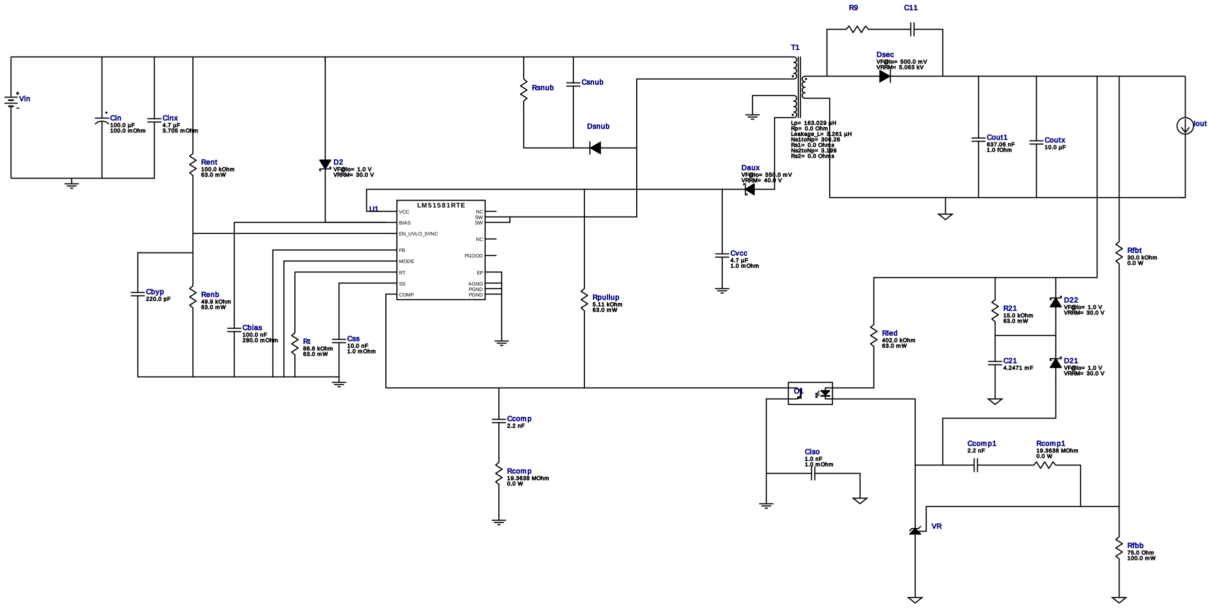
TEXAS INSTRUMENTS

WEBENCH ® Design Report

VinMin = 5.0V
VinMax = 5.0V
Vout = 1000.0V
Iout = 0.0A

Device = LM51581RTER
Topology = Flyback
Created = 2024-12-31 12:34:07.439
BOM Cost = NA
BOM Count = 32
Total Pd = 44.38W

Design : 2 LM51581RTER
LM51581RTER 5V-5V to 1000.00V @ 0.001A



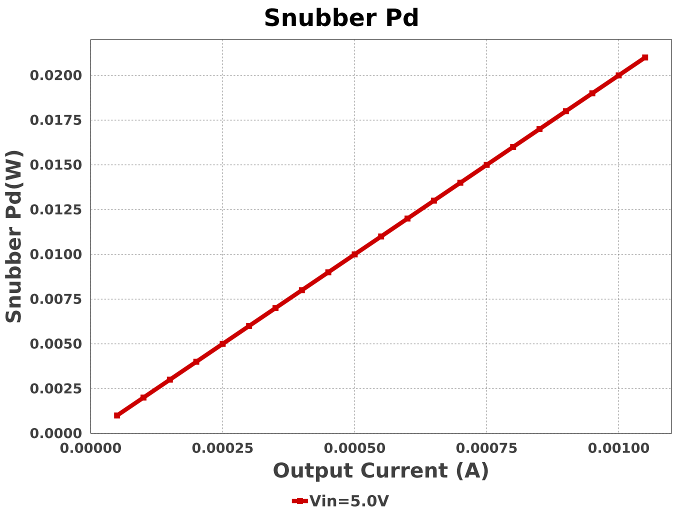
1. Notes: 1. Transformer windings: Np is the primary winding, Ns1 is the secondary winding and Ns2 is the winding for the auxiliary supply. 2. The primary side snubber (Rsnub,Csnub,Dsnub) and secondary side snubber(R9,C11),drive resistor (Rgate) are added as place holders. Kindly refer http://www.ti.com.cn/cn/lit/an/snva744/snva744.pdf for selecting diode for RCD snubber on switch node. Please refer http://www.ti.com/lit/an/slva255/slva255.pdf for design of snubber over the output diode. Hence the overall efficiency displayed is an approximate measure

