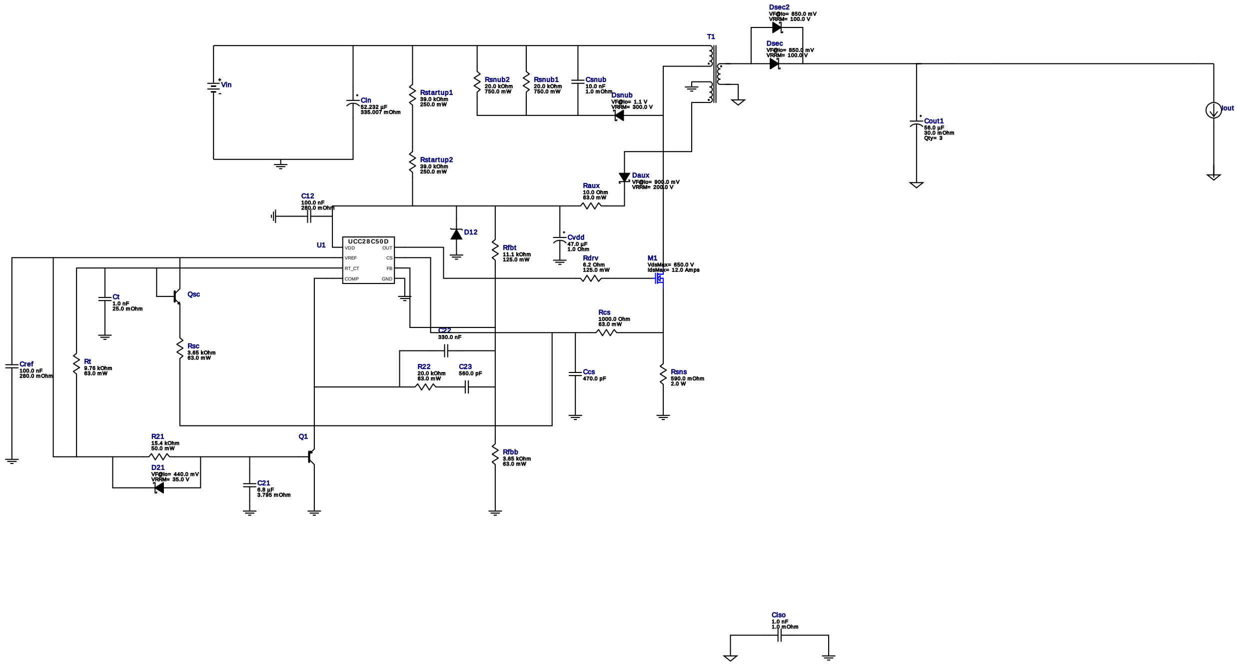
VinMin = 32.0V
VinMax = 150.0V
Vout = 6.5V
Iout = 1.5A

Device = UCC28C50DR
Topology = Flyback
Created = 2023-11-29 07:40:57.932
BOM Cost = NA
BOM Count = 39
Total Pd = 1.71W

WEBENCH ® Design Report

Design : 8 UCC28C50DR
UCC28C50DR 32V-150V to 6.50V @ 1.5A



Design Alerts

Component Selection Information

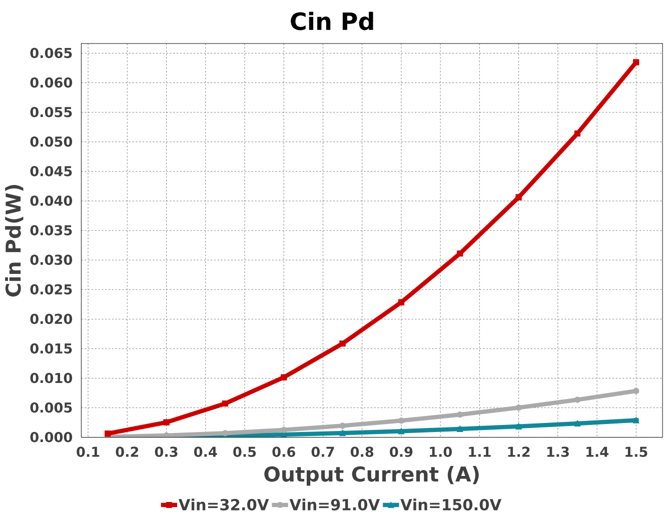
Use design suggestions or click on the transformer symbol in the schematic to explore the transformer core/ bobbin selection

