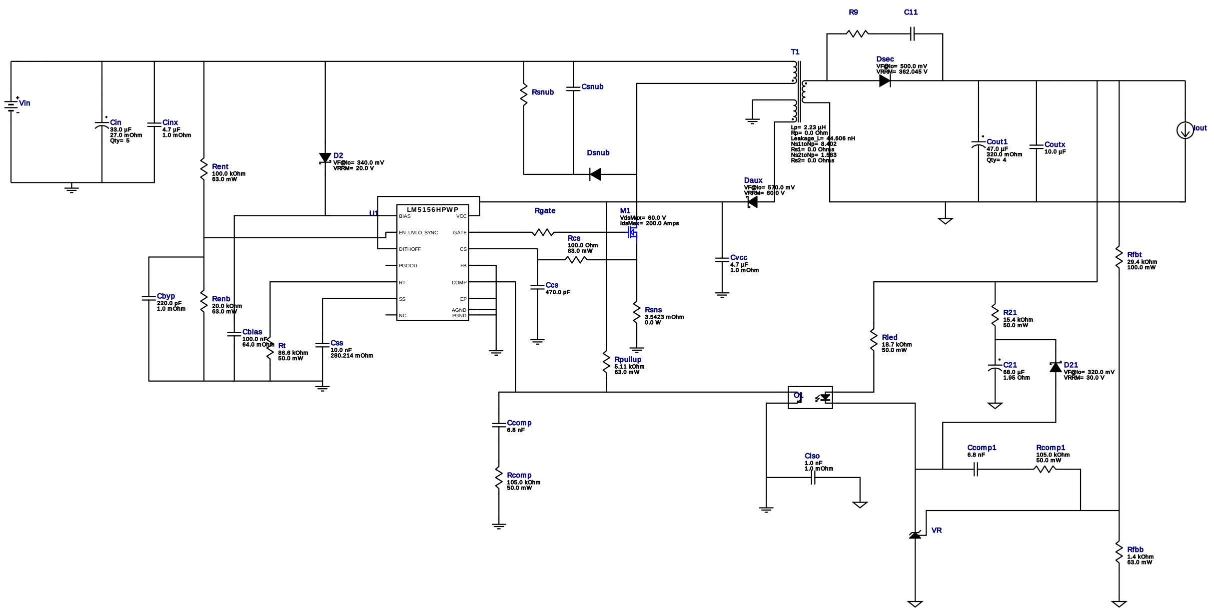
VinMin = 10.0V
VinMax = 15.0V
Vout = 55.0V
Iout = 1.1A

Device = LM5156HPWPR
Topology = Flyback
Created = 2022-02-23 00:45:25.821
BOM Cost = NA
BOM Count = 41
Total Pd = 6.94W

WEBENCH ® Design Report

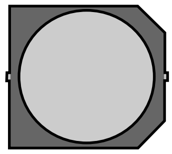
Design : 13 LM5156HPWPR
LM5156HPWPR 10V-15V to 55.00V @ 1.1A



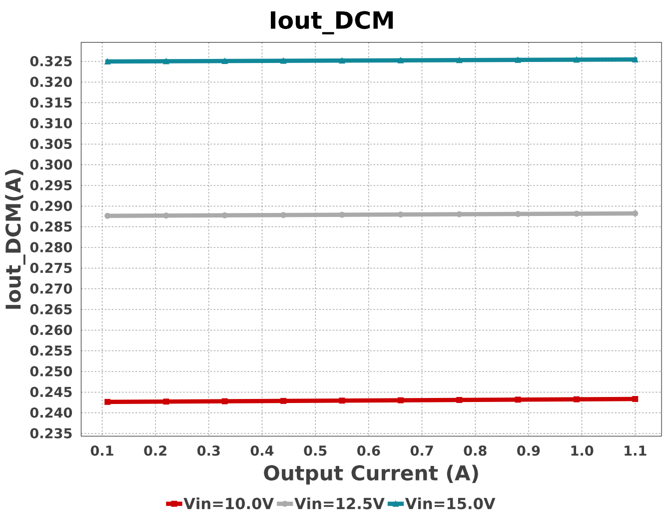
1. Notes: 1. Transformer windings: Np is the primary winding, Ns1 is the secondary winding and Ns2 is the winding for the auxiliary supply. 2. The primary side snubber (Rsnub,Csnub,Dsnub) and secondary side snubber(R9,C11),drive resistor (Rgate) are added as place holders. Kindly refer http://www.ti.com.cn/cn/lit/an/snva744/snva744.pdf 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

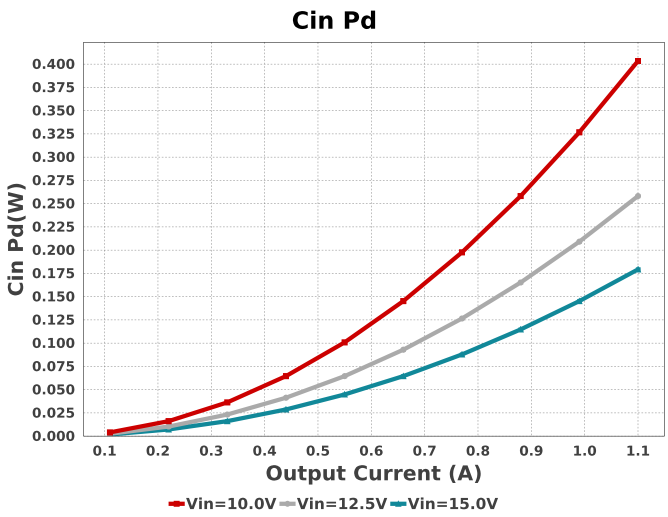
Electrical BOM

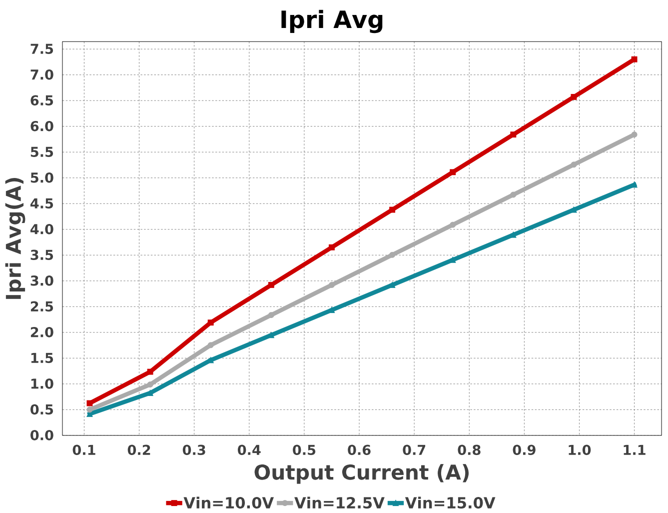
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
C21	Chemi-Con	ELXZ500ELL680MF15D Series= LXZ	Cap= 68.0 uF ESR= 1.95 Ohm VDC= 50.0 V IRMS= 360.0 mA	1	$0.09	Chemi-Con_630x1500 69 mm^2
Cbias	Kemet	C0805C104M5RACTU Series= X7R	Cap= 100.0 nF ESR= 64.0 mOhm VDC= 50.0 V IRMS= 1.64 A	1	$0.01	0805 7 mm^2
Cbyp	MuRata	GRM033R71C221KA01D Series= X7R	Cap= 220.0 pF ESR= 1.0 mOhm VDC= 16.0 V IRMS= 0.0 A	1	$0.01	0201 2 mm^2
Ccomp	TDK	C2012C0G1H682J060AA Series= C0G/NP0	Cap= 6.8 nF VDC= 50.0 V IRMS= 0.0 A	1	$0.04	0805 7 mm^2
Ccomp1	TDK	C2012C0G1H682J060AA Series= C0G/NP0	Cap= 6.8 nF VDC= 50.0 V IRMS= 0.0 A	1	$0.04	0805 7 mm^2
Ccs	AVX	04025A471JAT2A Series= C0G/NP0	Cap= 470.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Cin	Panasonic	20SVPG33M Series= SVPG	Cap= 33.0 uF ESR= 27.0 mOhm VDC= 20.0 V IRMS= 3.0 A	5	$0.40	CAPSMT_62_B45 53 mm^2