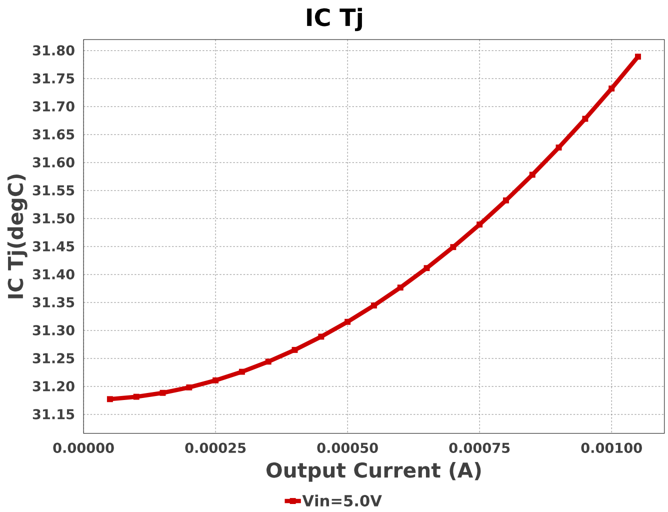
Electrical BOM

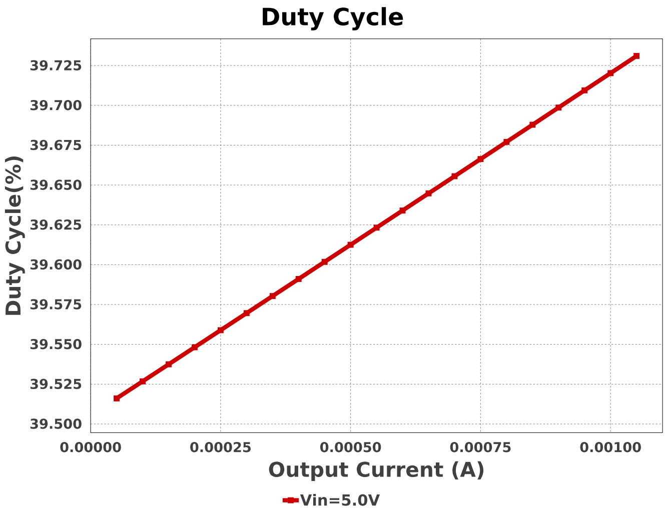
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
C21	CUSTOM	CUSTOM Series= ?	Cap= 4.2471 mF VDC= 25.0 V IRMS= 0.0 A	1	NA	CUSTOM 0 mm^2
Cbias	AVX	08053C104KAT2A Series= X7R	Cap= 100.0 nF ESR= 280.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm^2
Cbyp	MuRata	GRM1555C1H221JA01J Series= C0G/NP0	Cap= 220.0 pF VDC= 5.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Ccomp	Samsung Electro-Mechanics	CL21C222JBFNNNE Series= C0G/NP0	Cap= 2.2 nF VDC= 50.0 V IRMS= 0.0 A	1	$0.02	0805 7 mm^2
Ccomp1	Samsung Electro-Mechanics	CL21C222JBFNNNE Series= C0G/NP0	Cap= 2.2 nF VDC= 50.0 V IRMS= 0.0 A	1	$0.02	0805 7 mm^2
Cin	Vishay-Sprague	593D107X0010D2TE3 Series= 593D	Cap= 100.0 uF ESR= 100.0 mOhm VDC= 10.0 V IRMS= 1.22 A	1	$0.30	7343-31 59 mm^2
Cinx	MuRata	GRM31CR71C475KA01L Series= X7R	Cap= 4.7 uF ESR= 3.705 mOhm VDC= 16.0 V IRMS= 3.0989 A	1	$0.08	1206_190 11 mm^2
Ciso	Johanson Technology	202R18W102KV4E Series= X7R	Cap= 1.0 nF ESR= 1.0 mOhm VDC= 2.0 kV IRMS= 0.0 A	1	$0.06	1206_190 11 mm^2

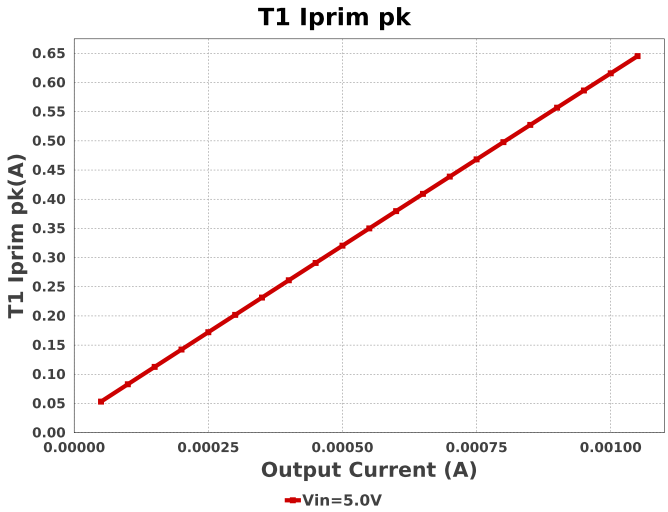
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cout1	CUSTOM	CUSTOM Series= ?	Cap= 637.06 nF ESR= 1.0 fOhm VDC= 2.0 kV IRMS= 1.38373 mA	1	NA	CUSTOM 0 mm^2
Coutx	CUSTOM	CUSTOM Series= ?	Cap= 10.0 uF VDC= 2.5 kV IRMS= 0.0 A	1	NA	CUSTOM 0 mm^2
Css	MuRata	GRM155R61A103KA01D Series= X5R	Cap= 10.0 nF ESR= 1.0 mOhm VDC= 10.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Cvcc	Taiyo Yuden	TMK212BJ475KG-T Series= X5R	Cap= 4.7 uF ESR= 1.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.06	0805 7 mm^2
D2	SMC Diode Solutions	BAT54WSTR	VF@Io= 1.0 V VRRM= 30.0 V	1	$0.02	SOD-323 9 mm^2
D21	SMC Diode Solutions	BAT54WSTR	VF@Io= 1.0 V VRRM= 30.0 V	1	$0.02	SOD-323 9 mm^2
D22	SMC Diode Solutions	BAT54WSTR	VF@Io= 1.0 V VRRM= 30.0 V	1	$0.02	SOD-323 9 mm^2
Daux	Fairchild Semiconductor	SS14FL	VF@Io= 550.0 mV VRRM= 40.0 V	1	$0.03	SOD-123F 12 mm^2
Dsec	CUSTOM	CUSTOM	VF@Io= 500.0 mV VRRM= 5.063 kV	1	NA	CUSTOM 0 mm^2
O1	Vishay-Semiconductor	TCMT1107	Optocoupler	1	$0.19	SOP-4 44 mm^2
R21	Vishay-Dale	CRCW040215K0FKED Series= CRCW..e3	Res= 15.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rcomp	CUSTOM	CUSTOM Series= ?	Res= 19.3638 MOhm Power= 0.0 W Tolerance= 0.0%	1	NA	CUSTOM 0 mm^2
Rcomp1	CUSTOM	CUSTOM Series= ?	Res= 19.3638 MOhm Power= 0.0 W Tolerance= 0.0%	1	NA	CUSTOM 0 mm^2
Renb	Vishay-Dale	CRCW040249K9FKED Series= CRCW..e3	Res= 49.9 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rent	Vishay-Dale	CRCW0402100KFKED Series= CRCW..e3	Res= 100.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbb	Yageo	RC0603FR-0775RL Series= ?	Res= 75.0 Ohm Power= 100.0 mW Tolerance= 1.0%	1	$0.01	0603 5 mm^2
Rfbt	CUSTOM	CUSTOM Series= ?	Res= 30.0 kOhm Power= 0.0 W Tolerance= 0.0%	1	NA	CUSTOM 0 mm^2
Rled	Vishay-Dale	CRCW0402402KFKED Series= CRCW..e3	Res= 402.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rled	Vishay-Dale	CRCW0402402KFKED Series= CRCW..e3	Res= 402.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rpullup	Vishay-Dale	CRCW04025K11FKED Series= CRCW..e3	Res= 5.11 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rt	Yageo	AC0402FR-0786K6L Series= ?	Res= 86.6 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2

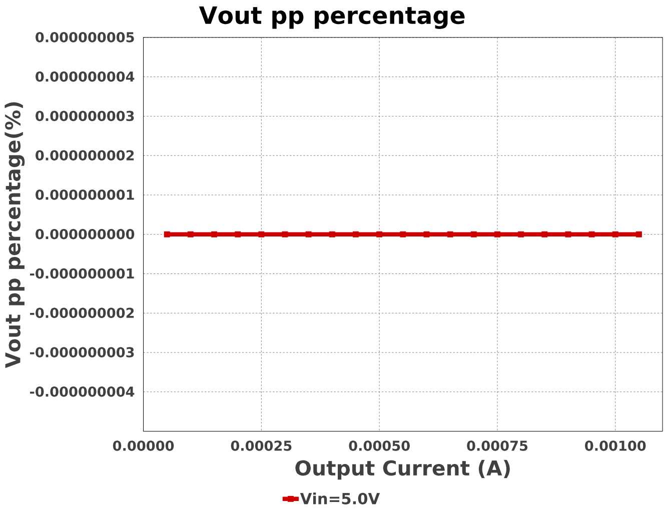
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
T1	CUSTOM	CUSTOM	Lp= 163.029 µH Rp= 0.0 Ohm Leakage_L= 3.261 µH Ns1toNp= 306.26 Rs1= 0.0 Ohms Ns2toNp= 3.199 Rs2= 0.0 Ohms	1	NA	CUSTOM 0 mm^2
U1	Texas Instruments	LM51581RTER	Switcher	1	$1.60	RTE0016K-IPC_A 16 mm^2
VR	Texas Instruments	TL431IDBVR	Voltage References	1	$0.05	 R-PDSO-G3 16 mm^2

