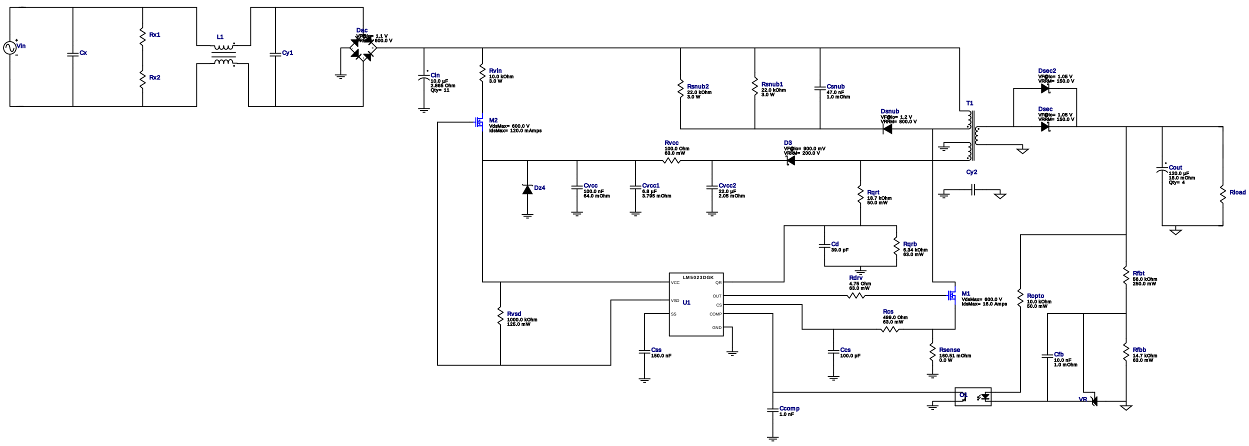
VinMin = 85.0V
VinMax = 265.0V
Vout = 12.0V
Iout = 5.0A

Device = LM5023MMX-2/NOPB
Topology = Flyback
Created = 2023-02-09 23:49:08.679
BOM Cost = NA
BOM Count = 49
Total Pd = 10.42W

WEBENCH ® Design Report

Design : 366 LM5023MMX-2/NOPB
LM5023MMX-2/NOPB 85V-265V to 12.00V @ 5A



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

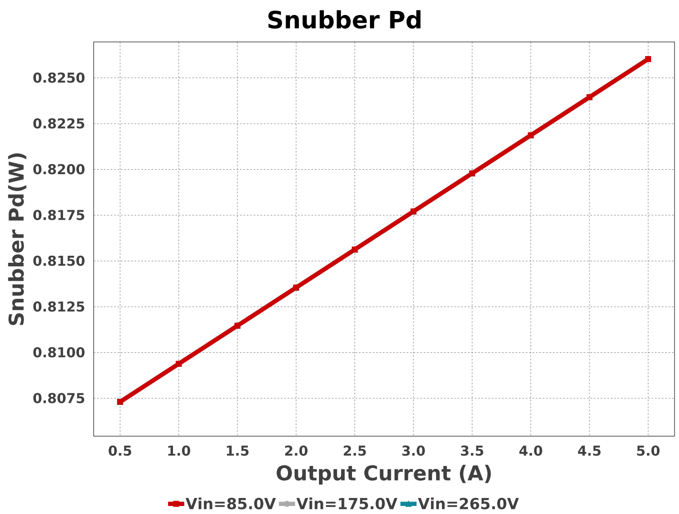
Click on the transformer symbol in the schematic and select "Explore Transformer Core/Bobbin Selection" to design using specific transformer cores and bobbin.

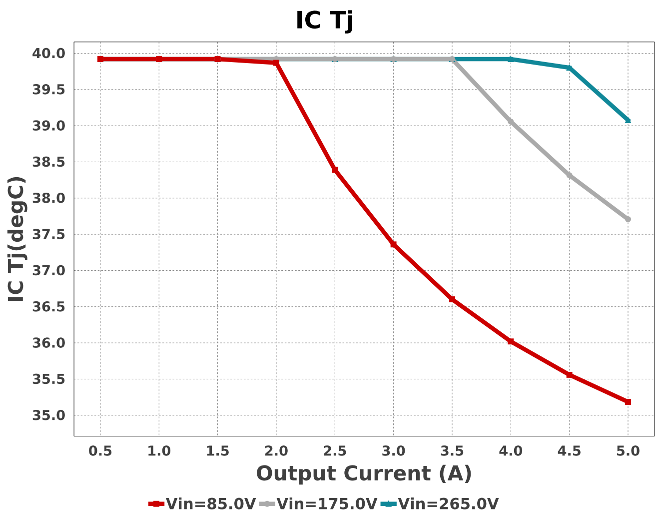
Electrical BOM

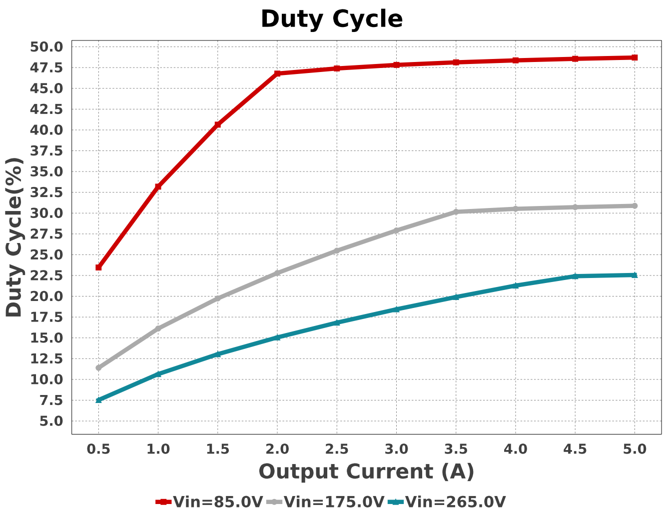
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Ccomp	Samsung Electro-Mechanics	CL21C102JBCNNNC Series= C0G/NP0	Cap= 1.0 nF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm^2
Ccs	Samsung Electro-Mechanics	CL21C101JBANNNC Series= C0G/NP0	Cap= 100.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm^2
Cd	Samsung Electro-Mechanics	CL21C390JBANNNC Series= C0G/NP0	Cap= 39.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 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	11	$0.31	CAPPR5-10X20 144 mm^2
Cout	Panasonic	35SEPF120M Series= SEPF	Cap= 120.0 uF ESR= 18.0 mOhm VDC= 35.0 V IRMS= 4.4 A	4	$0.96	SEPF_F13 144 mm^2
Csnub	MuRata	GRM43DR73A473KW01L Series= X7R	Cap= 47.0 nF ESR= 1.0 mOhm VDC= 1000.0 V IRMS= 0.0 A	1	$0.57	1812 23 mm^2