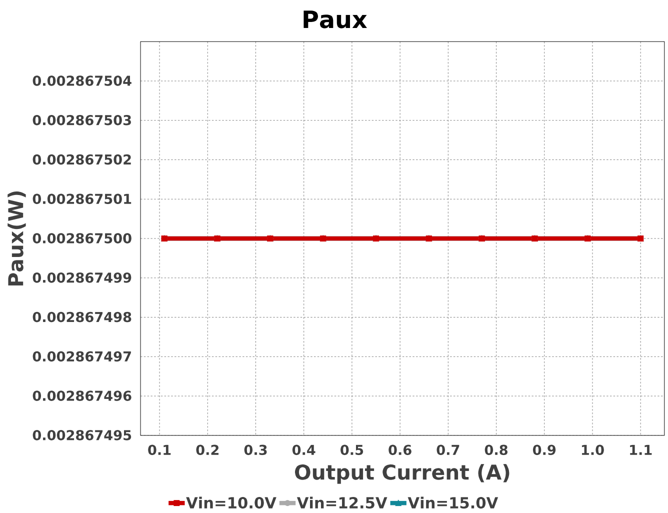
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cinx	CUSTOM	CUSTOM Series= ?	Cap= 4.7 uF ESR= 1.0 mOhm VDC= 19.5 V IRMS= 12.9643 A	1	NA	CUSTOM 0 mm^2
Ciso	Johanson Technology	202R18W102KV4E Series= X7R	Cap= 1.0 nF ESR= 1.0 mOhm VDC= 2.0 kV IRMS= 0.0 A	1	$0.08	1206_190 11 mm^2
Cout1	Panasonic	EEV-FK2A470Q Series= FK	Cap= 47.0 uF ESR= 320.0 mOhm VDC= 100.0 V IRMS= 500.0 mA	4	$0.45	 SM_RADIAL_H13 264 mm^2
Coutx	CUSTOM	CUSTOM Series= ?	Cap= 10.0 uF VDC= 137.5 V IRMS= 0.0 A	1	NA	CUSTOM 0 mm^2
Css	TDK	CGA1A2X7R1A103K030BA Series= X7R	Cap= 10.0 nF ESR= 280.21 mOhm VDC= 10.0 V IRMS= 245.72 mA	1	$0.01	0201_033 2 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	Fairchild Semiconductor	MBR1020VL	VF@Io= 340.0 mV VRRM= 20.0 V	1	$0.07	SOD-123F 12 mm^2
D21	Toshiba	CMS06	VF@Io= 320.0 mV VRRM= 30.0 V	1	$0.19	M-FLAT 19 mm^2
Daux	Nexperia	PMEG6010CEH,115	VF@Io= 570.0 mV VRRM= 60.0 V	1	$0.04	SOD-123F 12 mm^2
Dsec	CUSTOM	CUSTOM	VF@Io= 500.0 mV VRRM= 362.045 V	1	NA	CUSTOM 0 mm^2
M1	Texas Instruments	CSD18536KCS	VdsMax= 60.0 V IdsMax= 200.0 Amps	1	$1.79	KCS0003B 80 mm^2
O1	Fairchild Semiconductor	FOD817A	Optocoupler	1	$0.11	 DIP-4 71 mm^2
R21	Yageo	RC0201FR-0715K4L Series= ?	Res= 15.4 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm^2
Rcomp	Yageo	RC0201FR-07105KL Series= ?	Res= 105.0 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm^2
Rcomp1	Yageo	RC0201FR-07105KL Series= ?	Res= 105.0 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm^2
Rcs	Vishay-Dale	CRCW0402100RFKED Series= CRCW..e3	Res= 100.0 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Renb	Vishay-Dale	CRCW040220K0FKED Series= CRCW..e3	Res= 20.0 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	Vishay-Dale	CRCW04021K40FKED Series= CRCW..e3	Res= 1.4 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2

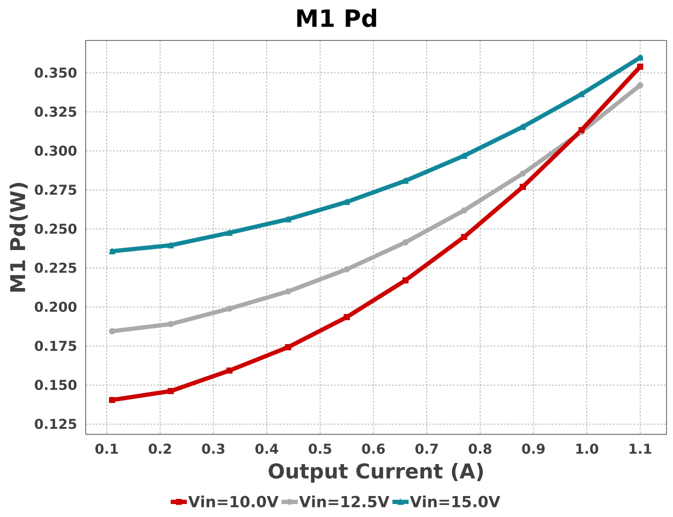
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Rfbt	Vishay-Dale	CRCW060329K4FKEA Series= CRCW..e3	Res= 29.4 kOhm Power= 100.0 mW Tolerance= 1.0%	1	$0.01	0603 5 mm²
Rled	Yageo	RC0201FR-0718K7L Series= ?	Res= 18.7 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm²
Rpullup	Vishay-Dale	CRCW04025K11FKED Series= CRCW..e3	Res= 5.11 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm²
Rsns	CUSTOM	CUSTOM Series= ?	Res= 3.5423 mOhm Power= 0.0 W Tolerance= 0.0%	1	NA	CUSTOM 0 mm²
Rt	Yageo	RC0201FR-0786K6L Series= ?	Res= 86.6 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm²
T1	CUSTOM	CUSTOM	Lp= 2.23 µH Rp= 0.0 Ohm Leakage_L= 44.606 nH Ns1toNp= 8.402 Rs1= 0.0 Ohms Ns2toNp= 1.583 Rs2= 0.0 Ohms	1	NA	CUSTOM 0 mm²
U1	Texas Instruments	LM5156HPWPR	Switcher	1	$0.73	PWP0014H 59 mm²
VR	Texas Instruments	TL431IDBVR	Voltage References	1	$0.07	R-PDSO-G3 16 mm²