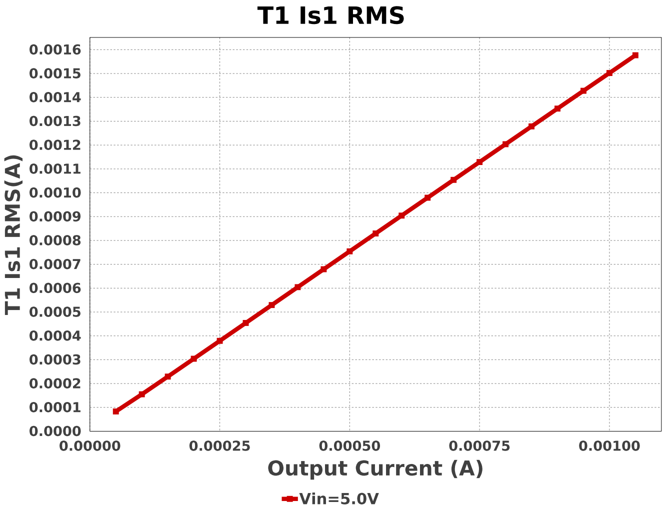


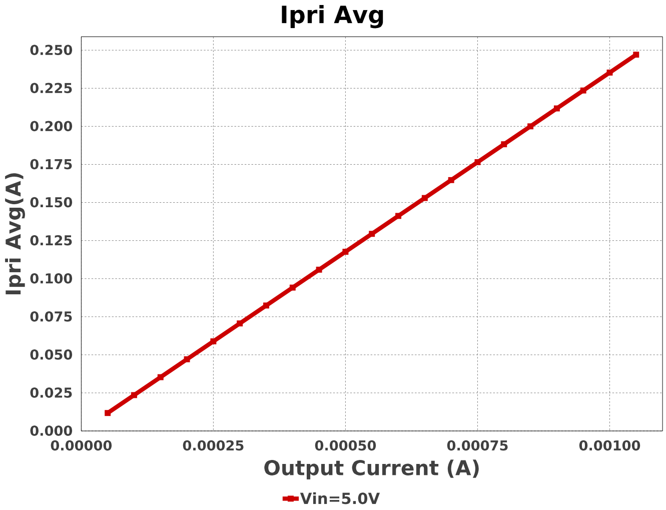


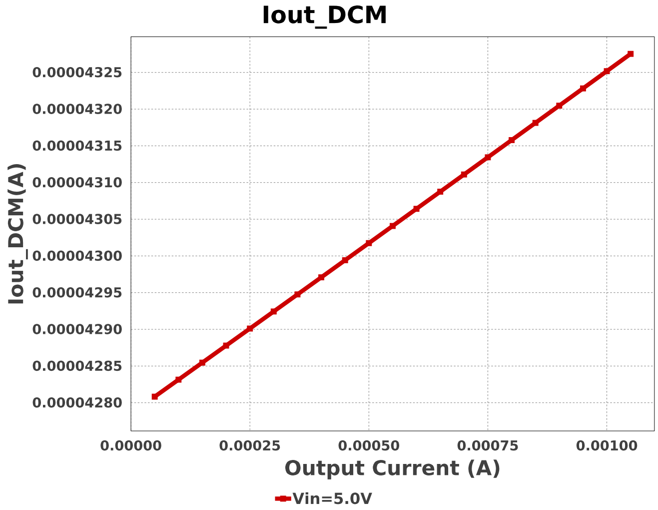


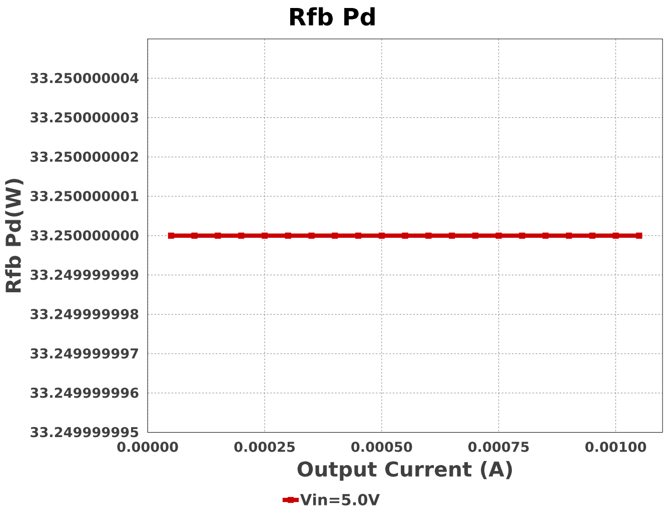


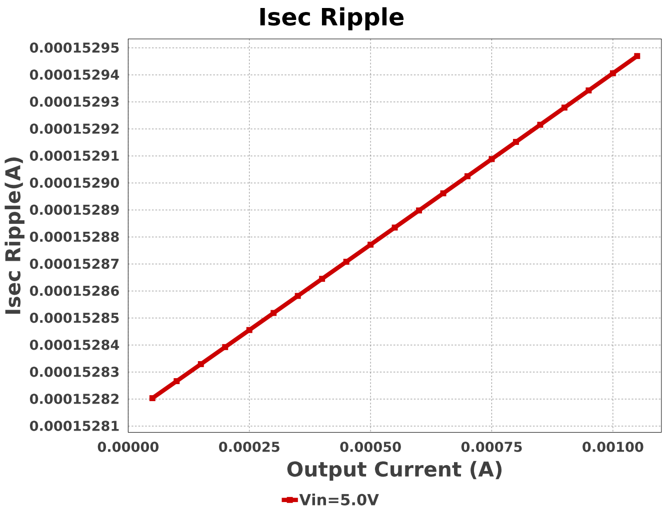

Vout pp percentage
0.000000005
0.000000004
0.000000003
0.000000002
0.000000001
0.000000000
-0.000000001
-0.000000002
-0.000000003
-0.000000004
Vout pp percentage(%)
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V


T1 Is1 RMS
0.0016
0.0015
0.0014
0.0013
0.0012
0.0011
0.0010
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0.0000
T1 Is1 RMS(A)
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V