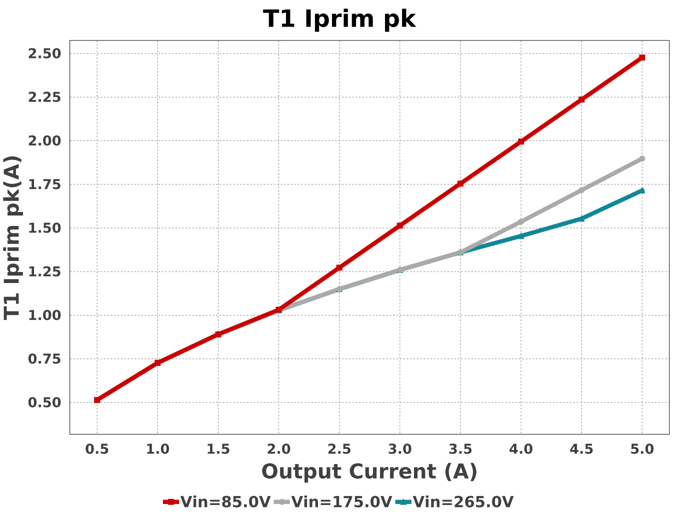
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Css	Panasonic	ECPU1C154MA5 Series= ECPU(A)	Cap= 150.0 nF VDC= 16.0 V IRMS= 0.0 A	1	$0.23	1206 11 mm^2
Cvcc	Kemet	C0805C104M5RACTU Series= X7R	Cap= 100.0 nF ESR= 64.0 mOhm VDC= 50.0 V IRMS= 1.64 A	1	$0.01	0805 7 mm^2
Cvcc1	TDK	C2012X5R1V685K125AC Series= X5R	Cap= 6.8 uF ESR= 3.795 mOhm VDC= 35.0 V IRMS= 3.3493 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	$0.31	0805 7 mm^2
D3	Fairchild Semiconductor	S320	VF@Io= 900.0 mV VRRM= 200.0 V	1	$0.33	SMB 44 mm^2
Dac	Diodes Inc.	DF1506S-T	VF@Io= 1.1 V VRRM= 600.0 V	1	$0.24	DF-S 99 mm^2
Dsec	SMC Diode Solutions	SB20150TR	VF@Io= 1.05 V VRRM= 150.0 V	1	$0.32	DO-201AD 166 mm^2
Dsec2	SMC Diode Solutions	SB20150TR	VF@Io= 1.05 V VRRM= 150.0 V	1	$0.32	DO-201AD 166 mm^2
Dsnub	Microsemi	UFS180JE3/TR13	VF@Io= 1.2 V VRRM= 800.0 V	1	$0.95	DO-214BA 42 mm^2
Dz4	ON Semiconductor	MMSZ4701T1G	Zener	1	$0.04	SOD-123 13 mm^2
M1	Infineon Technologies	IPW60R199CPFKSA1	VdsMax= 600.0 V IdsMax= 16.0 Amps	1	$4.42	TO-247 123 mm^2
M2	Infineon Technologies	BSP135H6327XTSA1	VdsMax= 600.0 V IdsMax= 120.0 mAmps	1	$0.79	SOT-223 76 mm^2
O1	Vishay-Semiconductor	TCMT1107	Optocoupler	1	$0.19	SOP-4 44 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	Yageo	RC1206FR-0756KL Series= ?	Res= 56.0 kOhm Power= 250.0 mW Tolerance= 1.0%	1	$0.01	1206 11 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	CRCW04026K34FKED Series= CRCW..e3	Res= 6.34 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2

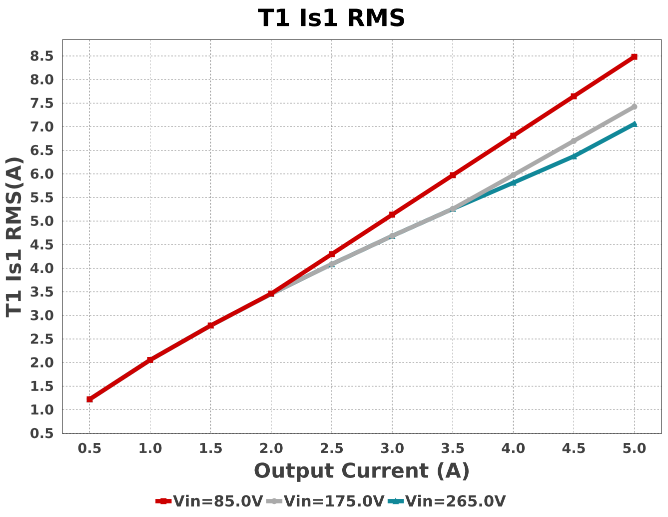
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Rqrt	Yageo	RC0201FR-0718K7L Series= ?	Res= 18.7 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm²
Rsense	CUSTOM	CUSTOM Series= ?	Res= 160.51 mOhm Power= 0.0 W Tolerance= 0.0%	1	NA	CUSTOM 0 mm²
Rsnub1	Yageo	FMP300JR-73-22K Series= ?	Res= 22.0 kOhm Power= 3.0 W Tolerance= 5.0%	1	$0.05	FMP300 181 mm²
Rsnub2	Yageo	FMP300JR-73-22K Series= ?	Res= 22.0 kOhm Power= 3.0 W Tolerance= 5.0%	1	$0.05	FMP300 181 mm²
Rvcc	Vishay-Dale	CRCW0402100RFKED Series= CRCW..e3	Res= 100.0 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=B66229G0000X187 , CoilFormer=B66230A1114T001	Lp= 422.0 µH Turns Ratio(Nas)= 6:7 Turns Ratio(Nps)= 61:7 Npri= 61.0 Naux= 6.0 Nsec= 7.0	1	$1.83	1462 mm²
U1	Texas Instruments	LM5023MMX-2/NOPB	Switcher	1	$0.42	DGK0008A 24 mm²
VR	Texas Instruments	TL431IDBVR	Voltage References	1	$0.09	R-PDSO-G3 16 mm²