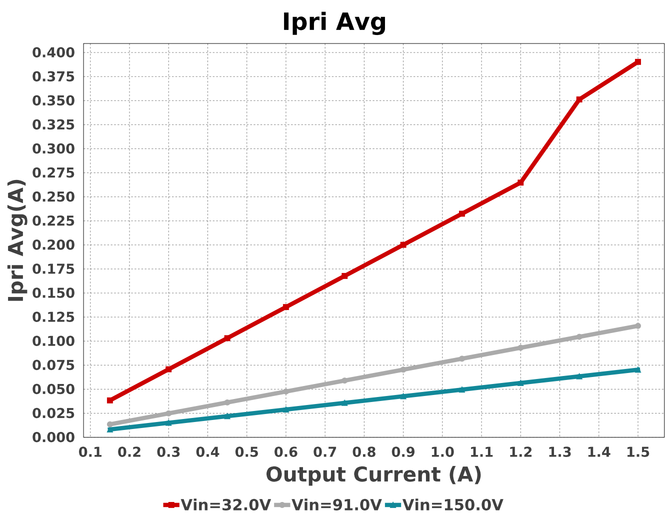
Electrical BOM

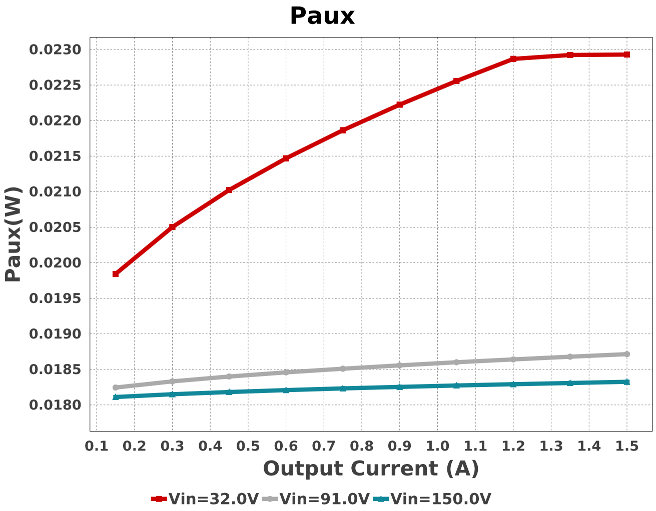
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
C12	AVX	08053C104KAT2A Series= X7R	Cap= 100.0 nF ESR= 280.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm²
C21	TDK	C2012X5R1V685K125AC Series= X5R	Cap= 6.8 uF ESR= 3.795 mOhm VDC= 35.0 V IRMS= 3.3493 A	1	$0.17	0805 7 mm²
C22	Panasonic	ECPU1C334MA5 Series= ECPU(A)	Cap= 330.0 nF VDC= 16.0 V IRMS= 0.0 A	1	$0.23	1206 11 mm²
C23	MuRata	GRM1555C1H561JA01J Series= C0G/NP0	Cap= 560.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm²
Ccs	Samsung Electro-Mechanics	CL21C471JBANNNC Series= C0G/NP0	Cap= 470.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm²
Cin	CUSTOM	CUSTOM Series= ?	Cap= 52.232 uF ESR= 335.01 mOhm VDC= 180.0 V IRMS= 652.9 mA	1	NA	CUSTOM 0 mm²
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 mm²

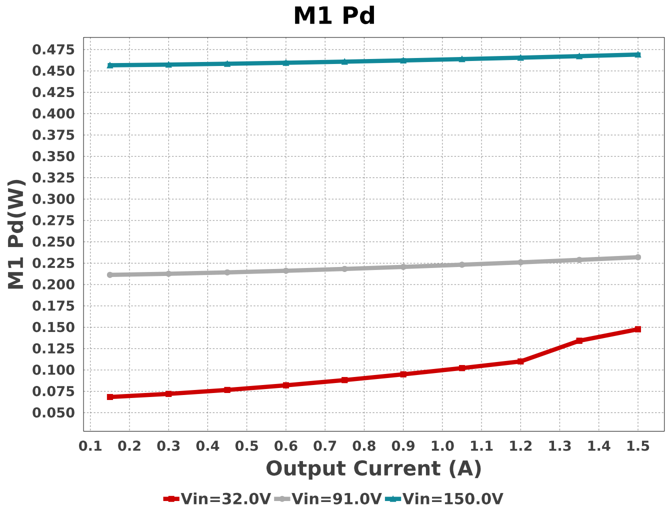
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cout1	Panasonic	20SVPF56MX Series= SVPF	Cap= 56.0 uF ESR= 30.0 mOhm VDC= 20.0 V IRMS= 2.8 A	3	$0.47	CAPSMT_62_E61 53 mm^2
Cref	AVX	08053C104KAT2A Series= X7R	Cap= 100.0 nF ESR= 280.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm^2
Csnub	MuRata	GRM188R72A103KA01D Series= X7R	Cap= 10.0 nF ESR= 1.0 mOhm VDC= 100.0 V IRMS= 0.0 A	1	$0.01	0603 5 mm^2
Ct	Kemet	C0805C102J5GACTU Series= C0G/NP0	Cap= 1.0 nF ESR= 25.0 mOhm VDC= 50.0 V IRMS= 1.71 A	1	$0.02	0805 7 mm^2
Cvdd	Chemi-Con	EMVY250ADA470MF55G Series= MVY	Cap= 47.0 uF ESR= 1.0 Ohm VDC= 25.0 V IRMS= 140.0 mA	1	$0.13	CAPSMT_62_F55 77 mm^2
D12	Diodes Inc.	MMSZ5248B-7-F	Zener	1	$0.04	SOD-123 13 mm^2
D21	Bourns	CD0603-B0130L	VF@Io= 440.0 mV VRRM= 35.0 V	1	$0.09	Diode_0603 5 mm^2
Daux	Fairchild Semiconductor	S320	VF@Io= 900.0 mV VRRM= 200.0 V	1	$0.33	SMB 44 mm^2
Dsec	Comchip Technology	CDBC5100-G	VF@Io= 850.0 mV VRRM= 100.0 V	1	$0.27	SMC 83 mm^2
Dsec2	Comchip Technology	CDBC5100-G	VF@Io= 850.0 mV VRRM= 100.0 V	1	$0.27	SMC 83 mm^2
Dsnub	SMC Diode Solutions	ST1300ATR	VF@Io= 1.1 V VRRM= 300.0 V	1	$0.12	SMA 37 mm^2
M1	STMicroelectronics	STD16N65M5	VdsMax= 650.0 V IdsMax= 12.0 Amps	1	$1.91	DPAK 102 mm^2
Q1	Diodes Inc.	MMBT3906-7-F	Bipolar Transistor	1	$0.02	SOT-23 14 mm^2
Qsc	STMicroelectronics	2N2222A	Bipolar Transistor	1	$1.19	TO-18 57 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
R22	Vishay-Dale	CRCW040220K0FKED Series= CRCW..e3	Res= 20.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Raux	Vishay-Dale	CRCW040210R0FKED Series= CRCW..e3	Res= 10.0 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rcs	Vishay-Dale	CRCW04021K00FKED Series= CRCW..e3	Res= 1000.0 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2