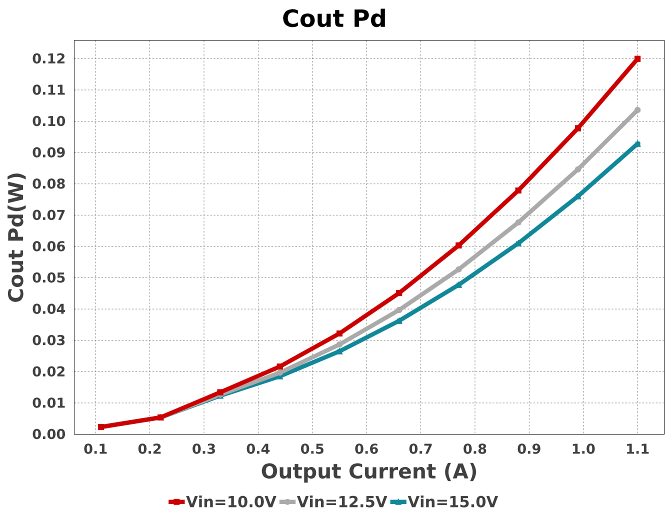


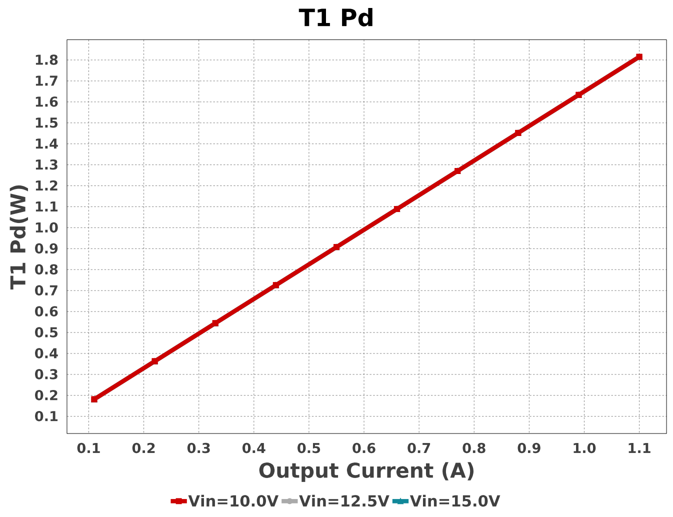


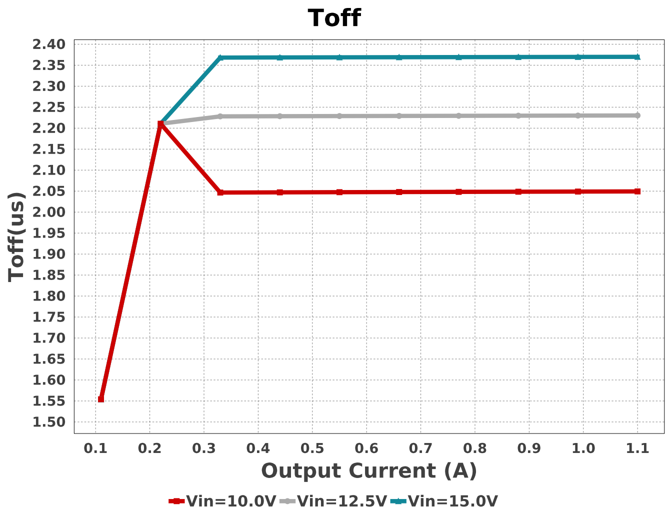


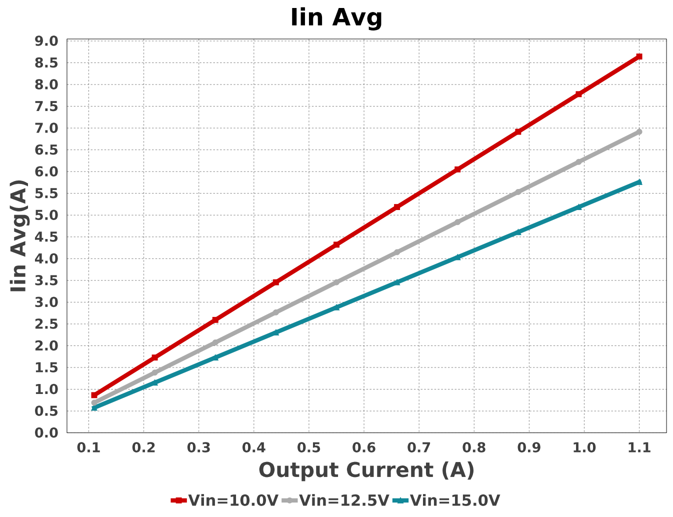


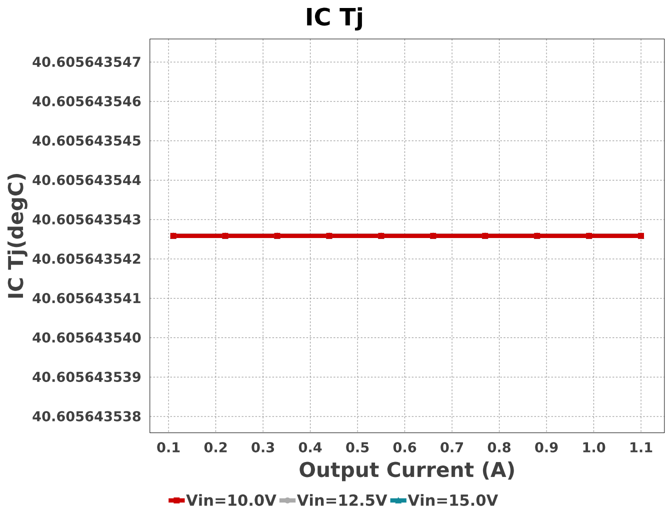

M1 Pd
M1 Pd(W)
0.350
0.325
0.300
0.275
0.250
0.225
0.200
0.175
0.150
0.125
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

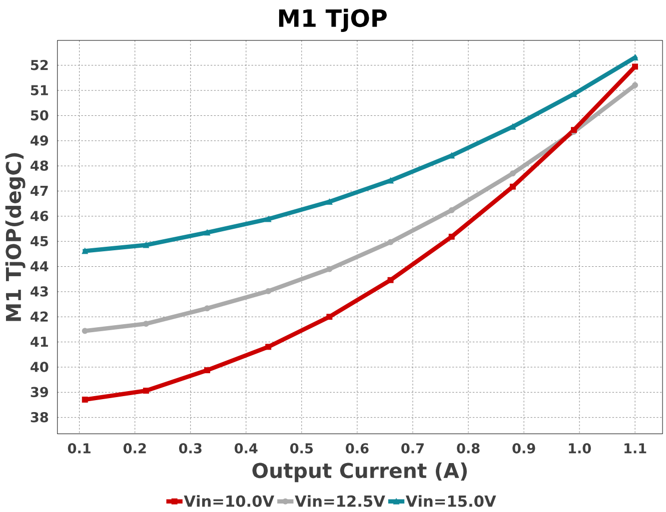

Cout Pd
Cout Pd(W)
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

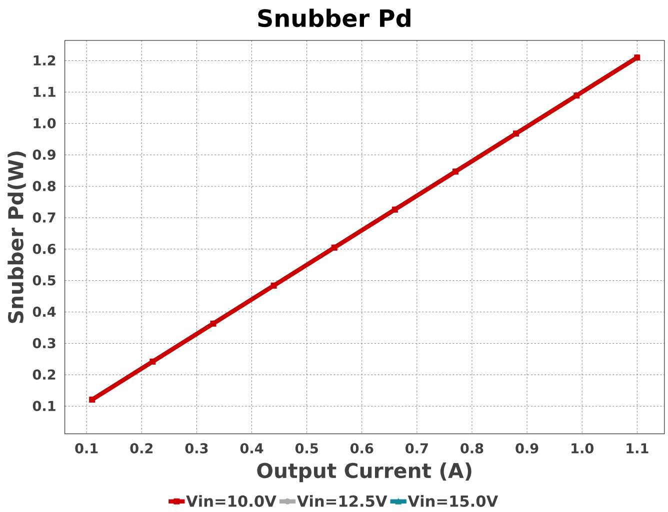

T1 Pd
T1 Pd(W)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

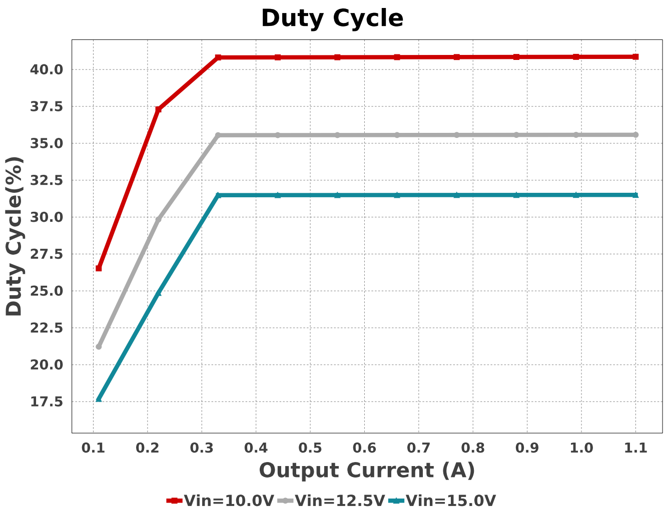

Toff
Toff(us)
2.40
2.35
2.30
2.25
2.20
2.15
2.10
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