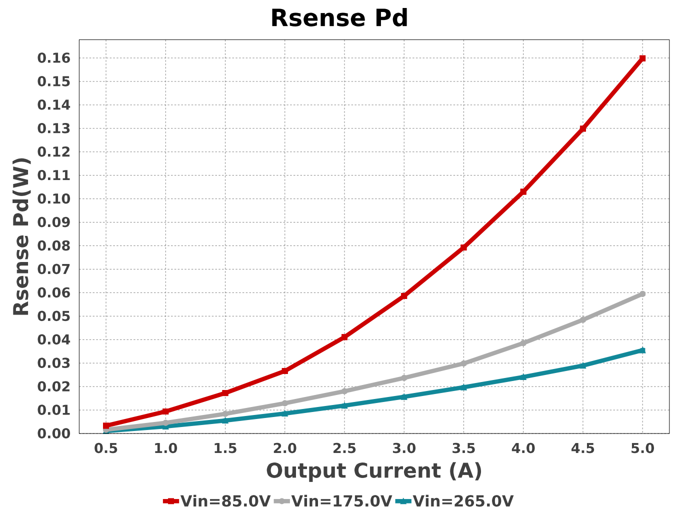


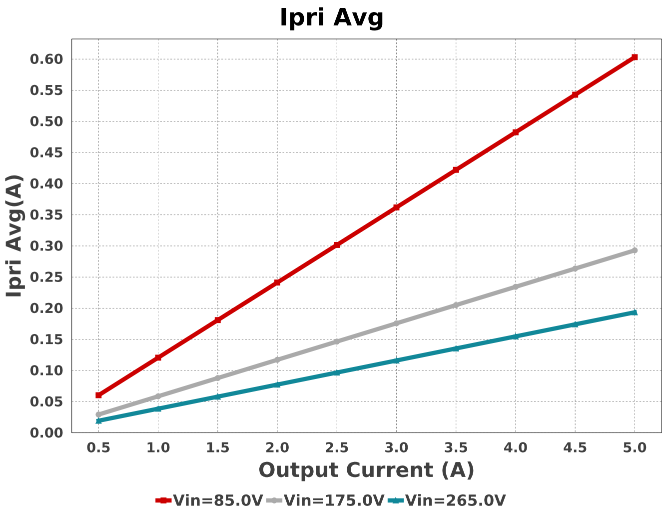


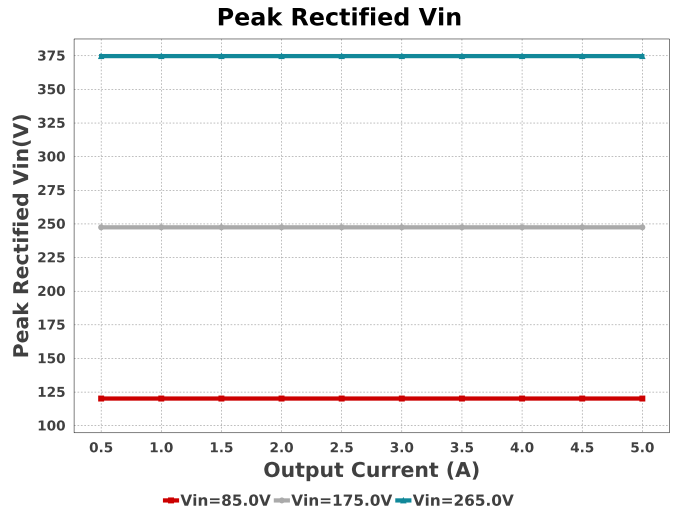

Duty Cycle
Duty Cycle(%)
Output Current (A)
Vin=85.0V
Vin=175.0V
Vin=265.0V

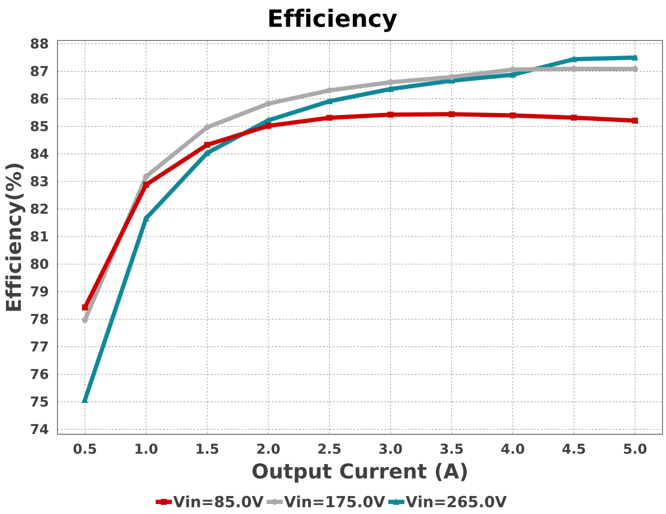

T1 Iprim pk
T1 Iprim pk(A)
Output Current (A)
Vin=85.0V
Vin=175.0V
Vin=265.0V

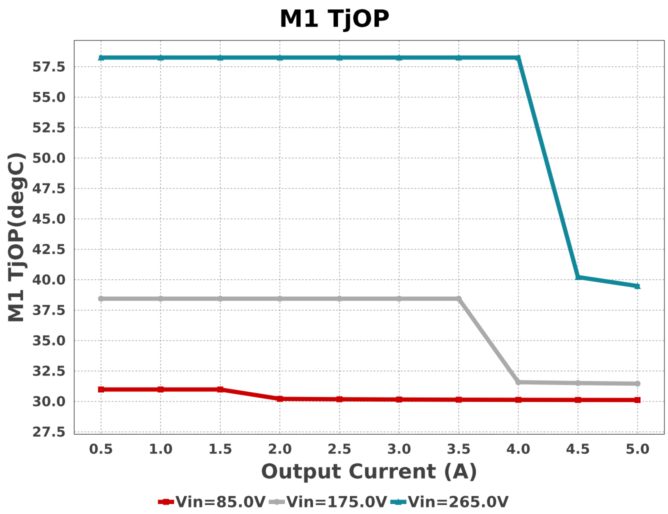

T1 Is1 RMS
T1 Is1 RMS(A)
Output Current (A)
Vin=85.0V
Vin=175.0V
Vin=265.0V

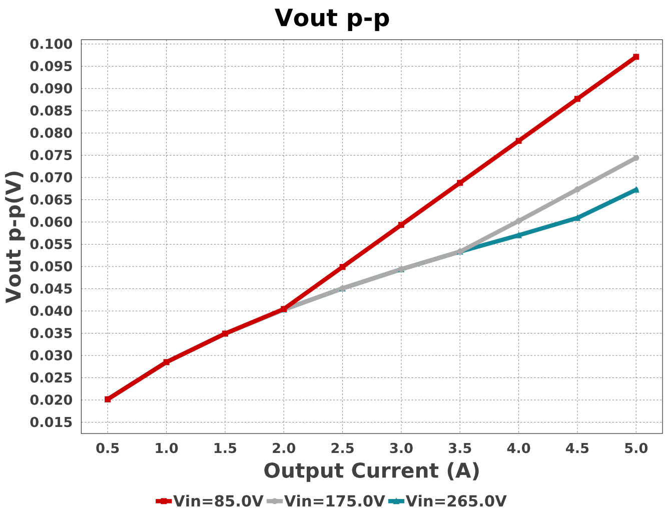

Rsense Pd
Rsense Pd(W)
Output Current (A)
Vin=85.0V
Vin=175.0V
Vin=265.0V

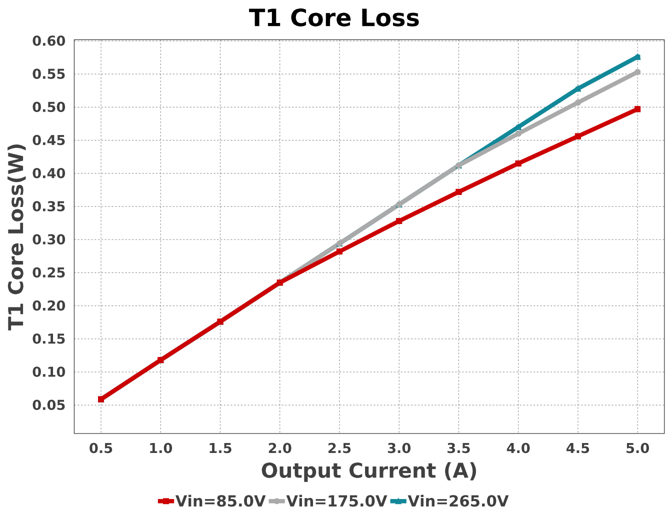

Ipri Avg
Ipri Avg(A)
Output Current (A)
Vin=85.0V
Vin=175.0V
Vin=265.0V

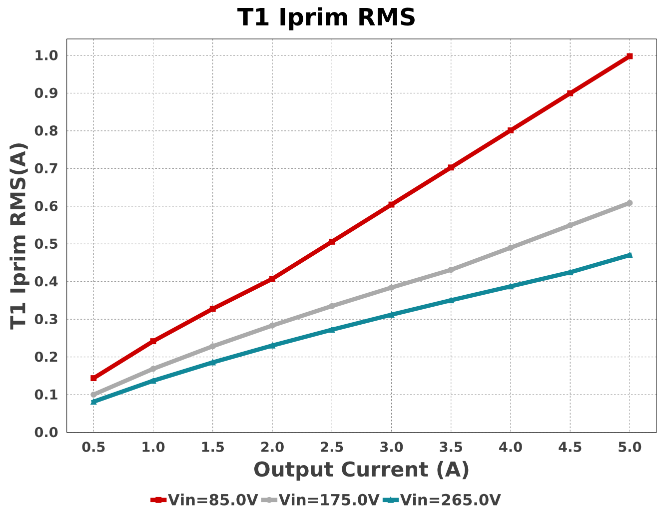

Peak Rectified Vin
Peak Rectified Vin(V)
Output Current (A)
Vin=85.0V
Vin=175.0V
Vin=265.0V