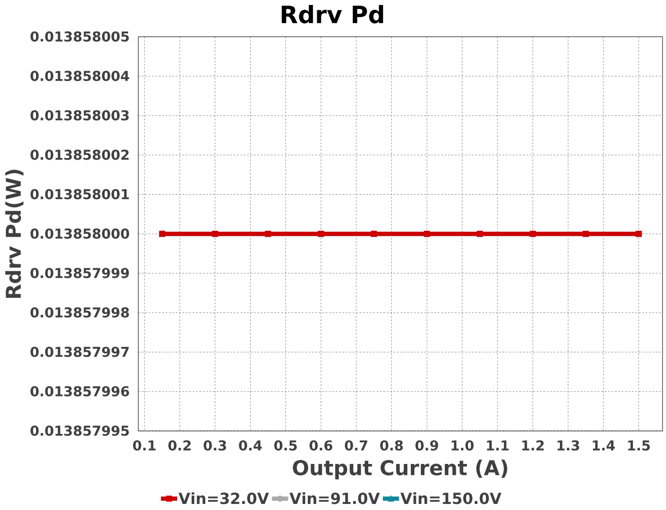
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Rdrv	Yageo	RC0805FR-076R2L Series= ?	Res= 6.2 Ohm Power= 125.0 mW Tolerance= 1.0%	1	$0.01	0805 7 mm^2
Rfbb	Vishay-Dale	CRCW04023K65FKED Series= CRCW..e3	Res= 3.65 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbt	Yageo	RT0805BRD0711K1L Series= ?	Res= 11.1 kOhm Power= 125.0 mW Tolerance= 0.1%	1	$0.05	0805 7 mm^2
Rsc	Vishay-Dale	CRCW04023K65FKED Series= CRCW..e3	Res= 3.65 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rsns	Vishay-Dale	RSMF2FTR590 Series= ?	Res= 590.0 mOhm Power= 2.0 W Tolerance= 1.0%	1	$0.06	CMF55 63 mm^2
Rsnub1	Vishay-Dale	CRCW201020K0FKEF Series= CRCW..e3	Res= 20.0 kOhm Power= 750.0 mW Tolerance= 1.0%	1	$0.04	2010 32 mm^2
Rsnub2	Vishay-Dale	CRCW201020K0FKEF Series= CRCW..e3	Res= 20.0 kOhm Power= 750.0 mW Tolerance= 1.0%	1	$0.04	2010 32 mm^2
Rstartup1	Yageo	RC1206FR-0739KL Series= ?	Res= 39.0 kOhm Power= 250.0 mW Tolerance= 1.0%	1	$0.01	1206 11 mm^2
Rstartup2	Yageo	RC1206FR-0739KL Series= ?	Res= 39.0 kOhm Power= 250.0 mW Tolerance= 1.0%	1	$0.01	1206 11 mm^2
Rt	Vishay-Dale	CRCW04029K76FKED Series= CRCW..e3	Res= 9.76 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
T1	Core=TDK , CoilFormer=TDK	Core=B65805P0000R049 , CoilFormer=B65806P1008D001	Lp= 120.0 µH Turns Ratio(Nas)= 7:4 Turns Ratio(Nps)= 26:4 Npri= 26.0 Naux= 7.0 Nsec= 4.0	1	$0.78	TDK_B65803 146 mm^2
U1	Texas Instruments	UCC28C50DR	Switcher	1	$0.29	D0008A 57 mm^2