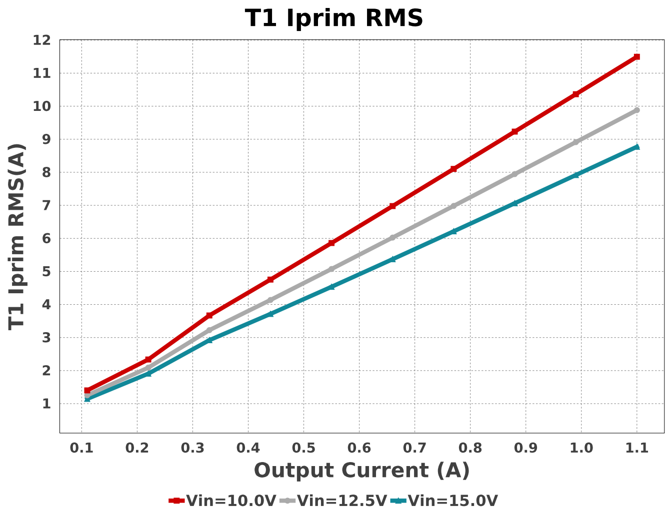

Iin Avg
Iin Avg(A)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

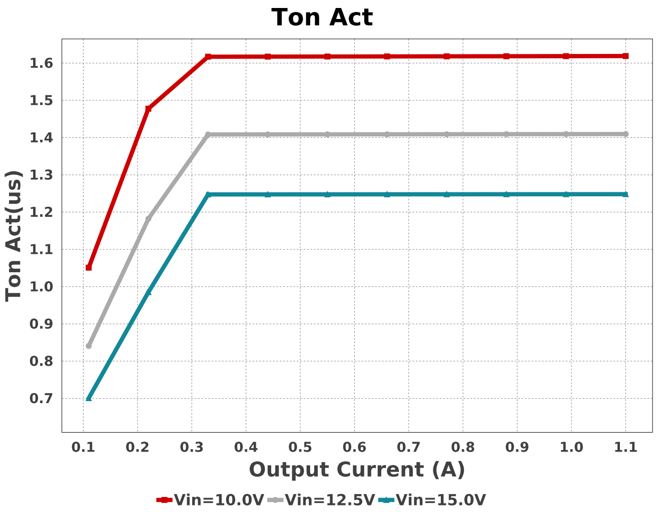

IC Tj
IC Tj(degC)
40.605643547
40.605643546
40.605643545
40.605643544
40.605643543
40.605643542
40.605643541
40.605643540
40.605643539
40.605643538
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