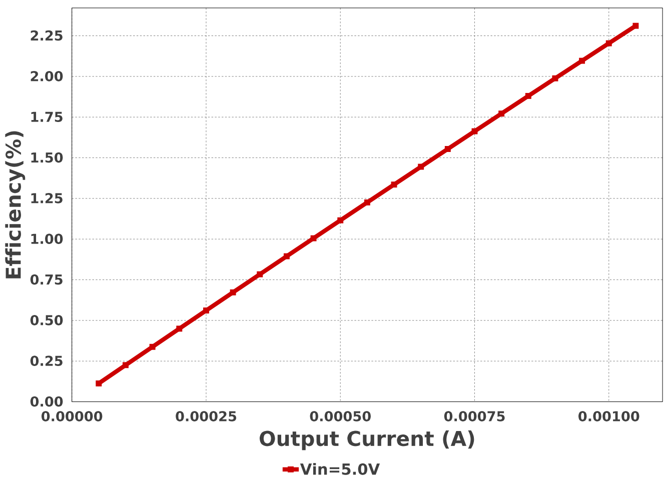

Ipri Avg
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
Ipri Avg(A)
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V


Iout_DCM
0.00004325
0.00004320
0.00004315
0.00004310
0.00004305
0.00004300
0.00004295
0.00004290
0.00004285
0.00004280
Iout_DCM(A)
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V

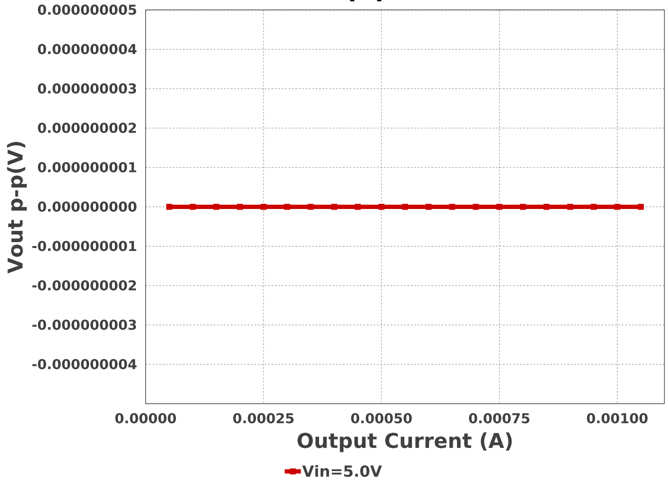

Rfb Pd
33.250000004
33.250000003
33.250000002
33.250000001
33.250000000
33.249999999
33.249999998
33.249999997
33.249999996
33.249999995
Rfb Pd(W)
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V


Isec Ripple
0.00015295
0.00015294
0.00015293
0.00015292
0.00015291
0.00015290
0.00015289
0.00015288
0.00015287
0.00015286
0.00015285
0.00015284
0.00015283
0.00015282
0.00015281
Isec Ripple(A)
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V