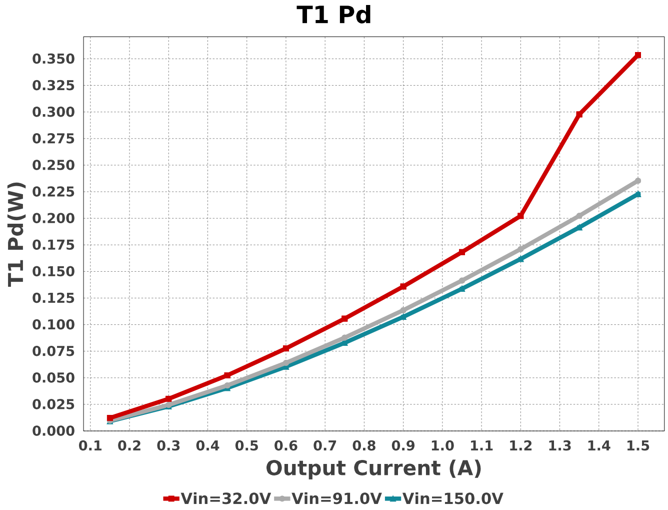


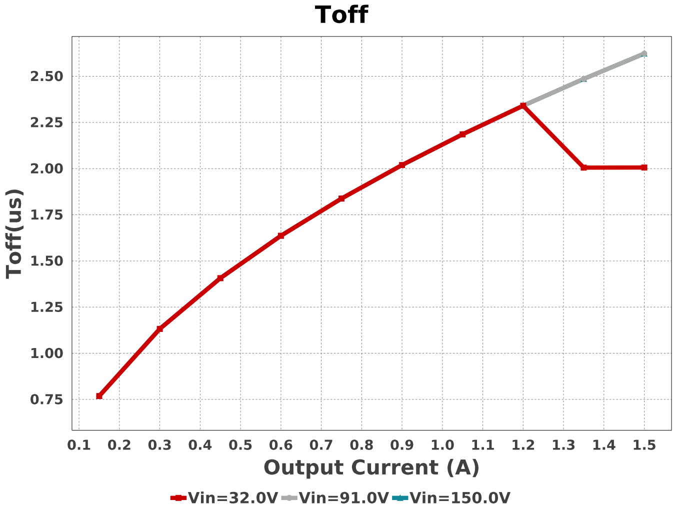


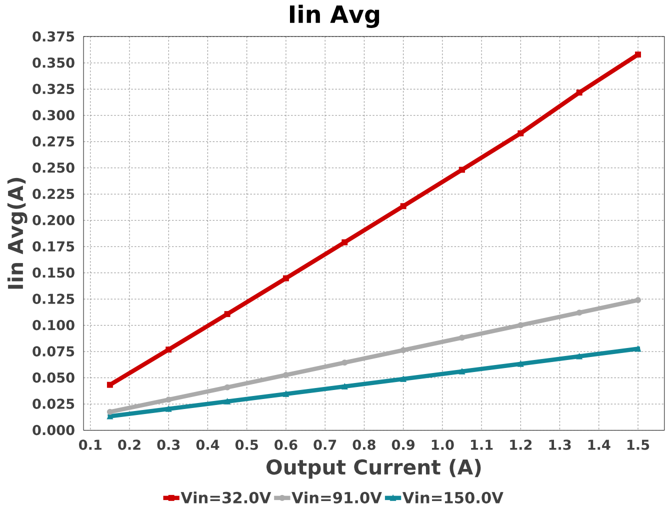

Paux
Paux(W)
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V


M1 Pd
M1 Pd(W)
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V

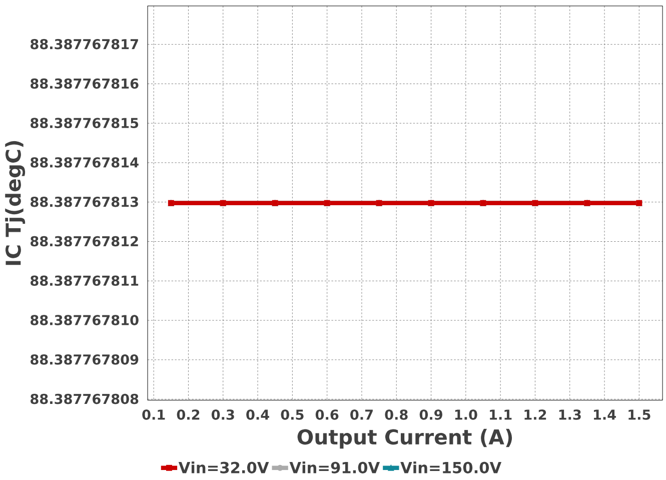

Rdrv Pd
Rdrv Pd(W)
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V


T1 Pd
T1 Pd(W)
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V