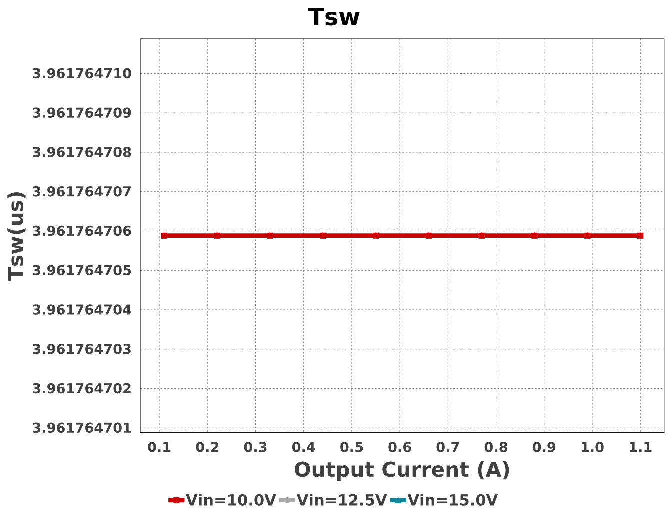

M1 TjOP
M1 TjOP(degC)
Output Current (A)
Vin=10.0V
Vin=12.5V
Vin=15.0V


Snubber Pd
Snubber Pd(W)
Output Current (A)
Vin=10.0V
Vin=12.5V
Vin=15.0V

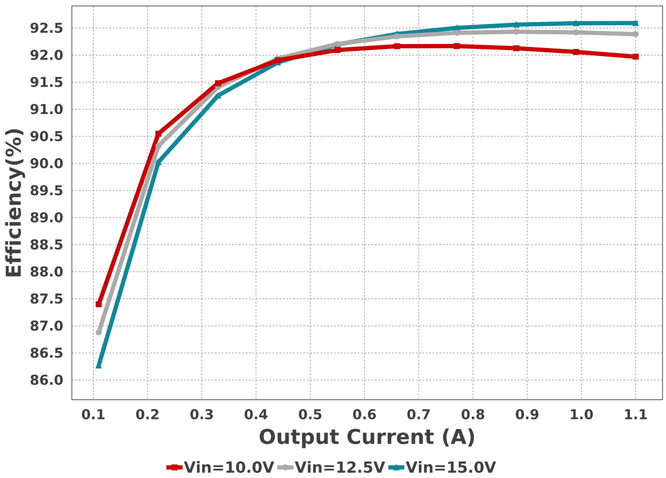

Duty Cycle
Duty Cycle(%)
Output Current (A)
Vin=10.0V
Vin=12.5V
Vin=15.0V


T1 Iprim RMS
T1 Iprim RMS(A)
Output Current (A)
Vin=10.0V
Vin=12.5V
Vin=15.0V

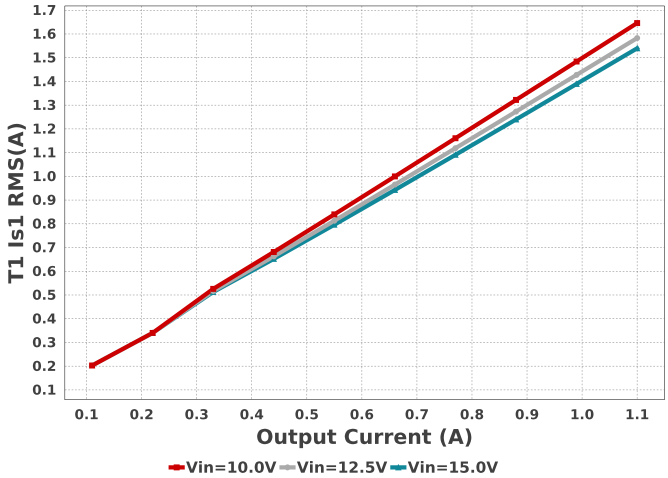

Ton Act
Ton Act(us)
Output Current (A)
Vin=10.0V
Vin=12.5V
Vin=15.0V


Tsw
Tsw(us)
Output Current (A)
Vin=10.0V
Vin=12.5V
Vin=15.0V

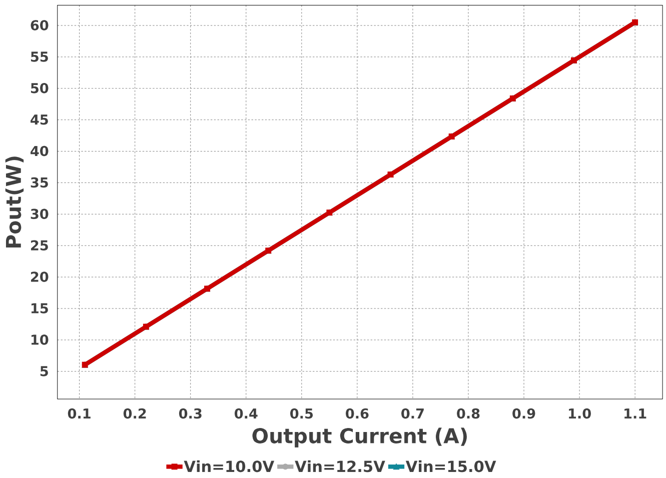
Efficiency



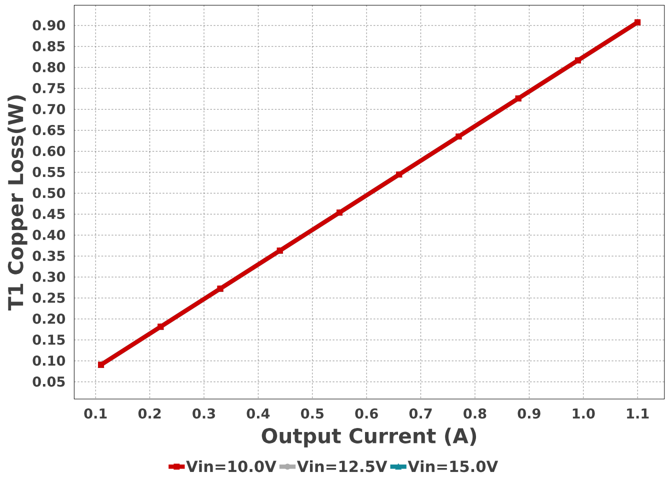
T1 Is1 RMS



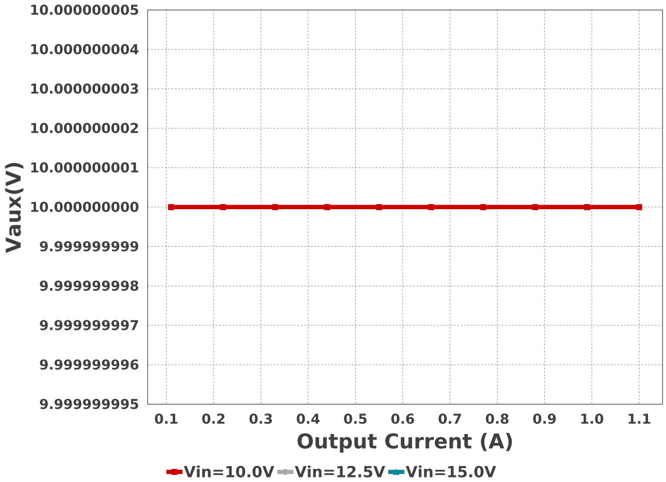
Pout



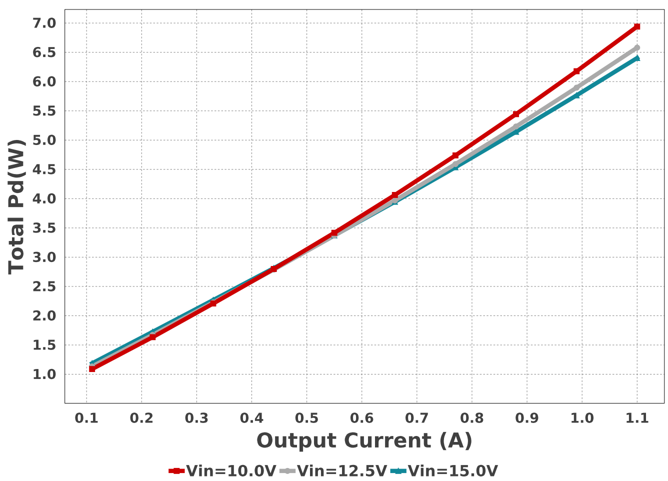
T1 Copper Loss

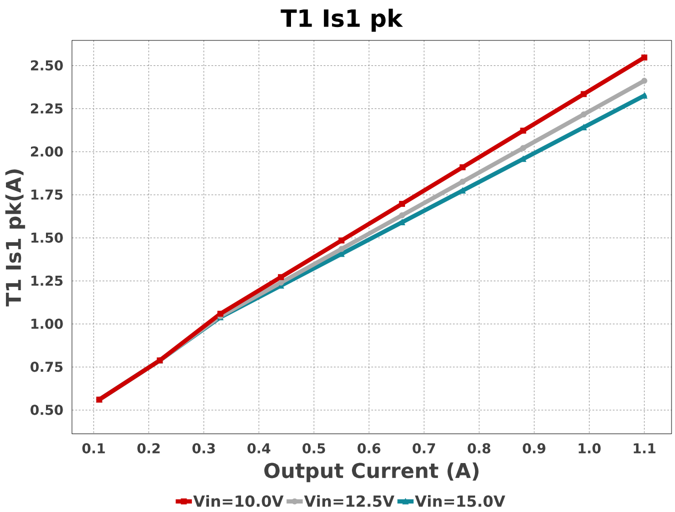


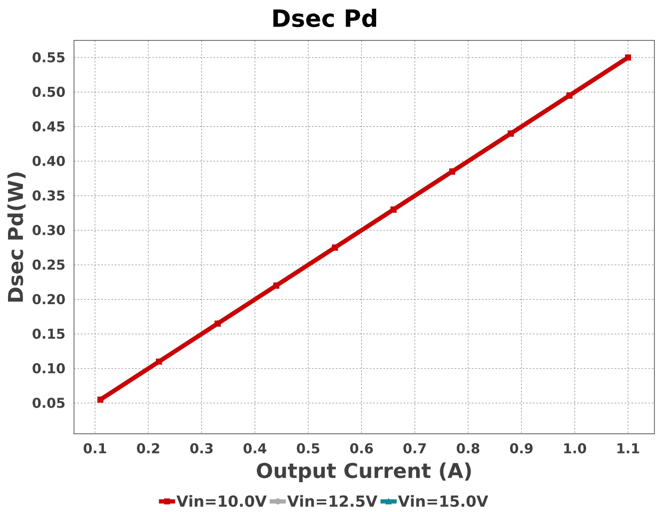
Vaux

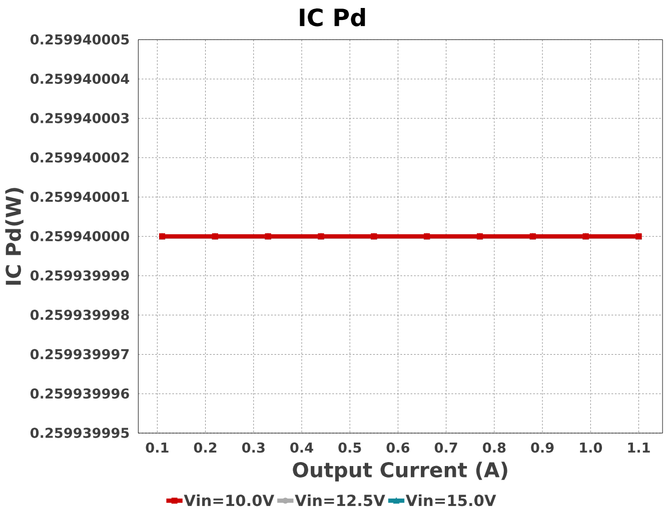