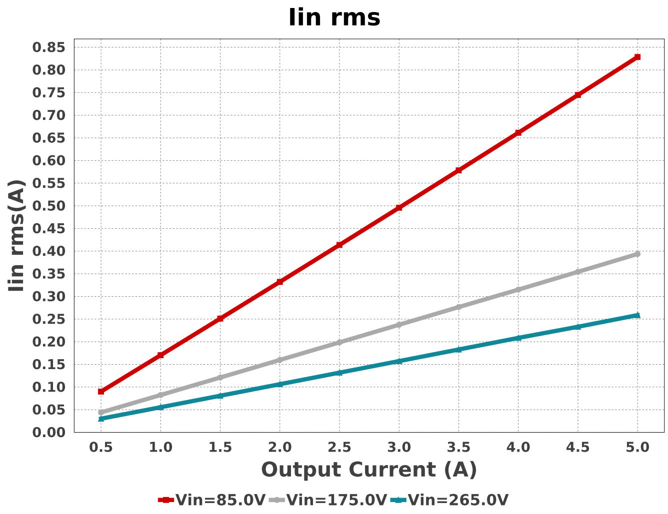

Efficiency
Efficiency(%)
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

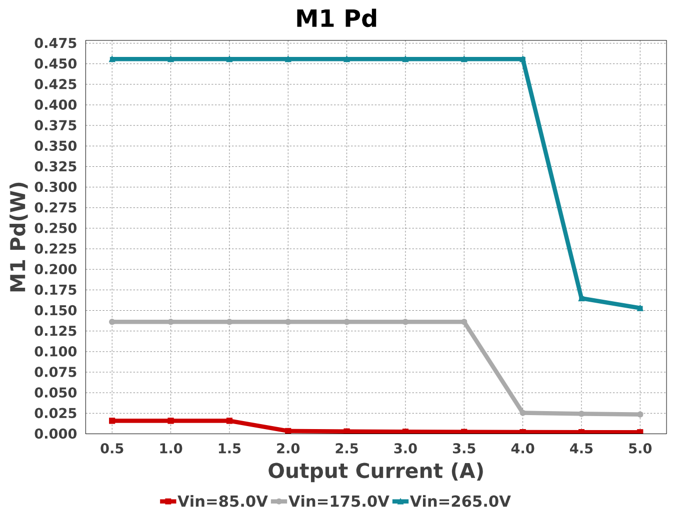

M1 TjOP
M1 TjOP(degC)
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

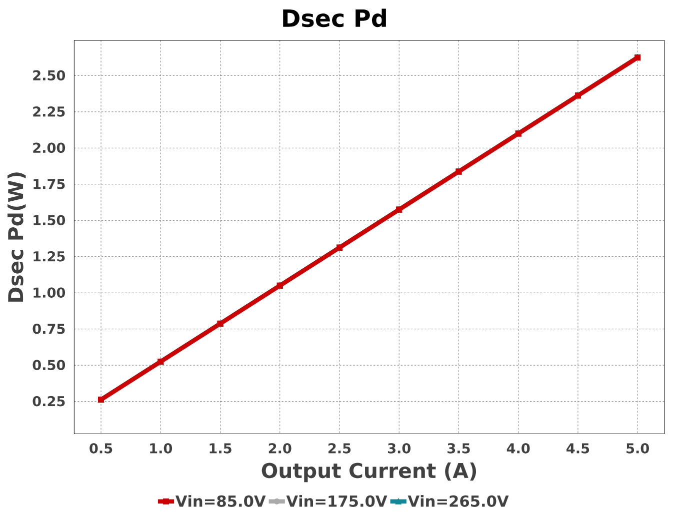

Vout p-p
Vout p-p(V)
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

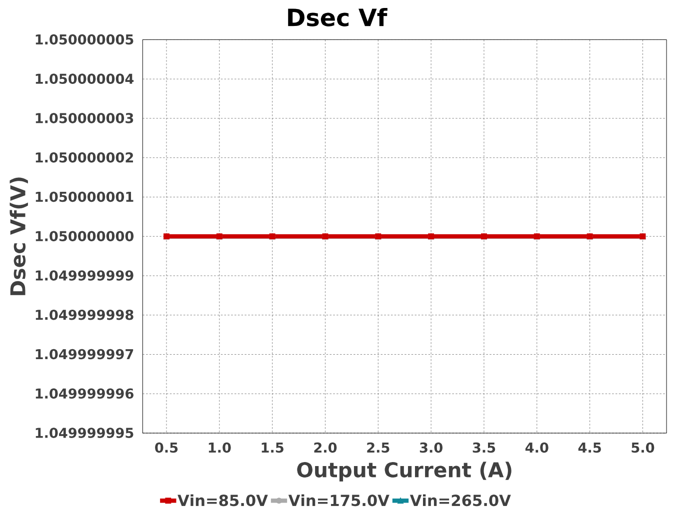

T1 Core Loss
T1 Core Loss(W)
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

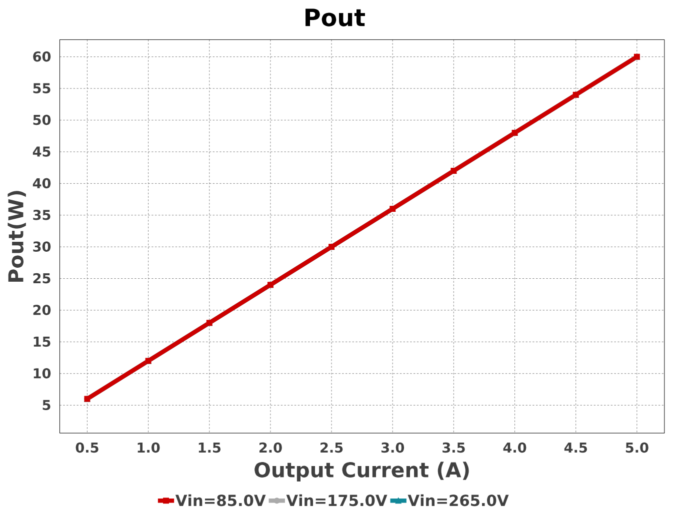

T1 Iprim RMS
T1 Iprim RMS(A)
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