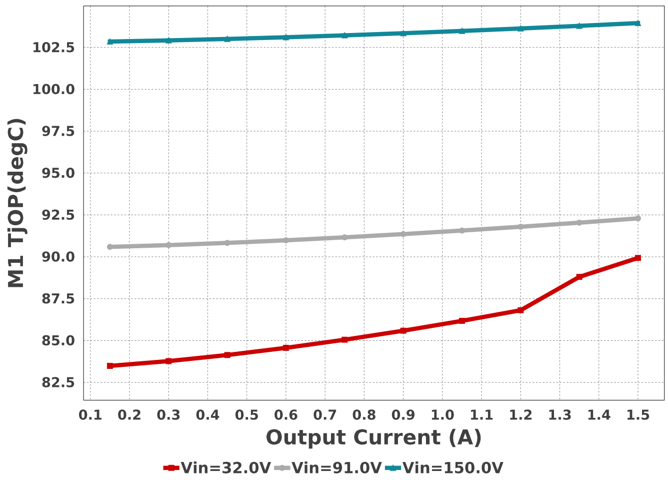

Toff
Toff(us)
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V


Iin Avg
Iin Avg(A)
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V

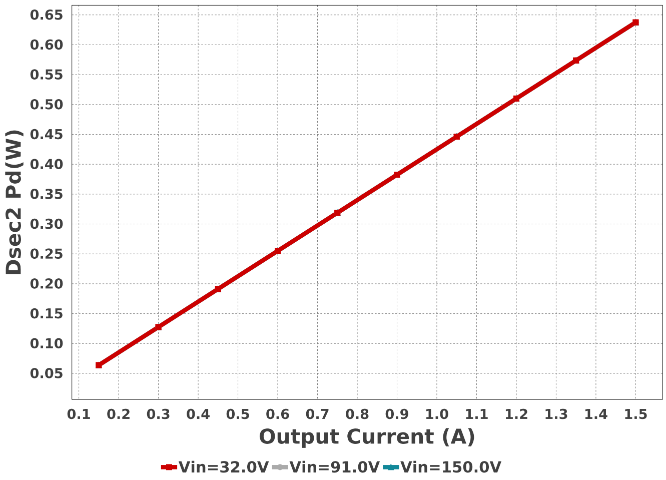
IC Tj



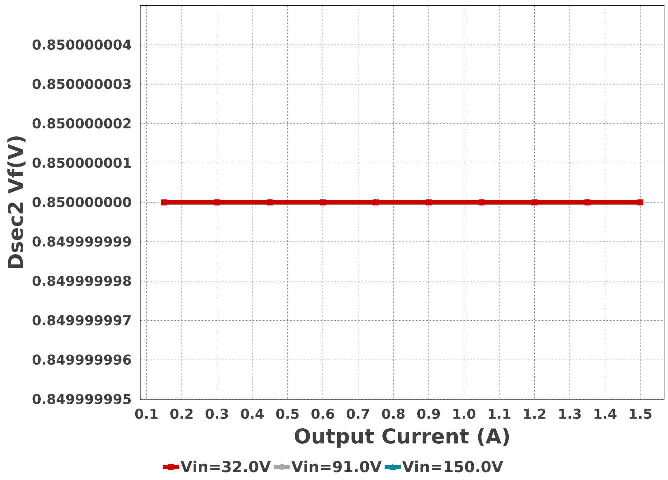
M1 TjOP



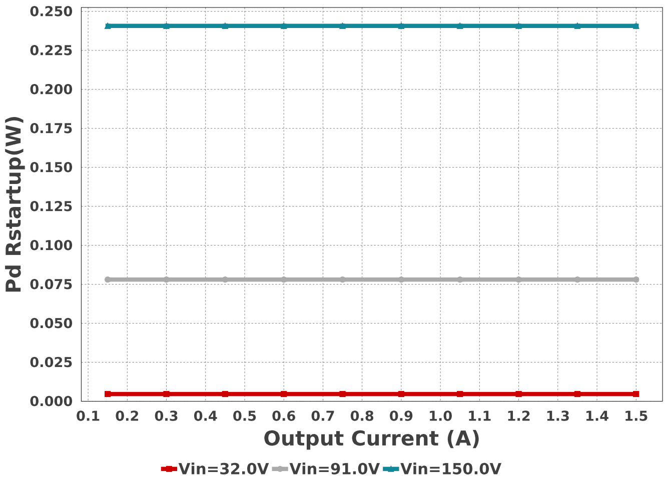
Dsec2 Pd



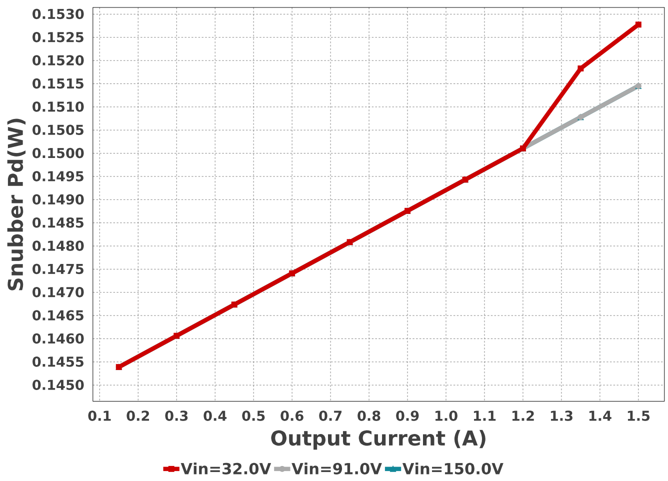
Dsec2 Vf



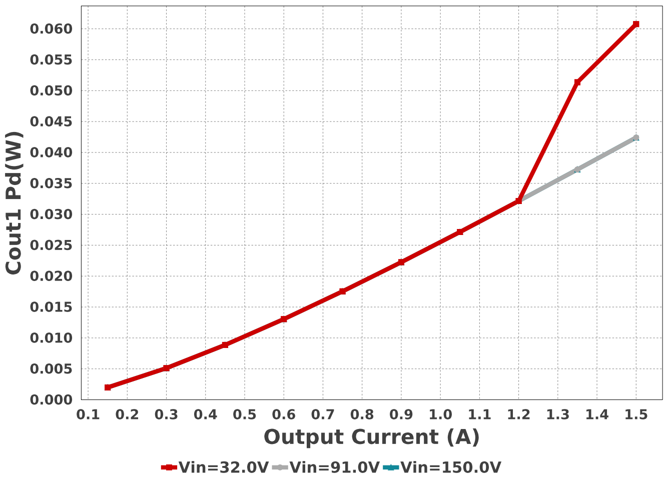
Pd Rstartup



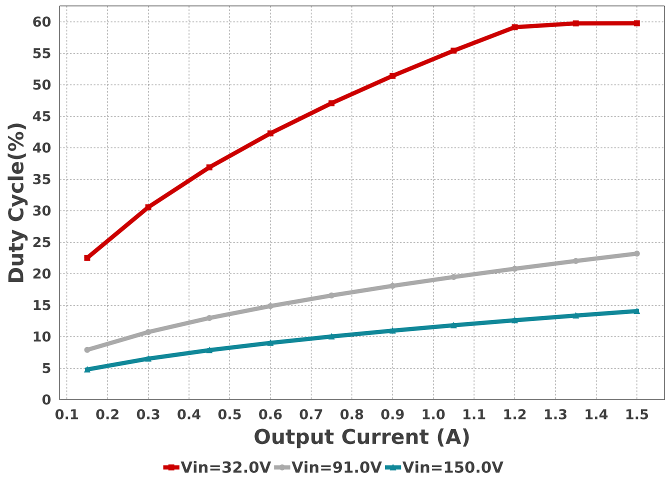