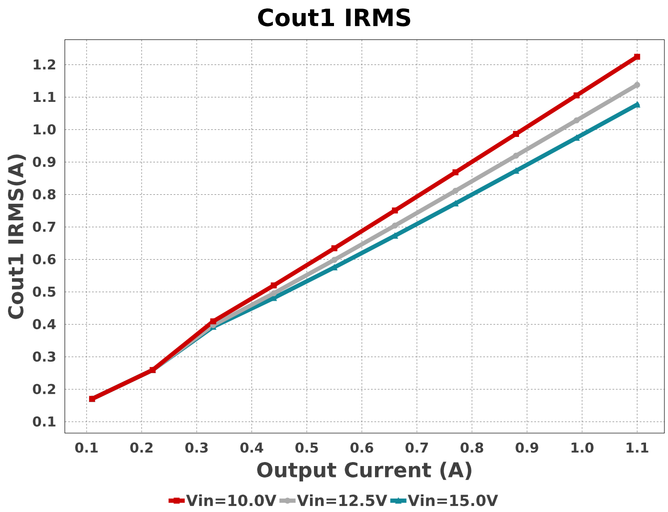
Total Pd

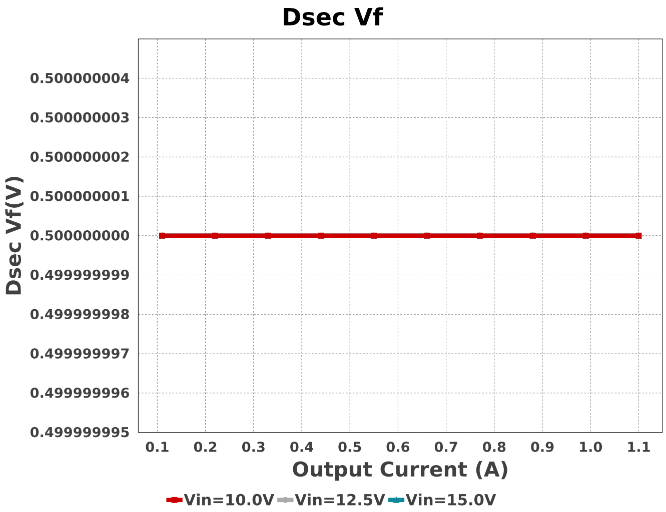


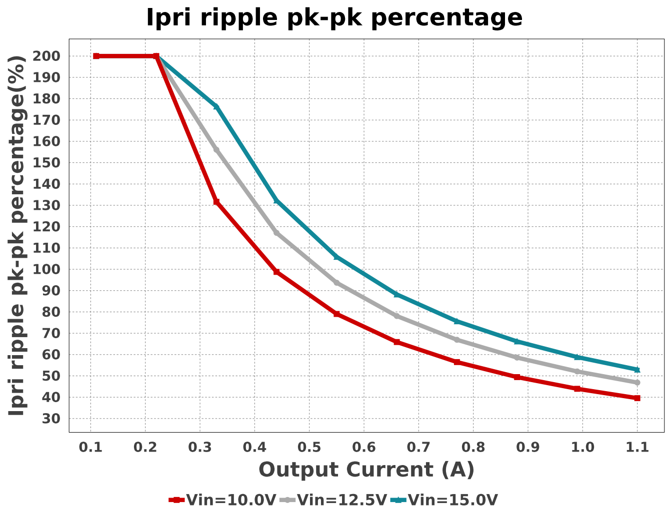

T1 Is1 pk
T1 Is1 pk(A)
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

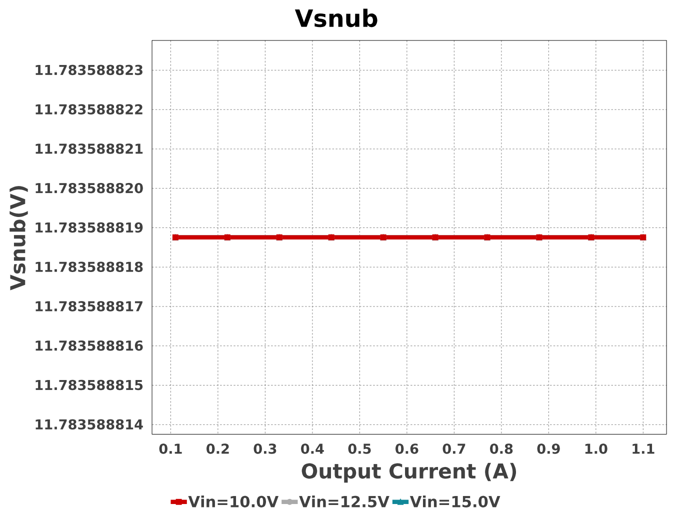

Dsec Pd
Dsec Pd(W)
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

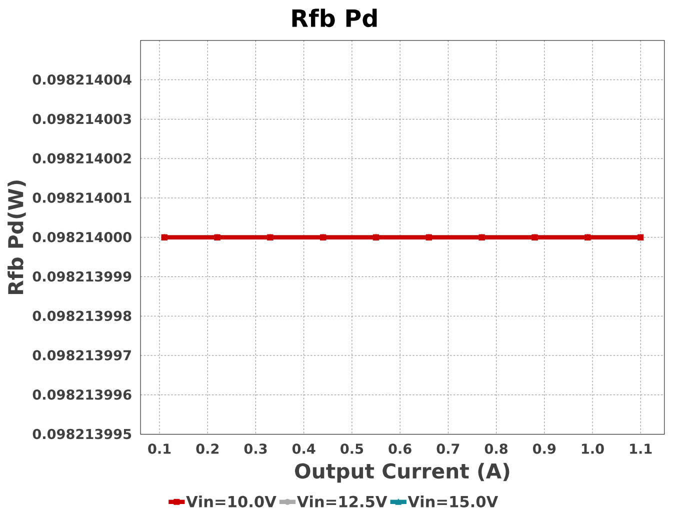

IC Pd
IC Pd(W)
0.259940005
0.259940004
0.259940003
0.259940002
0.259940001
0.259940000
0.259939999
0.259939998
0.259939997
0.259939996
0.259939995
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

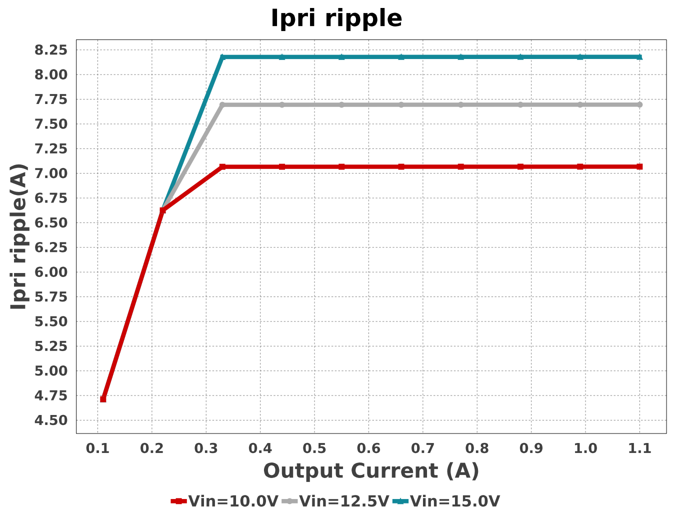

Cout1 IRMS
Cout1 IRMS(A)
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

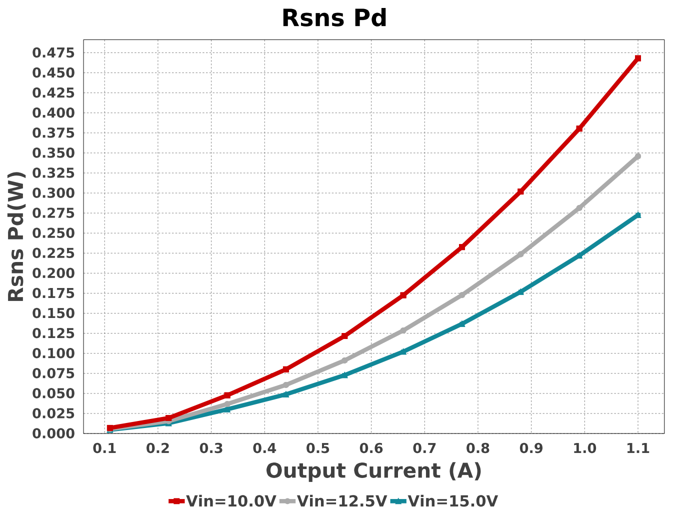

Dsec Vf
Dsec Vf(V)
0.500000004
0.500000003
0.500000002
0.500000001
0.500000000
0.499999999
0.499999998
0.499999997
0.499999996
0.499999995
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