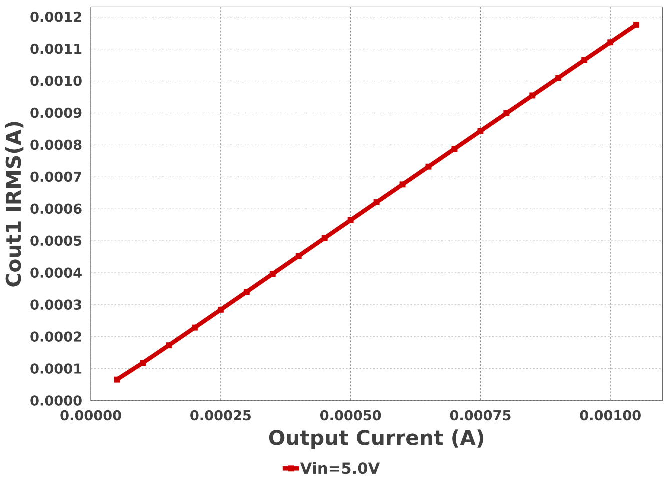
Efficiency



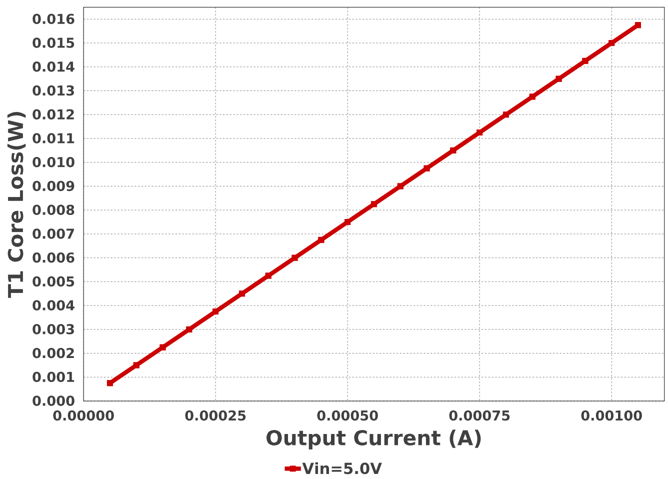
Vout p-p



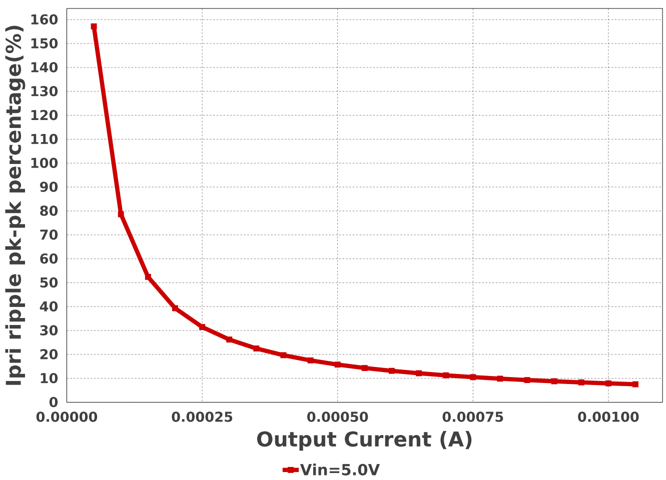
Cout1 IRMS



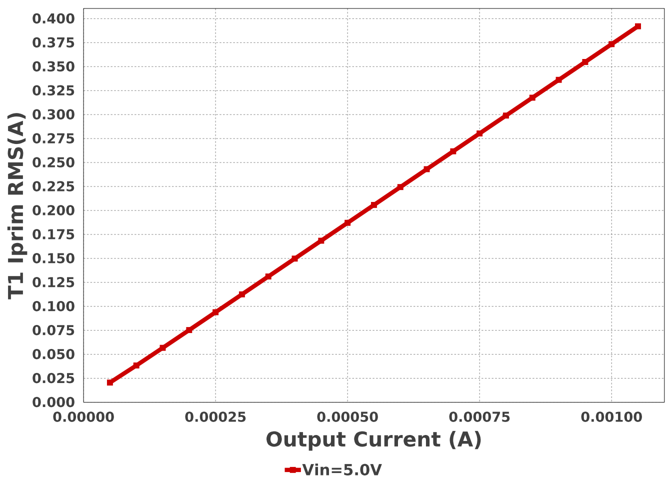
T1 Core Loss

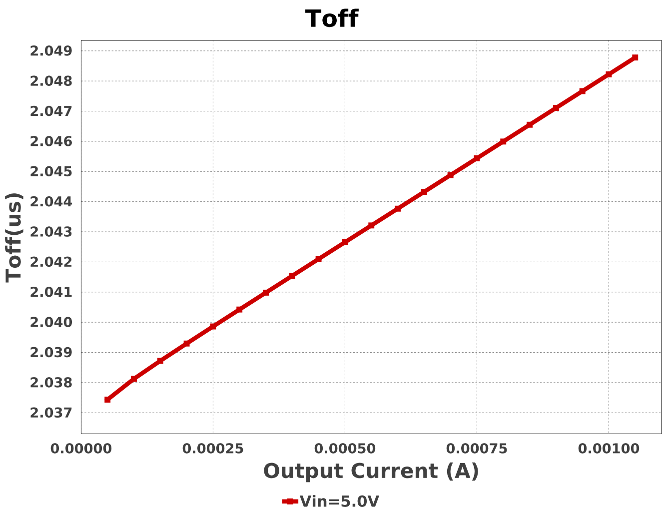


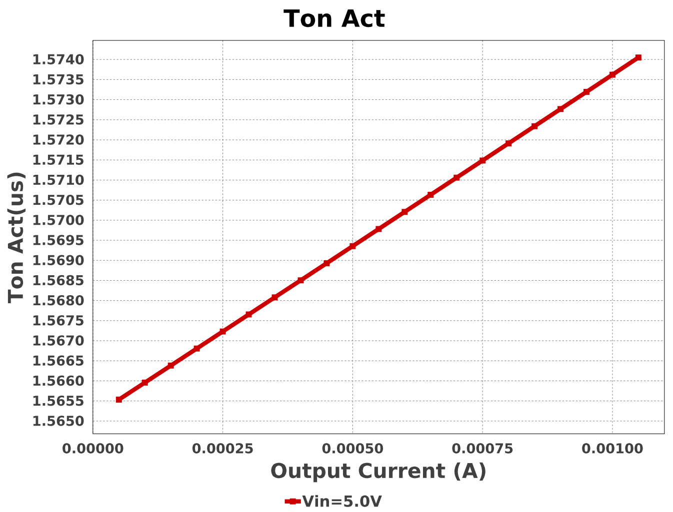
Ipri ripple pk-pk percentage

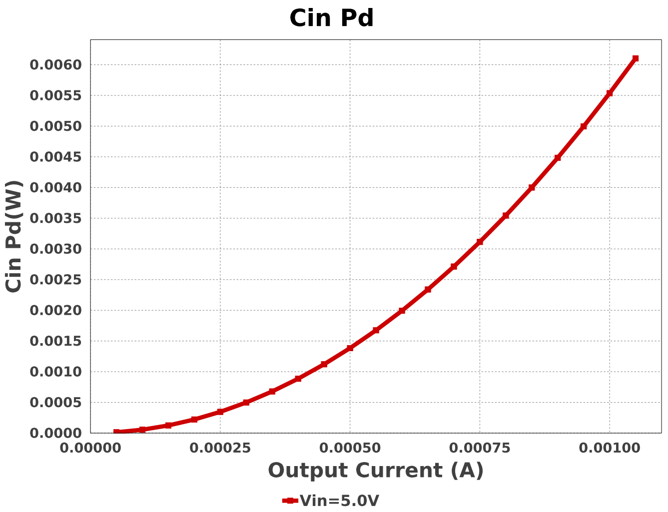


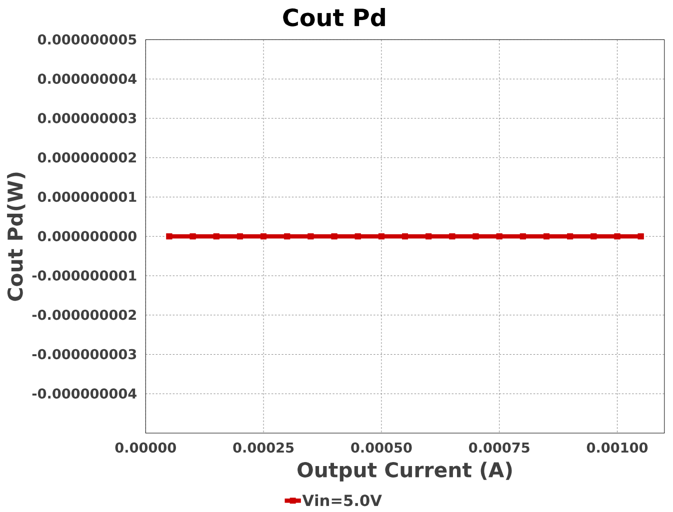
T1 Iprim RMS

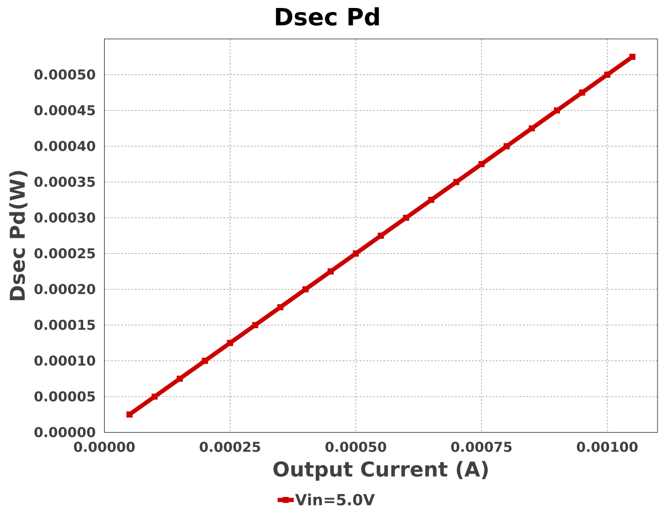


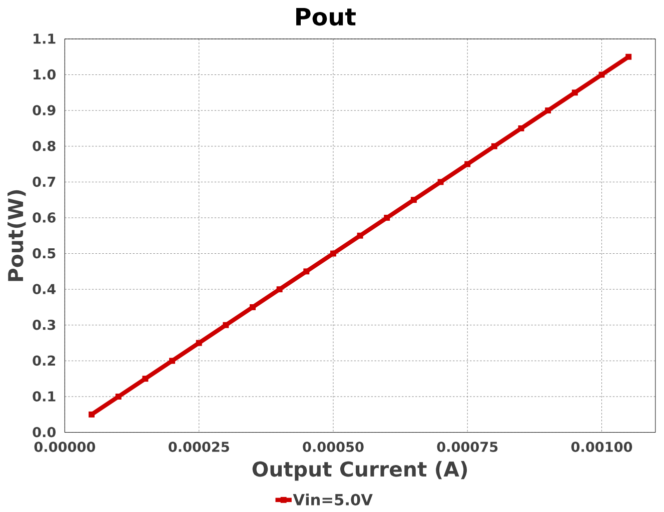

Toff
Toff(us)
2.049
2.048
2.047
2.046
2.045
2.044
2.043
2.042
2.041
2.040
2.039
2.038
2.037
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V