Snubber Pd



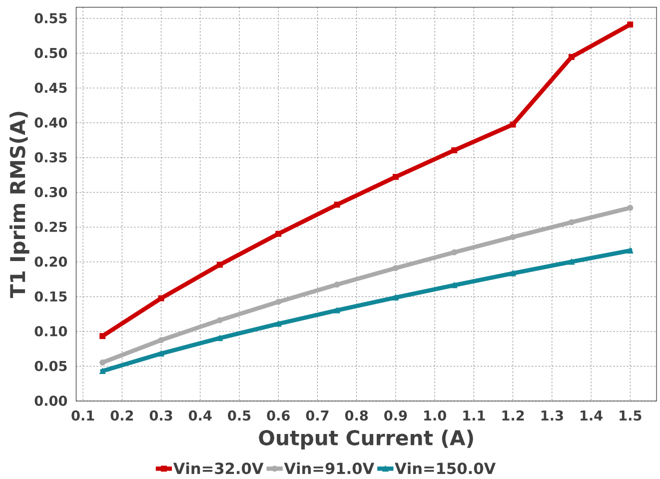
Cout1 Pd



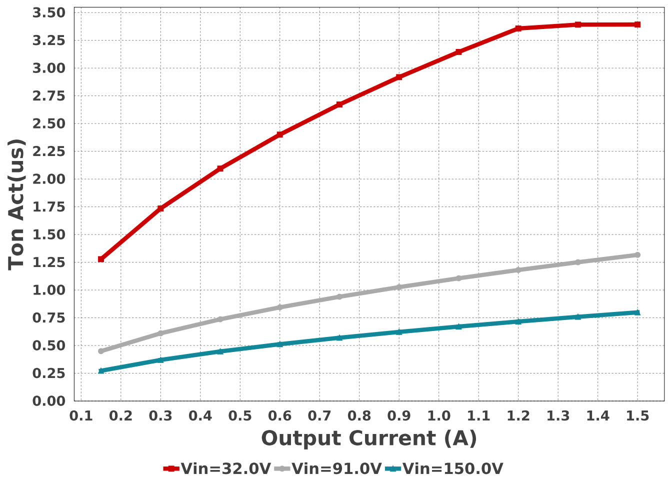
Duty Cycle



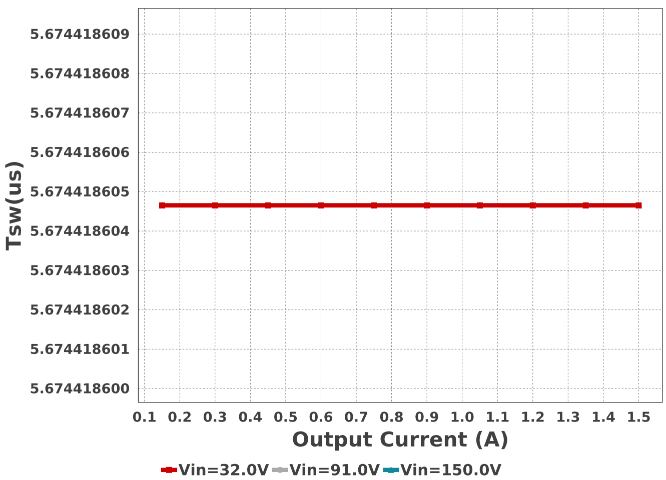
T1 Iprim RMS



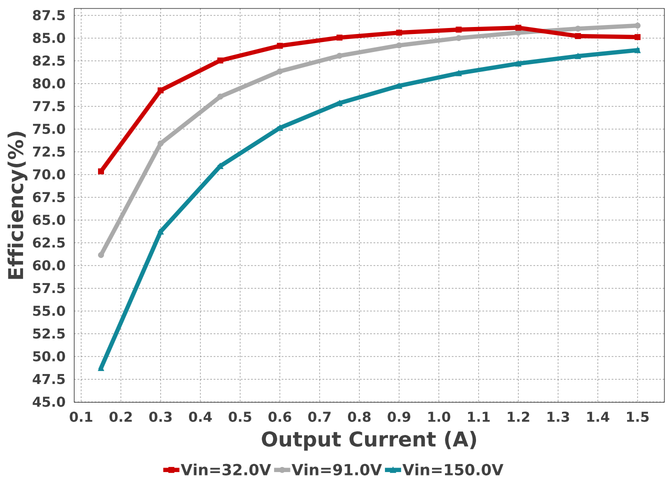
Ton Act

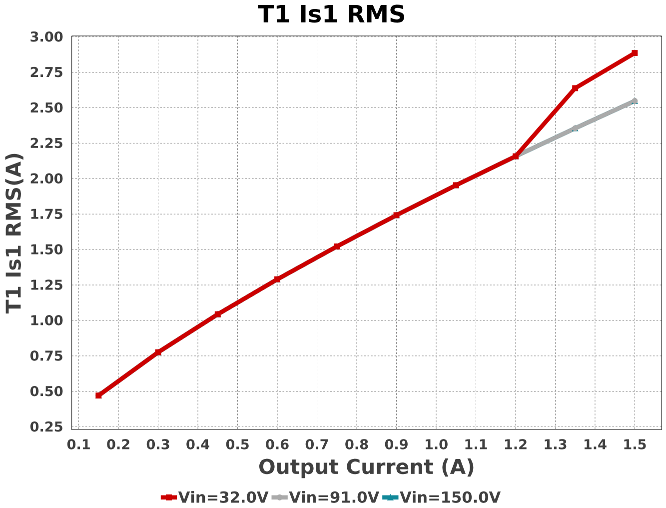


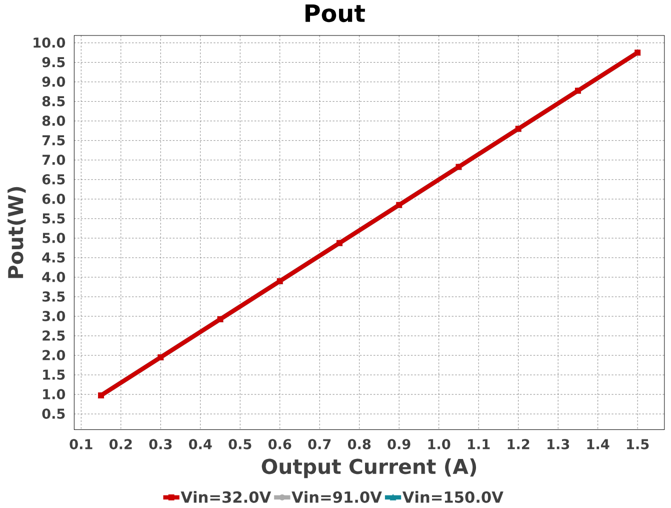
Tsw

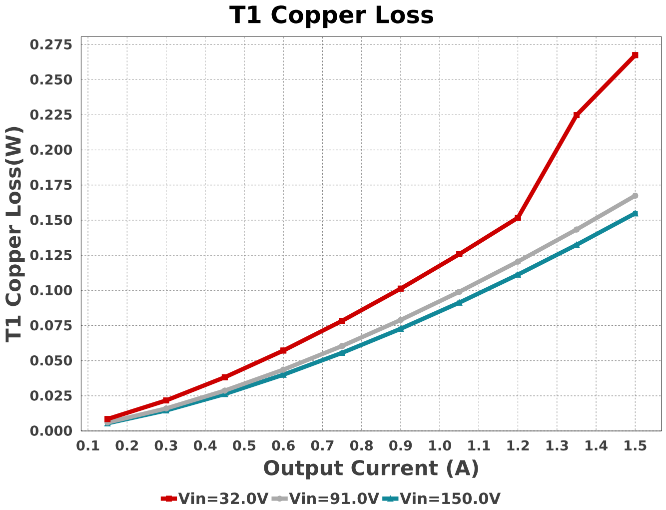


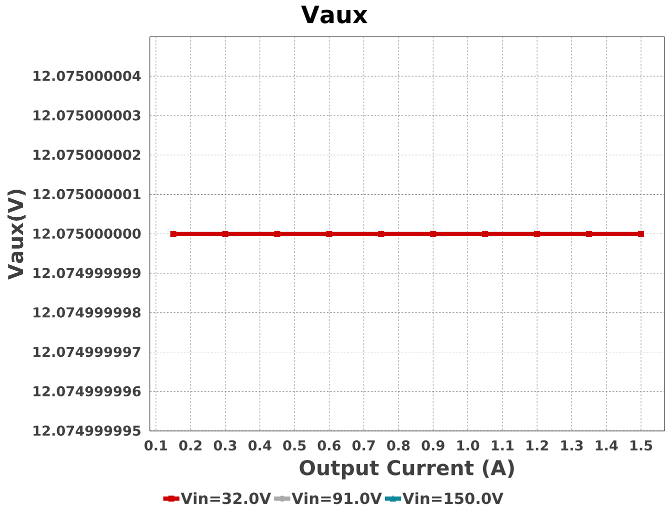
Efficiency

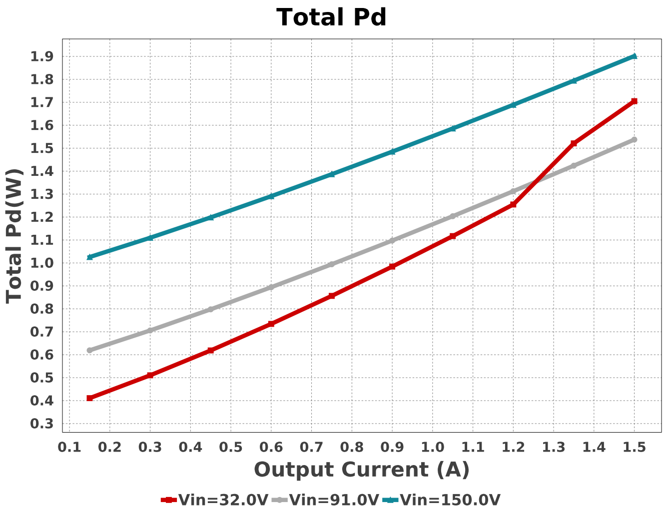