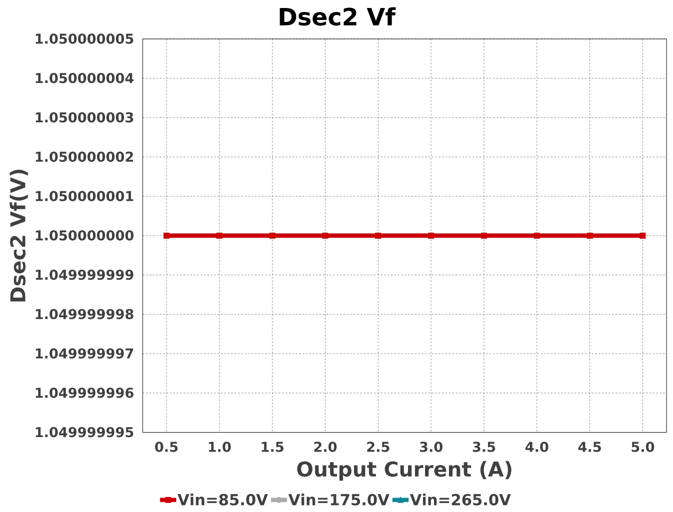

Iin rms
Iin rms(A)
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

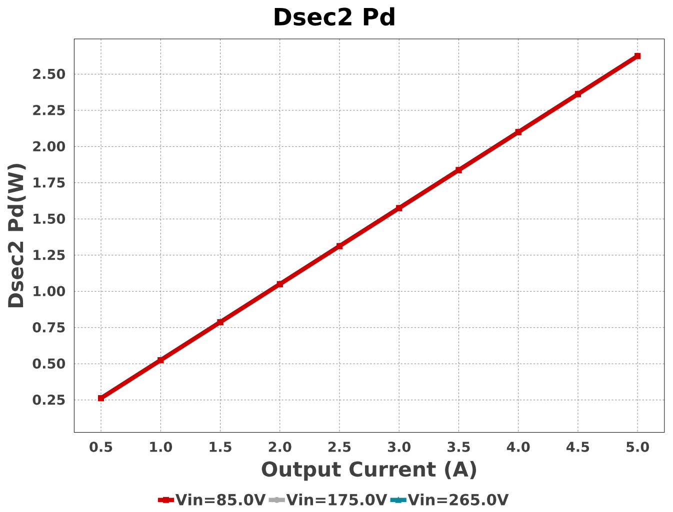

M1 Pd
M1 Pd(W)
0.475
0.450
0.425
0.400
0.375
0.350
0.325
0.300
0.275
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

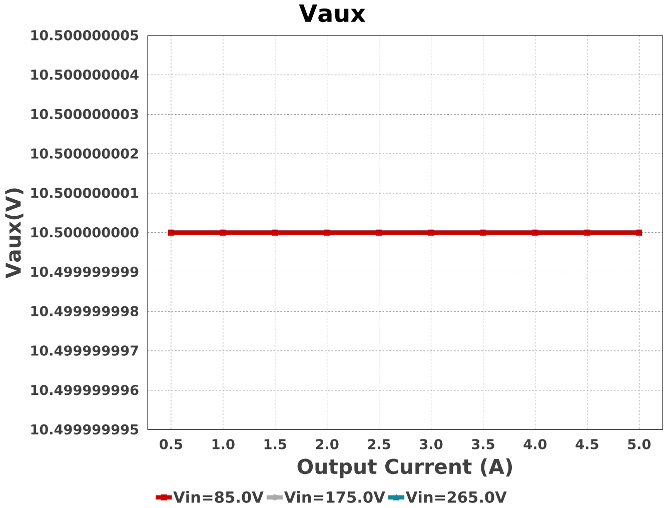

Dsec Pd
Dsec Pd(W)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

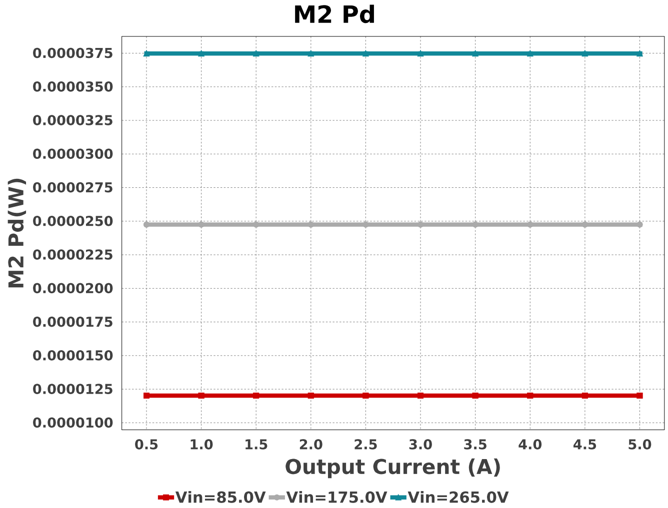

Dsec Vf
Dsec Vf(V)
1.050000005
1.050000004
1.050000003
1.050000002
1.050000001
1.050000000
1.049999999
1.049999998
1.049999997
1.049999996
1.049999995
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