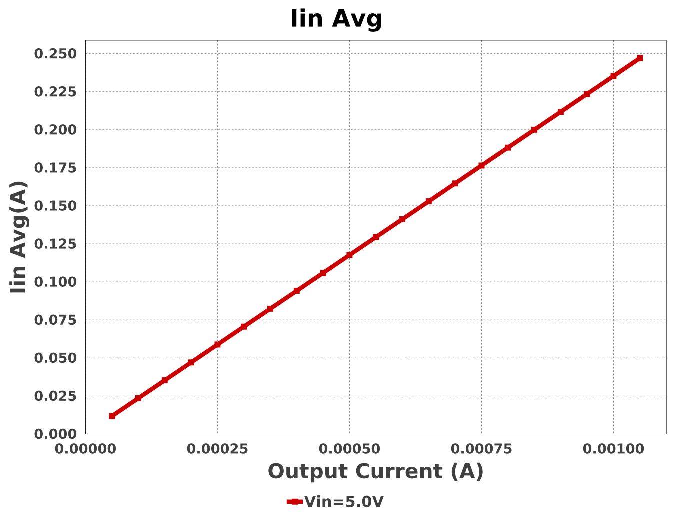

Ton Act
Ton Act(us)
1.5740
1.5735
1.5730
1.5725
1.5720
1.5715
1.5710
1.5705
1.5700
1.5695
1.5690
1.5685
1.5680
1.5675
1.5670
1.5665
1.5660
1.5655
1.5650
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V

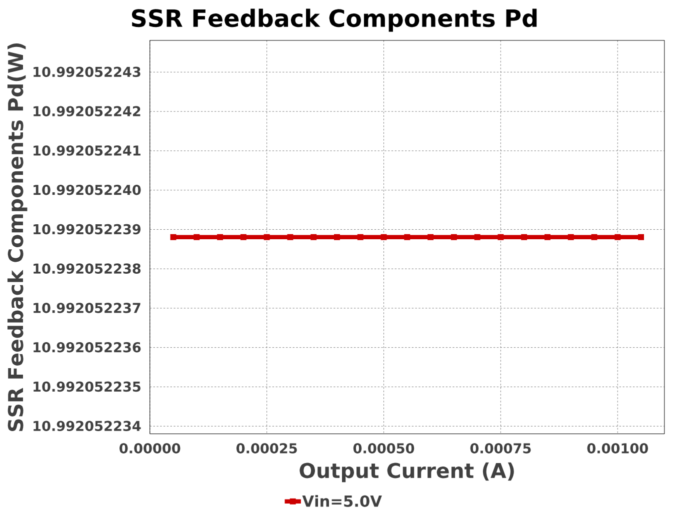

Cin Pd
Cin Pd(W)
0.0060
0.0055
0.0050
0.0045
0.0040
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V

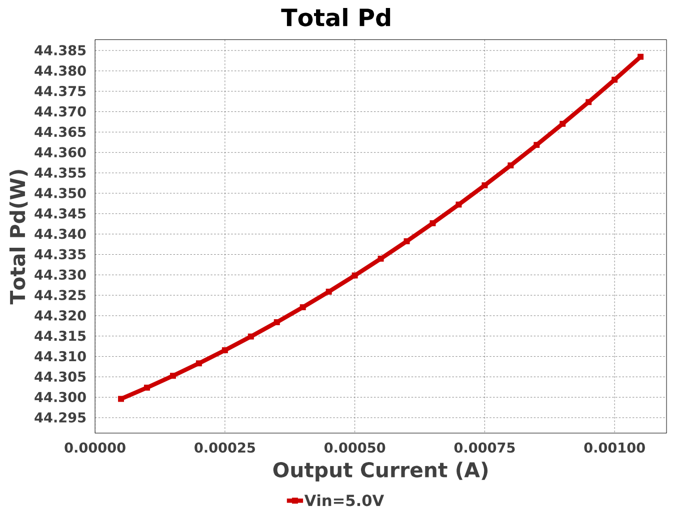

Cout Pd
Cout Pd(W)
0.000000005
0.000000004
0.000000003
0.000000002
0.000000001
0.000000000
-0.000000001
-0.000000002
-0.000000003
-0.000000004
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V

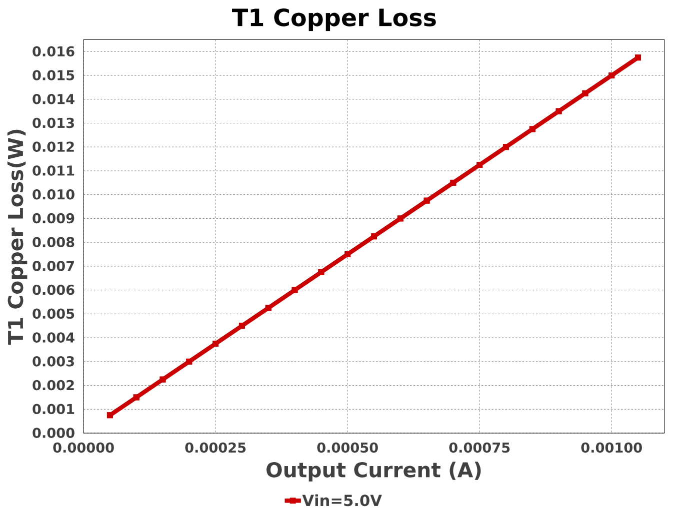

Dsec Pd
Dsec Pd(W)
0.00050
0.00045
0.00040
0.00035
0.00030
0.00025
0.00020
0.00015
0.00010
0.00005
0.00000
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V