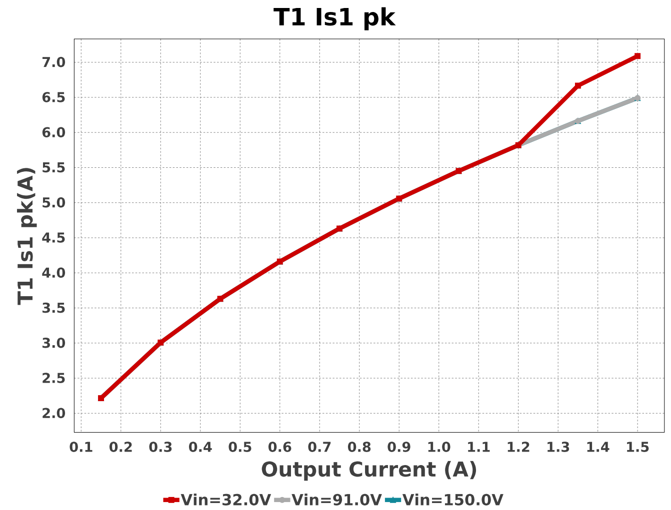

T1 Is1 RMS
T1 Is1 RMS(A)
3.00 2.75 2.50 2.25 2.00 1.75 1.50 1.25 1.00 0.75 0.50 0.25
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V

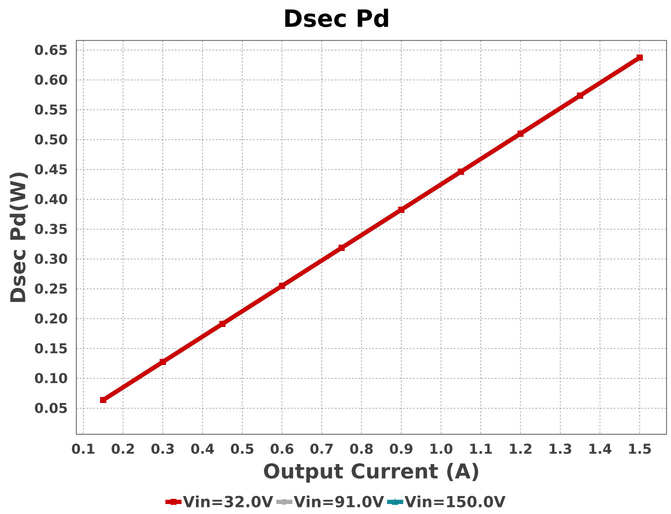

Pout
Pout(W)
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V

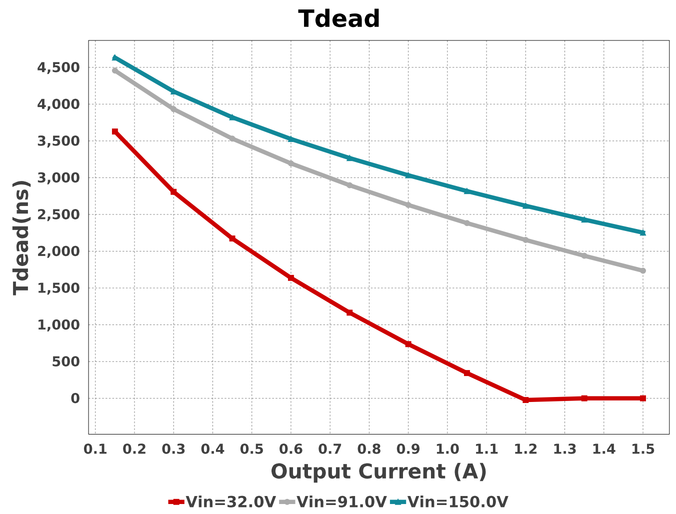

T1 Copper Loss
T1 Copper Loss(W)
0.275 0.250 0.225 0.200 0.175 0.150 0.125 0.100 0.075 0.050 0.025 0.000
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V