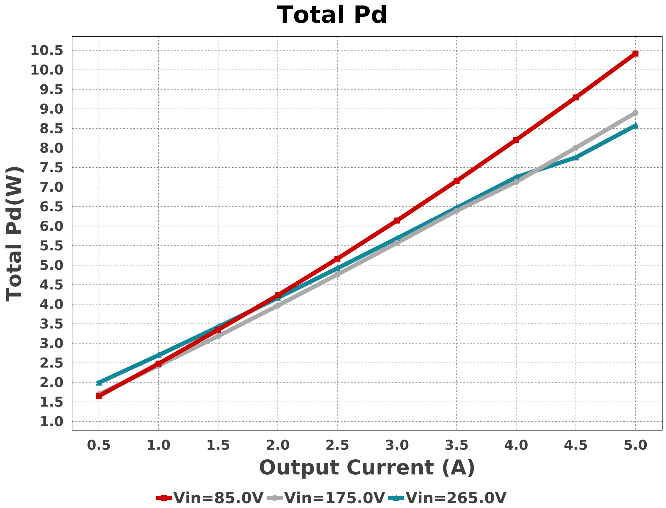

Pout
Pout(W)
60
55
50
45
40
35
30
25
20
15
10
5
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

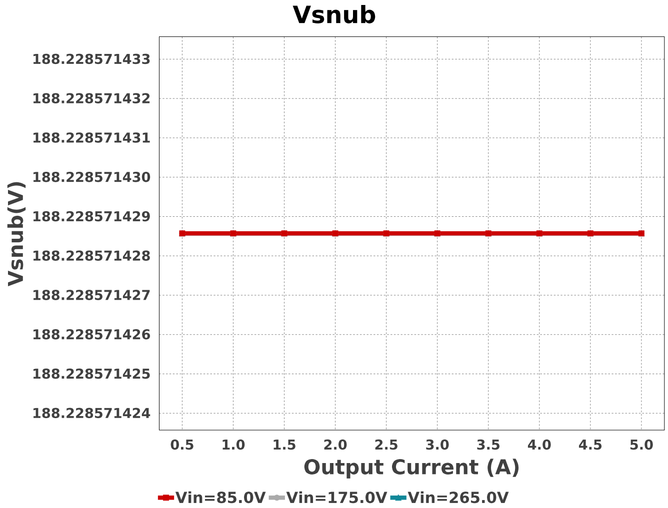

Dsec2 Vf
Dsec2 Vf(V)
1.050000005
1.050000004
1.050000003
1.050000002
1.050000001
1.050000000
1.049999999
1.049999998
1.049999997
1.049999996
1.049999995
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

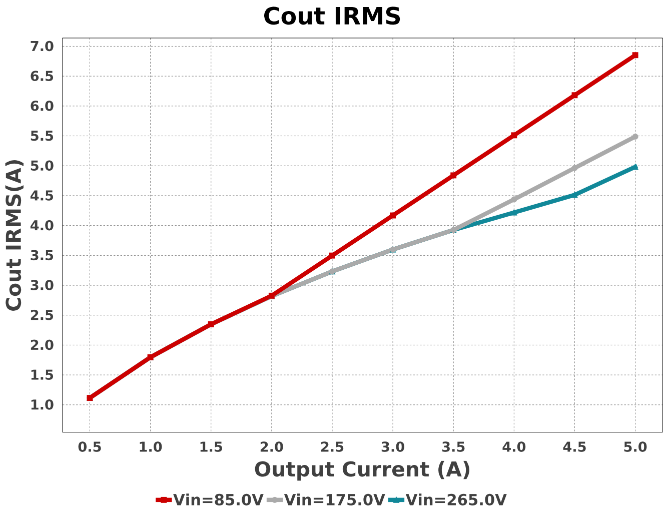

Dsec2 Pd
Dsec2 Pd(W)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

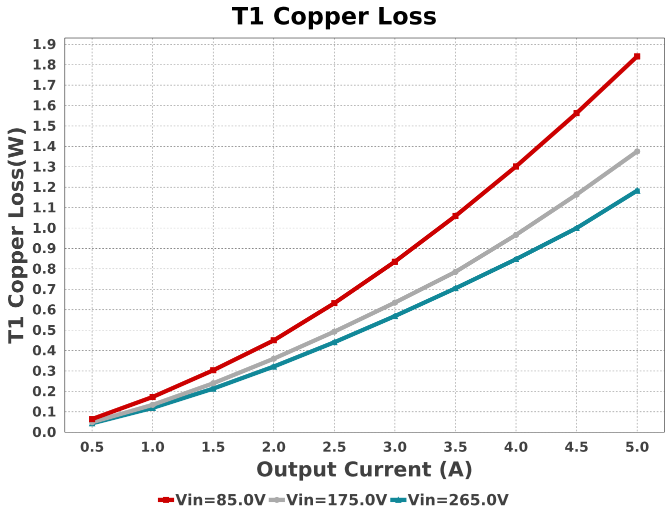

Vaux
Vaux(V)
10.500000005
10.500000004
10.500000003
10.500000002
10.500000001
10.500000000
10.499999999
10.499999998
10.499999997
10.499999996
10.499999995
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V


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
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