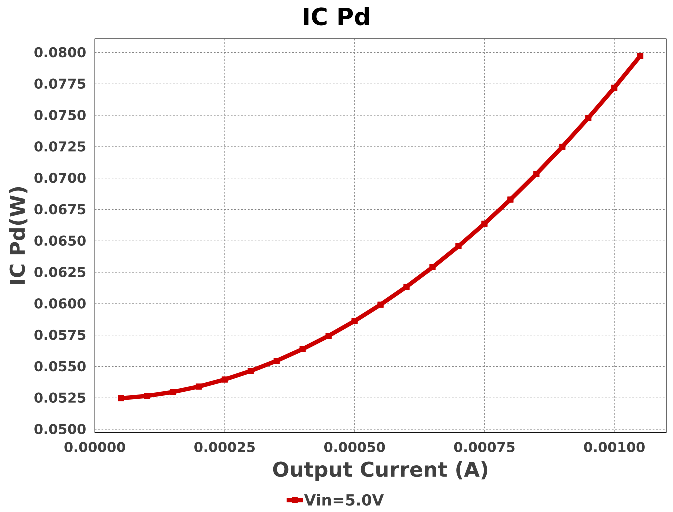

Pout
Pout(W)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V

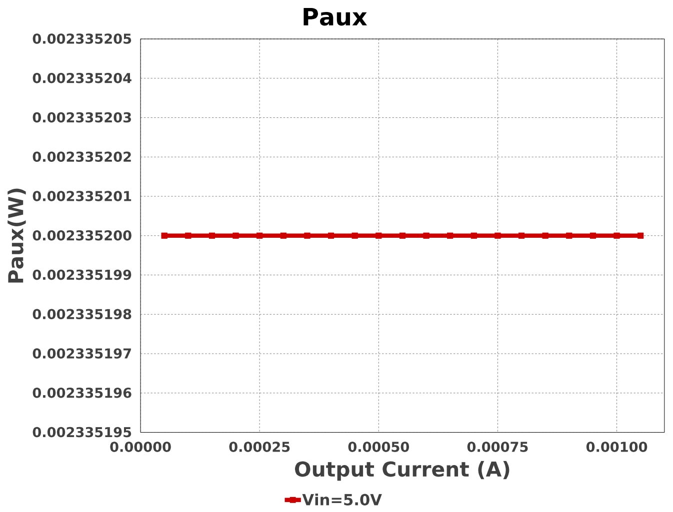

Iin Avg
Iin Avg(A)
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V

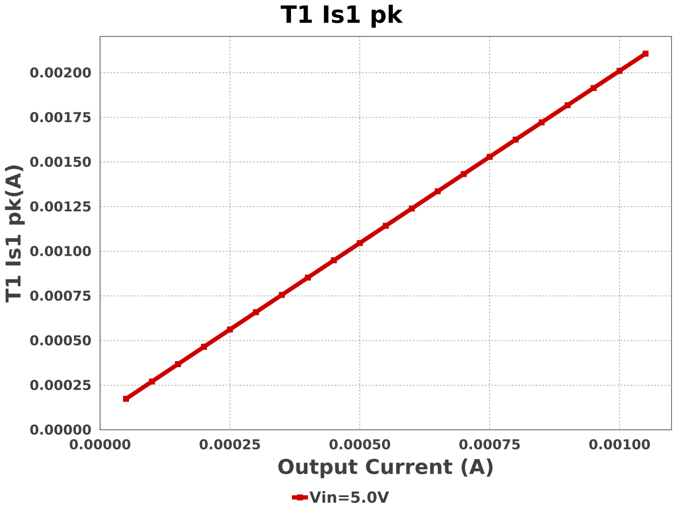

SSR Feedback Components Pd
SSR Feedback Components Pd(W)
10.992052243
10.992052242
10.992052241
10.992052240
10.992052239
10.992052238
10.992052237
10.992052236
10.992052235
10.992052234
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V

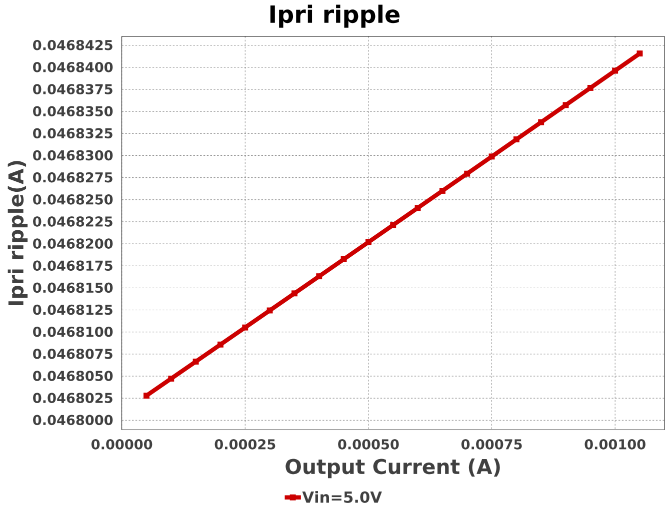

Total Pd
Total Pd(W)
44.385
44.380
44.375
44.370
44.365
44.360
44.355
44.350
44.345
44.340
44.335
44.330
44.325
44.320
44.315
44.310
44.305
44.300
44.295
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V

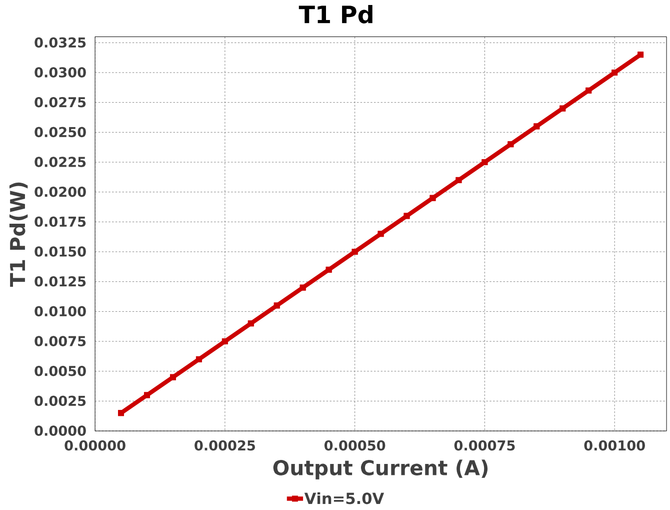

T1 Copper Loss
T1 Copper Loss(W)
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V

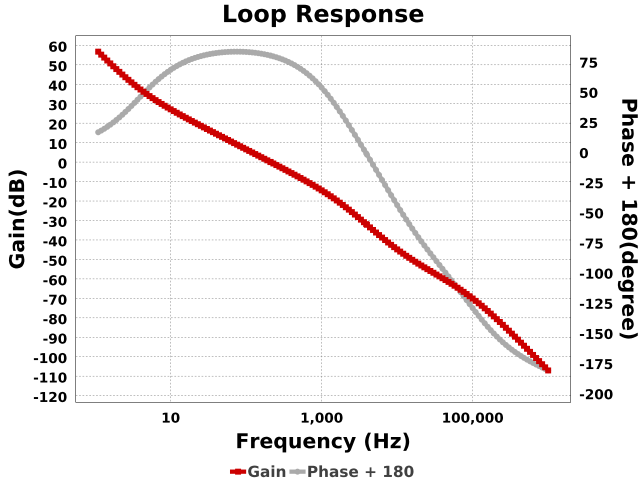

IC Pd
IC Pd(W)
0.0800
0.0775
0.0750
0.0725
0.0700
0.0675
0.0650
0.0625
0.0600
0.0575
0.0550
0.0525
0.0500
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V


Paux
Paux(W)
0.002335205
0.002335204
0.002335203
0.002335202
0.002335201
0.002335200
0.002335199
0.002335198
0.002335197
0.002335196
0.002335195
0.00000
0.00025
0.00050
0.00075
0.00100
Output Current (A)
Vin=5.0V