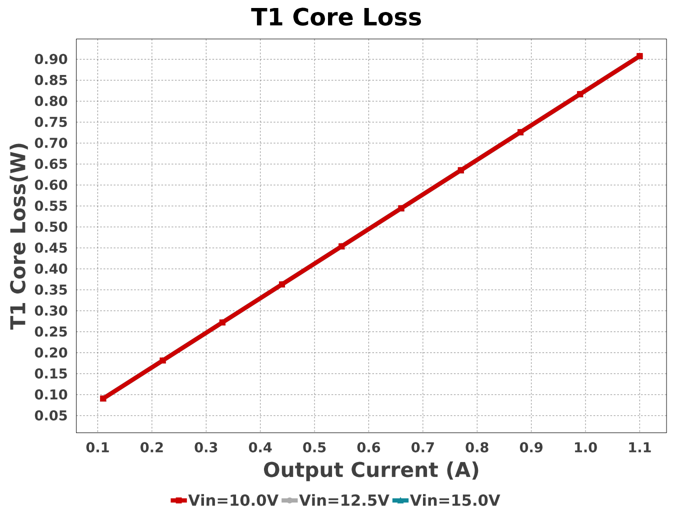

Ipri ripple pk-pk percentage
Ipri ripple pk-pk percentage(%)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

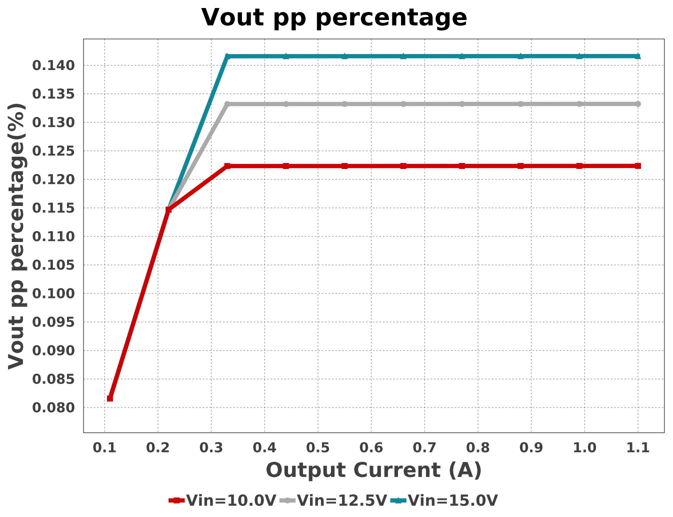

Vsnub
Vsnub(V)
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

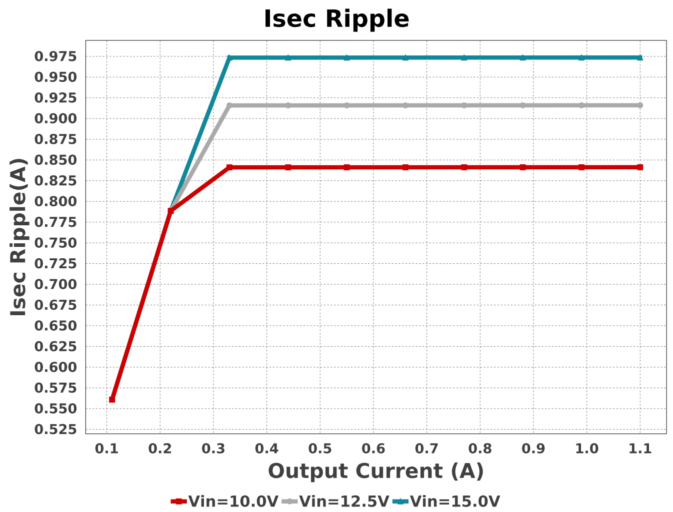

Rfb Pd
Rfb Pd(W)
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

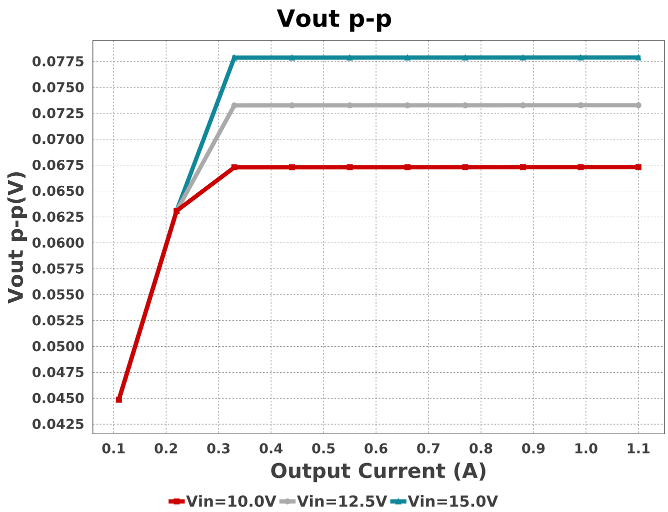

Ipri ripple
Ipri ripple(A)
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

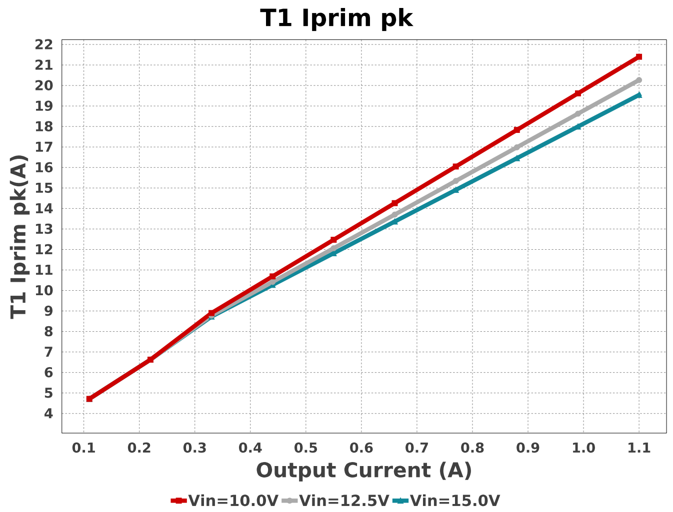

Rsns Pd
Rsns Pd(W)
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V

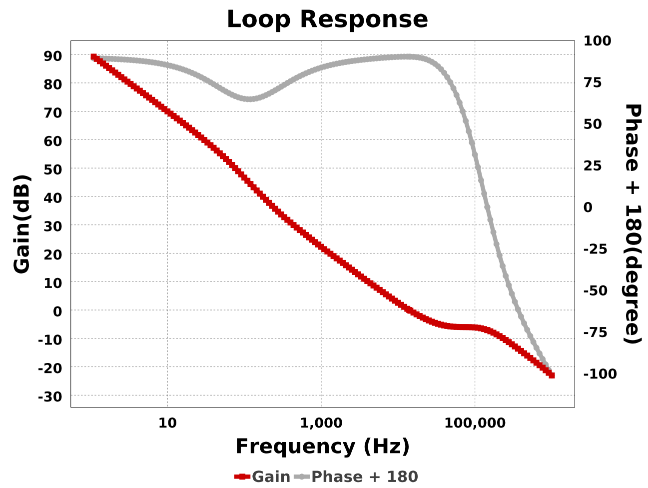

T1 Core Loss
T1 Core Loss(W)
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V


