mW	IC	IC power dissipation
11.	IC Tj	33.879 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	894.12 mW	Mosfet	M1 MOSFET total power dissipation
14.	M1 TjOP	119.41 degC	Mosfet	M1 MOSFET junction temperature
15.	M2 Pd	12.021 µW	Mosfet	M2 MOSFET total power dissipation
16.	Avg Bridge Diode Pd	405.52 mW	Power	Average Power Dissipation in the Bridge Diode over the AC Line Period
17.	Dsec Pd	950.0 mW	Power	Secondary Diode Power Dissipation
18.	Dsec2 Pd	950.0 mW	Power	Secondary Diode Power Dissipation
19.	Feedback Pd	2.037 mW	Power	Power Dissipation in Feedback Resistors
20.	IC Pd	19.396 mW	Power	IC power dissipation
21.	M1 Pd	894.12 mW	Power	M1 MOSFET total power dissipation
22.	M2 Pd	12.021 µW	Power	M2 MOSFET total power dissipation
23.	Rsense Pd	65.421 mW	Power	LED Current Rsns Power Dissipation
24.	Snubber Pd	424.612 mW	Power	Snubber Power Dissipation
25.	T1 Copper Loss	512.91 mW	Power	Transformer Copper Loss Power Dissipation
26.	T1 Core Loss	288.0 mW	Power	Transformer Core Loss Power Dissipation
27.	T1 Pd	800.91 mW	Power	Estimated Losses in Transformer
28.	Total Pd	4.78 W	Power	Total Power Dissipation
29.	Feedback Pd	2.037 mW	Resistor	Power Dissipation in Feedback Resistors
30.	Rsense Pd	65.421 mW	Resistor	LED Current Rsns Power Dissipation
31.	BOM Count	42	System Information	Total Design BOM count
32.	Duty Cycle	50.228 %	System Information	Duty cycle
33.	Efficiency	83.39 %	System Information	Steady state efficiency
34.	FootPrint	2.486 k mm^2	System Information	Total Foot Print Area of BOM components
35.	Frequency	59.979 kHz	System Information	Switching frequency
36.	Iin rms	338.59 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	120.207 V	System Information	Peak voltage seen at rectified input
40.	Pout	24.0 W	System Information	Total output power
41.	Total BOM	$9.03	System Information	Total BOM Cost
42.	Vin_RMS	85.0 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	1.926 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
46.	Vout p-p	90.03 mV	System Information	Peak-to-peak output ripple voltage
47.	Vsnub	204.0 V	System Information	Voltage Across the Snubber
48.	Ipri Avg	239.402 mA	Transformer	Average Current in Primary Winding over the complete Switching Period
49.	T1 Copper Loss	512.91 mW	Transformer	Transformer Copper Loss Power Dissipation
50.	T1 Core Loss	288.0 mW	Transformer	Transformer Core Loss Power Dissipation
51.	T1 Iprim RMS	390.054 mA	Transformer	Transformer Primary RMS Current
52.	T1 Iprim pk	953.262 mA	Transformer	Transformer Primary Peak Current
53.	T1 Is1 RMS	3.465 A	Transformer	Transformer Secondary1 RMS Current
54.	T1 Is1 pk	9.003 A	Transformer	Transformer Secondary1 Peak Current
55.	T1 Pd	800.91 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	265.0	Maximum input voltage
VinMin	85.0	Minimum input voltage
Vout	12.0	Output Voltage
acFrequency	60.0	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

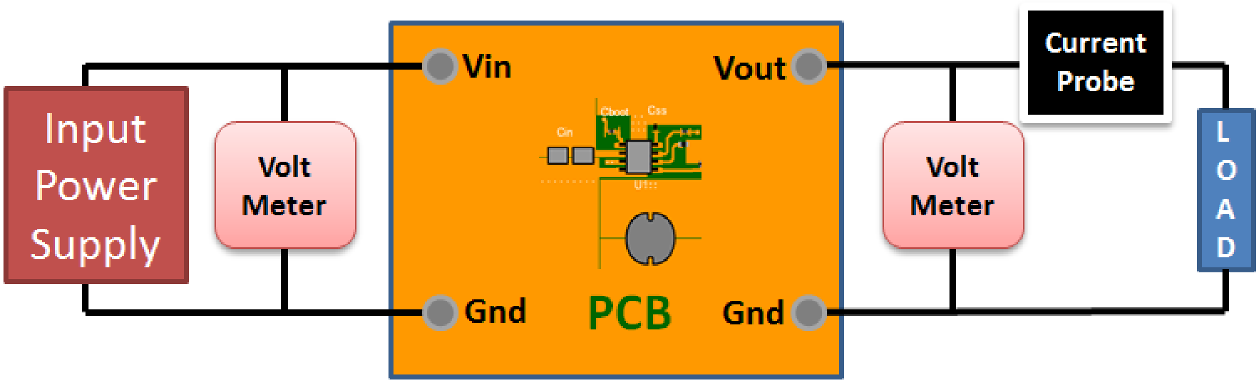
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. 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 85.0V 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	B66208X1110T001
4.	Coil Former Manufacturer	TDK

Transformer Electrical Diagram

Primary

Turns	85.0
AWG	26.0
Layers	3.0
Strands	1.0
Insulation Type	Heavy Insulated Magnet Wire

Secondary

Turns	9.0
AWG	25.0
Layers	1.0
Strands	2.0
Insulation Type	Triple Insulated

Auxiliary

Turns	8.0
AWG	28.0
Layers	1.0
Strands	4.0
Insulation Type	Heavy Insulated Magnet Wire

Transformer Construction Diagram

Winding Instruction

Winding	AWG	Turns	Winding Orientation
Primary First 2/3.0	26.0	57	Clockwise
Auxiliary	28.0	8.0	Counter Clockwise
Triple Insulated Secondary	25.0	9.0	Counter Clockwise
Primary Second 1/3.0	26.0	28	Clockwise

Transformer Parameters

#	Name	Value
1.	Lpri	0.00106H
2.	Inductance Factor(Al)	147.0nH
3.	Npri	85.0
4.	Nsec	9.0
5.	Naux	8.0
6.	Core Type	E25/13/7
7.	Core Material	N87

#	Name	Value
8.	Bmax	0.23T
9.	Switching Frequency	55.00kHz
10.	DMax	0.45
11.	Ipk(Primary)	0.96A
12.	Irms(Primary)	0.37A
13.	Ipk(Secondary)	9.05A
14.	Irms(Secondary)	3.52A

Design Assistance

1. Master key : 0760D1CF250B4DF0DAEC74FCF0899DAE[v1]
2. **LM5023** Product Folder : http://www.ti.com/product/LM5023 : contains the data sheet and other resources.