Operating Values

#	Name	Value	Category	Description
1.	Cin Pd	5.536 mW	Capacitor	Input capacitor power dissipation
2.	Cout Pd	0.0 fW	Capacitor	Output capacitor1 power dissipation
3.	Cout1 IRMS	1.121 mA	Capacitor	Output capacitor1 RMS ripple current
4.	Dsec Pd	500.0 µW	Diode	Secondary Diode Power Dissipation
5.	Dsec Vf	500.0 mV	Diode	Effective Forward Voltage Drop at the Operating Current
6.	IC Pd	77.198 mW	IC	IC power dissipation
7.	IC Tj	31.732 degC	IC	IC junction temperature
8.	ICThetaJA Effective	22.44 degC/W	IC	Effective IC Junction-to-Ambient Thermal Resistance
9.	Iin Avg	235.29 mA	IC	Average input current
10.	Cin Pd	5.536 mW	Power	Input capacitor power dissipation
11.	Cout Pd	0.0 fW	Power	Output capacitor1 power dissipation
12.	Dsec Pd	500.0 µW	Power	Secondary Diode Power Dissipation
13.	IC Pd	77.198 mW	Power	IC power dissipation
14.	Paux	2.335 mW	Power	Power Dissipation in Raux and Daux
15.	Rfb Pd	33.25 W	Power	Rfb Power Dissipation
16.	SSR Feedback Components Pd	10.992 W	Power	SSR control Mode Feedback Components Power Dissipation.
17.	Snubber Pd	20.0 mW	Power	Approximate Snubber Power Dissipation (Assumed 2% of Output Power)
18.	T1 Copper Loss	15.0 mW	Power	Transformer Copper Loss Power Dissipation
19.	T1 Core Loss	15.0 mW	Power	Transformer Core Loss Power Dissipation
20.	T1 Pd	30.0 mW	Power	Estimated Losses in Transformer
21.	Total Pd	44.378 W	Power	Total Power Dissipation
22.	Rfb Pd	33.25 W	Resistor	Rfb Power Dissipation
23.	BOM Count	32	System Information	Total Design BOM count
24.	Cross Freq	169.614 Hz	System Information	Bode plot crossover frequency
25.	Duty Cycle	39.72 %	System Information	Duty cycle
26.	Efficiency	2.204 %	System Information	Steady state efficiency

#	Name	Value	Category	Description
27.	FootPrint	363.0 mm^2	System Information	Total Foot Print Area of BOM components
28.	Frequency	252.413 kHz	System Information	Switching frequency
29.	Gain Marg	-34.185 dB	System Information	Bode Plot Gain Margin
30.	Iout	1.0 mA	System Information	Iout operating point
31.	Iout_DCM	43.252 µA	System Information	Approximate Current below which DCM mode of operation will begin
32.	Low Freq Gain	54.81 dB	System Information	Gain at 1Hz
33.	Mode	CCM	System Information	Conduction Mode
34.	Phase Marg	82.383 deg	System Information	Bode Plot Phase Margin
35.	Pout	1.0 W	System Information	Total output power
36.	Toff	2.048 us	System Information	Approximate Converter Off Time
37.	Ton Act	1.574 us	System Information	Approximate Converter On Time
38.	Total BOM	NA	System Information	Total BOM Cost
39.	Tsw	3.962 us	System Information	Switching Time Period
40.	Vin	5.0 V	System Information	Vin operating point
41.	Vout	1,000.0 V	System Information	Operational Output Voltage
42.	Vout Actual	1.0 kV	System Information	Vout Actual calculated based on selected voltage divider resistors
43.	Vout Tolerance	1.412 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
44.	Vout p-p	0.0 fV	System Information	Peak-to-peak output ripple voltage
45.	Vout pp percentage	0.0 f%	System Information	Output Voltage ripple percentage
46.	Vsnub	5.877 V	System Information	Voltage Across the Snubber
47.	Ipri Avg	235.296 mA	Transformer	Average Current in Primary Winding over the complete Switching Period
48.	Ipri ripple	46.84 mA	Transformer	Ripple Current in the Primary Winding
49.	Ipri ripple pk-pk percentage	7.907 %	Transformer	Primary Current pk-pk ripple percentage(of Ipri avg during ton only)
50.	Isec Ripple	152.941 µA	Transformer	Ripple Current in the Secondary Winding
51.	Paux	2.335 mW	Transformer	Power Dissipation in Raux and Daux
52.	T1 Copper Loss	15.0 mW	Transformer	Transformer Copper Loss Power Dissipation
53.	T1 Core Loss	15.0 mW	Transformer	Transformer Core Loss Power Dissipation
54.	T1 Iprim RMS	373.44 mA	Transformer	Transformer Primary RMS Current
55.	T1 Iprim pk	615.802 mA	Transformer	Transformer Primary Peak Current
56.	T1 Is1 RMS	1.502 mA	Transformer	Transformer Secondary1 RMS Current
57.	T1 Is1 pk	2.011 mA	Transformer	Transformer Secondary1 Peak Current
58.	T1 Pd	30.0 mW	Transformer	Estimated Losses in Transformer
59.	Vaux	10.0 V	Transformer	Auxiliary Voltage

Design Inputs

Name	Value	Description
Iout	1.0 m	Maximum Output Current
VinMax	5.0	Maximum input voltage
VinMin	5.0	Minimum input voltage
Vout	1,000.0	Output Voltage
base_pn	LM51581	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

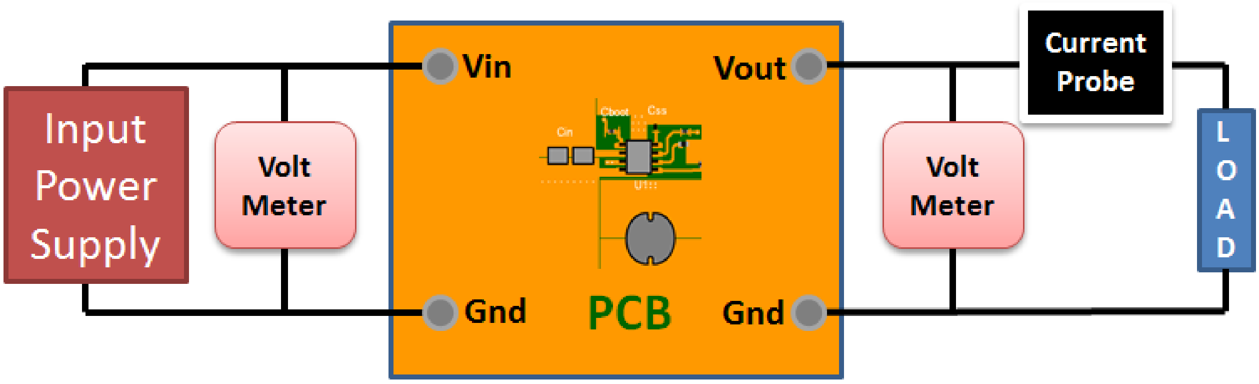
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. 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 5.0V 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 : 25084DDD31280D39C566B62A7A79E8ED[v1]

2. **LM51581** Product Folder : http://www.ti.com/product/LM51581 : contains the data sheet and other resources.

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