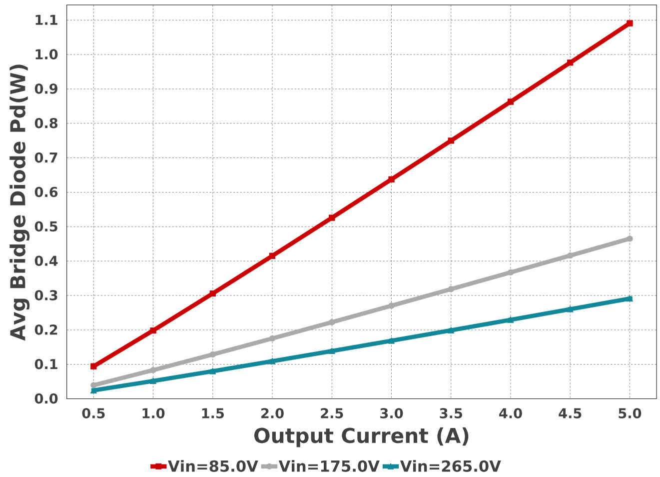

Total Pd
Total Pd(W)
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V


Vsnub
Vsnub(V)
188.228571433
188.228571432
188.228571431
188.228571430
188.228571429
188.228571428
188.228571427
188.228571426
188.228571425
188.228571424
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

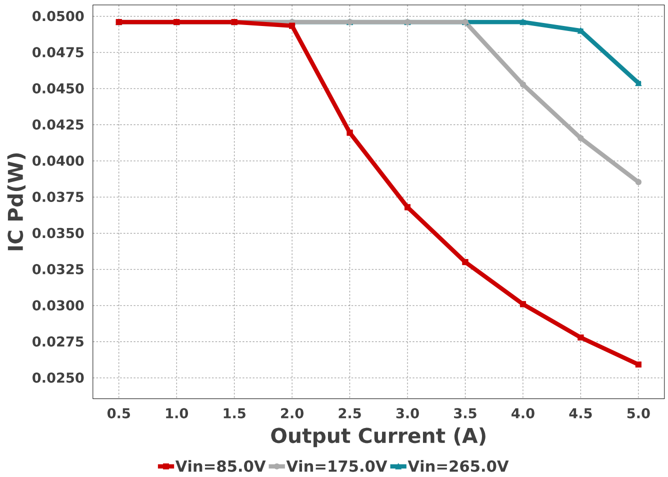

Cout IRMS
Cout IRMS(A)
7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V


T1 Copper Loss
T1 Copper Loss(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 0.0
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=85.0V Vin=175.0V Vin=265.0V

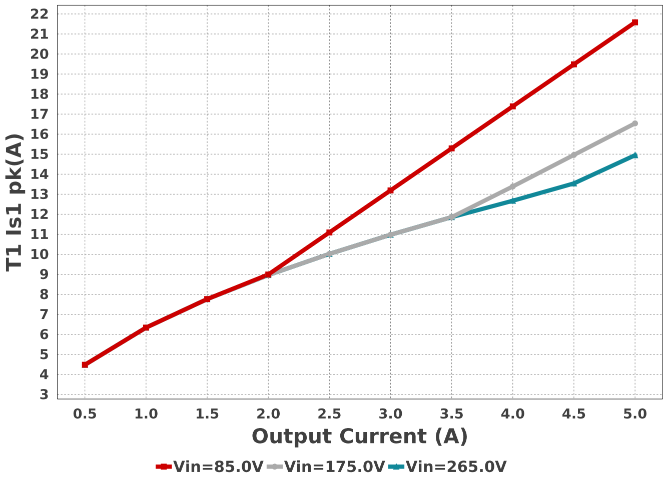
Avg Bridge Diode Pd



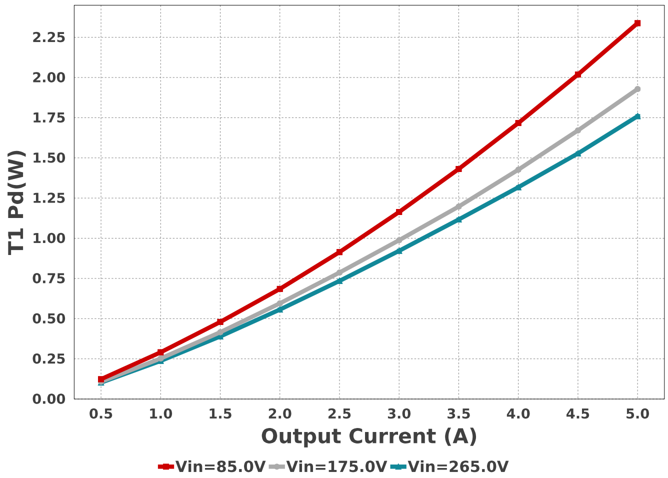
IC Pd



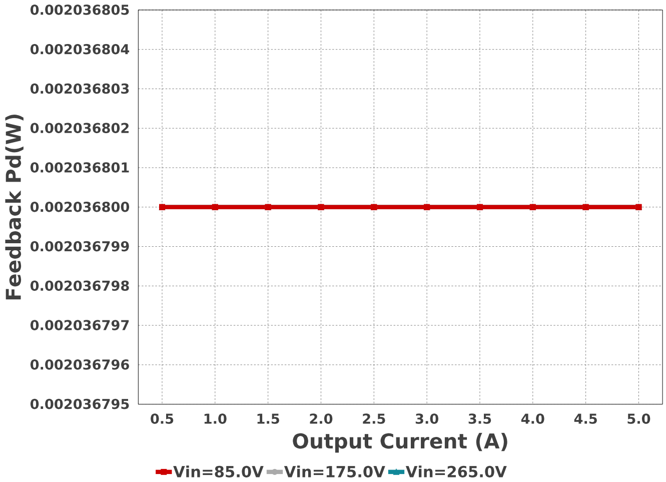
T1 Is1 pk



T1 Pd



Feedback Pd



Operating Values

#	Name	Value	Category	Description
1.	BOM Count	49		Total Design BOM count
2.	Total BOM	NA		Total BOM Cost
3.	Cout IRMS	6.851 A	Capacitor	Output capacitor RMS ripple current
4.	Avg Bridge Diode Pd	1.091 W	Diode	Average Power Dissipation in the Bridge Diode over the AC Line Period
5.	Dsec Pd	2.625 W	Diode	Secondary Diode Power Dissipation
6.	Dsec Vf	1.05 V	Diode	Effective Forward Voltage Drop at the Operating Current
7.	Dsec2 Pd	2.625 W	Diode	Secondary Diode Power Dissipation
8.	Dsec2 Vf	1.05 V	Diode	Effective Forward Voltage Drop at the Operating Current
9.	IC Pd	25.926 mW	IC	IC power dissipation
10.	IC Tj	35.185 degC	IC	IC junction temperature
11.	ICThetaJA	200.0 degC/W	IC	IC junction-to-ambient thermal resistance