Vout pp percentage
Vout pp percentage(%)
Output Current (A)
Vin=10.0V Vin=12.5V Vin=15.0V









Operating Values

#	Name	Value	Category	Description
1.	Cin Pd	403.37 mW	Capacitor	Input capacitor power dissipation
2.	Cout Pd	119.94 mW	Capacitor	Output capacitor1 power dissipation
3.	Cout1 IRMS	1.224 A	Capacitor	Output capacitor1 RMS ripple current
4.	Dsec Pd	550.0 mW	Diode	Secondary Diode Power Dissipation
5.	Dsec Vf	500.0 mV	Diode	Effective Forward Voltage Drop at the Operating Current
6.	IC Pd	259.94 mW	IC	IC power dissipation
7.	IC Tj	40.606 degC	IC	IC junction temperature
8.	ICThetaJA Effective	40.8 degC/W	IC	Effective IC Junction-to-Ambient Thermal Resistance
9.	Iin Avg	8.643 A	IC	Average input current
10.	M1 Pd	353.97 mW	Mosfet	M1 MOSFET total power dissipation
11.	M1 TjOP	51.946 degC	Mosfet	M1 MOSFET junction temperature
12.	Cin Pd	403.37 mW	Power	Input capacitor power dissipation
13.	Cout Pd	119.94 mW	Power	Output capacitor1 power dissipation
14.	Dsec Pd	550.0 mW	Power	Secondary Diode Power Dissipation
15.	IC Pd	259.94 mW	Power	IC power dissipation
16.	M1 Pd	353.97 mW	Power	M1 MOSFET total power dissipation
17.	Paux	2.867 mW	Power	Power Dissipation in Raux and Daux
18.	Rfb Pd	98.214 mW	Power	Rfb Power Dissipation
19.	Rsns Pd	468.08 mW	Power	Current Limit Sense Resistor Power Dissipation
20.	Snubber Pd	1.21 W	Power	Snubber Power Dissipation
21.	T1 Copper Loss	907.5 mW	Power	Transformer Copper Loss Power Dissipation
22.	T1 Core Loss	907.5 mW	Power	Transformer Core Loss Power Dissipation
23.	T1 Pd	1.815 W	Power	Estimated Losses in Transformer
24.	Total Pd	6.939 W	Power	Total Power Dissipation
25.	Rfb Pd	98.214 mW	Resistor	Rfb Power Dissipation
26.	Rsns Pd	468.08 mW	Resistor	Current Limit Sense Resistor Power Dissipation
27.	BOM Count	41	System Information	Total Design BOM count
28.	Cross Freq	2.642 kHz	System Information	Bode plot crossover frequency
29.	Duty Cycle	40.863 %	System Information	Duty cycle

#	Name	Value	Category	Description
30.	Efficiency	91.971 %	System Information	Steady state efficiency
31.	FootPrint	1.83 k mm^2	System Information	Total Foot Print Area of BOM components
32.	Frequency	252.413 kHz	System Information	Switching frequency
33.	Gain Marg	-7.401 dB	System Information	Bode Plot Gain Margin
34.	Iout	1.1 A	System Information	Iout operating point
35.	Iout_DCM	243.351 mA	System Information	Approximate Current below which DCM mode of operation will begin
36.	Low Freq Gain	85.425 dB	System Information	Gain at 1Hz
37.	Mode	CCM	System Information	Conduction Mode
38.	Phase Marg	95.525 deg	System Information	Bode Plot Phase Margin
39.	Pout	60.5 W	System Information	Total output power
40.	Toff	2.049 us	System Information	Approximate Converter Off Time
41.	Ton Act	1.619 us	System Information	Approximate Converter On Time
42.	Total BOM	NA	System Information	Total BOM Cost
43.	Tsw	3.962 us	System Information	Switching Time Period
44.	Vin	10.0 V	System Information	Vin operating point
45.	Vout	55.0 V	System Information	Operational Output Voltage
46.	Vout Actual	54.89 V	System Information	Vout Actual calculated based on selected voltage divider resistors
47.	Vout Tolerance	2.991 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
48.	Vout p-p	67.3 mV	System Information	Peak-to-peak output ripple voltage
49.	Vout pp percentage	122.363 m%	System Information	Output Voltage ripple percentage
50.	Vsnub	11.784 V	System Information	Voltage Across the Snubber
51.	Ipri Avg	7.301 A	Transformer	Average Current in Primary Winding over the complete Switching Period
52.	Ipri ripple	7.068 A	Transformer	Ripple Current in the Primary Winding
53.	Ipri ripple pk-pk percentage	39.559 %	Transformer	Primary Current pk-pk ripple percentage(of Ipri avg during ton only)
54.	Isec Ripple	841.244 mA	Transformer	Ripple Current in the Secondary Winding
55.	Paux	2.867 mW	Transformer	Power Dissipation in Raux and Daux
56.	T1 Copper Loss	907.5 mW	Transformer	Transformer Copper Loss Power Dissipation
57.	T1 Core Loss	907.5 mW	Transformer	Transformer Core Loss Power Dissipation
58.	T1 Iprim RMS	11.495 A	Transformer	Transformer Primary RMS Current
59.	T1 Iprim pk	21.4 A	Transformer	Transformer Primary Peak Current
60.	T1 Is1 RMS	1.646 A	Transformer	Transformer Secondary1 RMS Current
61.	T1 Is1 pk	2.547 A	Transformer	Transformer Secondary1 Peak Current
62.	T1 Pd	1.815 W	Transformer	Estimated Losses in Transformer
63.	Vaux	10.0 V	Transformer	Auxiliary Voltage

Design Inputs

Name	Value	Description
Iout	1.1	Maximum Output Current
VinMax	15.0	Maximum input voltage
VinMin	10.0	Minimum input voltage
Vout	55.0	Output Voltage
base_pn	LM5156H	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

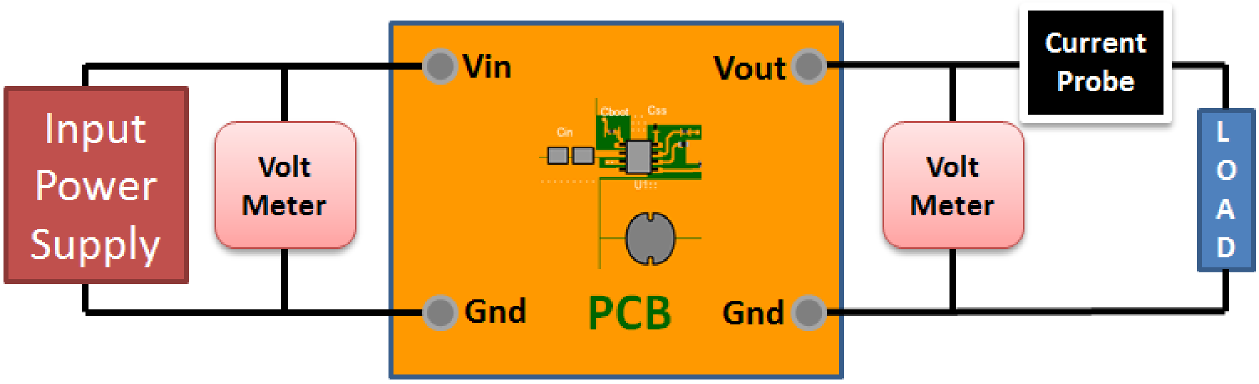
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. 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 10.0V 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 : 5D26F4D0A6AA1A04[v1]

2. **LM5156H** Product Folder : http://www.ti.com/product/LM5156H : contains the data sheet and other resources.