#	Name	Value	Category	Description
12.	M1 Pd	1.916 mW	Mosfet	M1 MOSFET total power dissipation
13.	M1 TjOP	30.119 degC	Mosfet	M1 MOSFET junction temperature
14.	M2 Pd	12.021 µW	Mosfet	M2 MOSFET total power dissipation
15.	Avg Bridge Diode Pd	1.091 W	Power	Average Power Dissipation in the Bridge Diode over the AC Line Period
16.	Dsec Pd	2.625 W	Power	Secondary Diode Power Dissipation
17.	Dsec2 Pd	2.625 W	Power	Secondary Diode Power Dissipation
18.	Feedback Pd	2.037 mW	Power	Power Dissipation in Feedback Resistors
19.	IC Pd	25.926 mW	Power	IC power dissipation
20.	M1 Pd	1.916 mW	Power	M1 MOSFET total power dissipation
21.	M2 Pd	12.021 µW	Power	M2 MOSFET total power dissipation
22.	Rsense Pd	159.84 mW	Power	LED Current Rsns Power Dissipation
23.	Snubber Pd	826.026 mW	Power	Snubber Power Dissipation
24.	T1 Copper Loss	1.841 W	Power	Transformer Copper Loss Power Dissipation
25.	T1 Core Loss	497.0 mW	Power	Transformer Core Loss Power Dissipation
26.	T1 Pd	2.338 W	Power	Estimated Losses in Transformer
27.	Total Pd	10.416 W	Power	Total Power Dissipation
28.	Feedback Pd	2.037 mW	Resistor	Power Dissipation in Feedback Resistors
29.	Rsense Pd	159.84 mW	Resistor	LED Current Rsns Power Dissipation
30.	Duty Cycle	48.705 %	System Information	Duty cycle
31.	Efficiency	85.208 %	System Information	Steady state efficiency
32.	FootPrint	5.112 k mm^2	System Information	Total Foot Print Area of BOM components
33.	Frequency	56.018 kHz	System Information	Switching frequency
34.	Iin rms	828.42 mA	System Information	RMS Input Current
35.	Iout	5.0 A	System Information	Iout operating point
36.	Mode	TM	System Information	Conduction Mode
37.	Peak Rectified Vin	120.207 V	System Information	Peak voltage seen at rectified input
38.	Pout	60.0 W	System Information	Total output power
39.	Vin_RMS	85.0 V	System Information	Vin operating point
40.	Vout	12.0 V	System Information	Operational Output Voltage
41.	Vout Actual	12.0 V	System Information	Vout Actual calculated based on selected voltage divider resistors
42.	Vout Tolerance	1.926 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
43.	Vout p-p	97.12 mV	System Information	Peak-to-peak output ripple voltage
44.	Vsnub	188.229 V	System Information	Voltage Across the Snubber
45.	Ipri Avg	603.126 mA	Transformer	Average Current in Primary Winding over the complete Switching Period
46.	T1 Copper Loss	1.841 W	Transformer	Transformer Copper Loss Power Dissipation
47.	T1 Core Loss	497.0 mW	Transformer	Transformer Core Loss Power Dissipation
48.	T1 Iprim RMS	997.906 mA	Transformer	Transformer Primary RMS Current
49.	T1 Iprim pk	2.477 A	Transformer	Transformer Primary Peak Current
50.	T1 Is1 RMS	8.482 A	Transformer	Transformer Secondary1 RMS Current
51.	T1 Is1 pk	21.582 A	Transformer	Transformer Secondary1 Peak Current
52.	T1 Pd	2.338 W	Transformer	Estimated Losses in Transformer
53.	Vaux	10.5 V	Transformer	Auxiliary Voltage

Design Inputs

Name	Value	Description
Iout	5.0	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

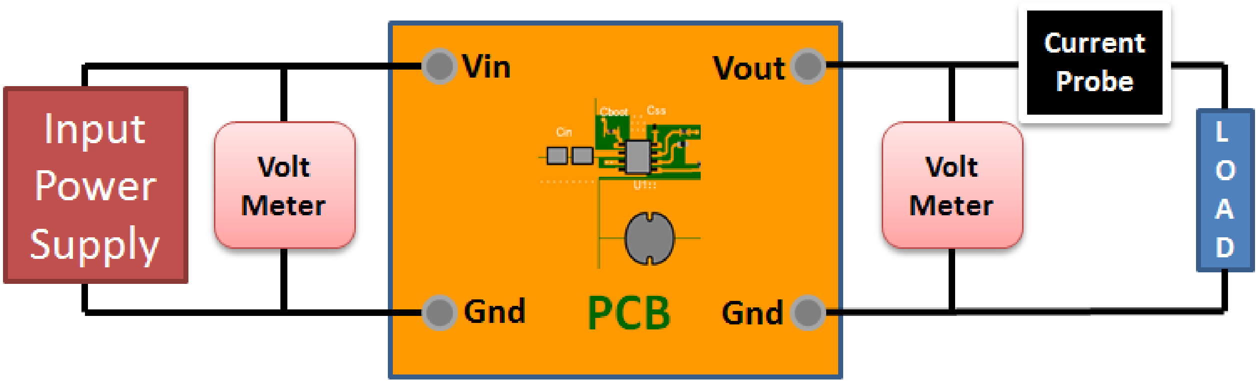
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. 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	B66229G0000X187
2.	Core Manufacturer	TDK
3.	Coil Former Part Number	B66230A1114T001
4.	Coil Former Manufacturer	TDK

Transformer Electrical Diagram

Primary

Turns	61.0
AWG	24.0
Layers	2.0
Strands	1.0
Insulation Type	Heavy Insulated Magnet Wire

Secondary

Turns	7.0
AWG	24.0
Layers	1.0
Strands	3.0
Insulation Type	Triple Insulated

Auxiliary

Turns	6.0
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 1/2.0	24.0	31	Clockwise
Auxiliary	28.0	6.0	Counter Clockwise
Triple Insulated Secondary	24.0	7.0	Counter Clockwise
Primary Second 1/2.0	24.0	30	Clockwise

Transformer Parameters

#	Name	Value
1.	Lpri	4.22E-4H
2.	Inductance Factor(Al)	114.0nH
3.	Npri	61.0
4.	Nsec	7.0
5.	Naux	6.0
6.	Core Type	E32/16/9
7.	Core Material	N87

#	Name	Value
8.	Bmax	0.20T
9.	Switching Frequency	55.00kHz
10.	DMax	0.45
11.	Ipk(Primary)	2.4A
12.	Irms(Primary)	0.93A
13.	Ipk(Secondary)	20.9A
14.	Irms(Secondary)	8.12A

Design Assistance

1. Master key : 82E2568724610D4C8CEA1FBE8C56E442[v1]
2. **LM5023** Product Folder : http://www.ti.com/product/LM5023 : contains the data sheet and other resources.