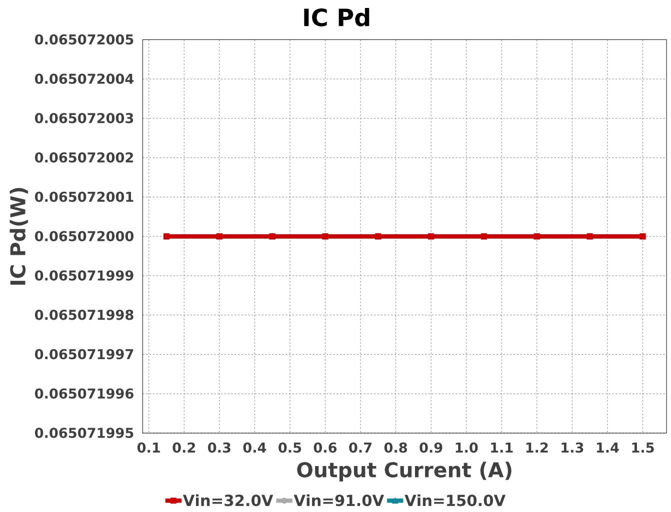

Vaux
Vaux(V)
12.075000004 12.075000003 12.075000002 12.075000001 12.075000000 12.074999999 12.074999998 12.074999997 12.074999996 12.074999995
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V

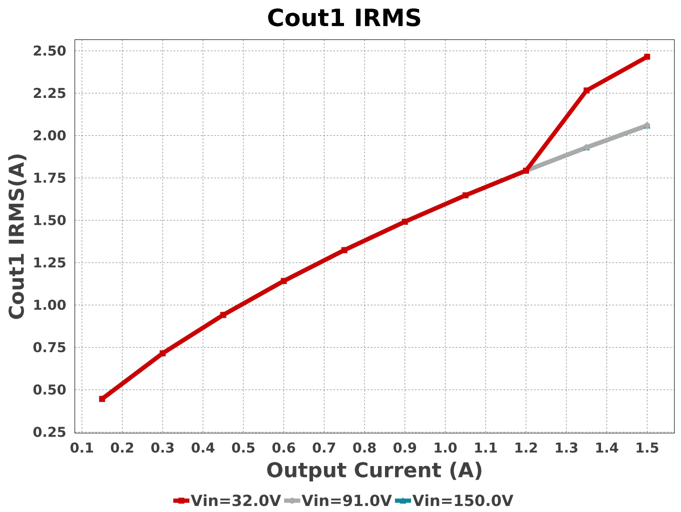

Total Pd
Total Pd(W)
1.9 1.8 1.7 1.6 1.5 1.4 1.3 1.2 1.1 1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V

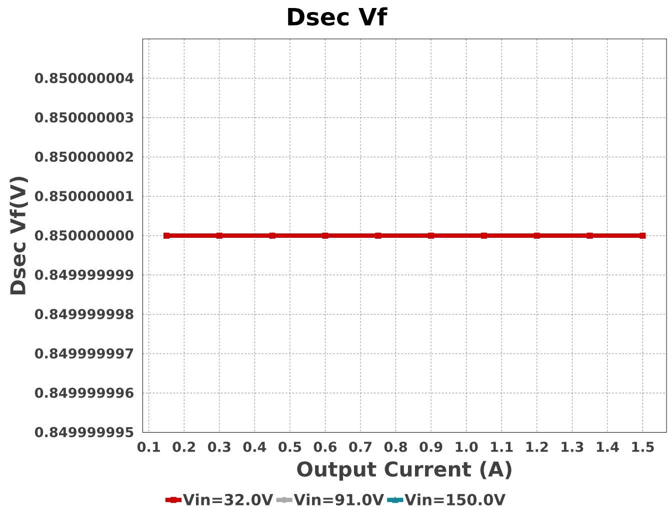

T1 Is1 pk
T1 Is1 pk(A)
7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V

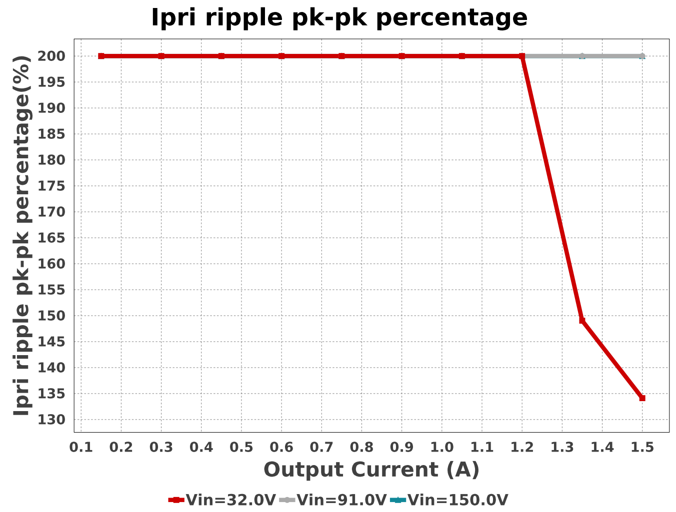

Dsec Pd
Dsec Pd(W)
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V


Tdead
Tdead(ns)
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V

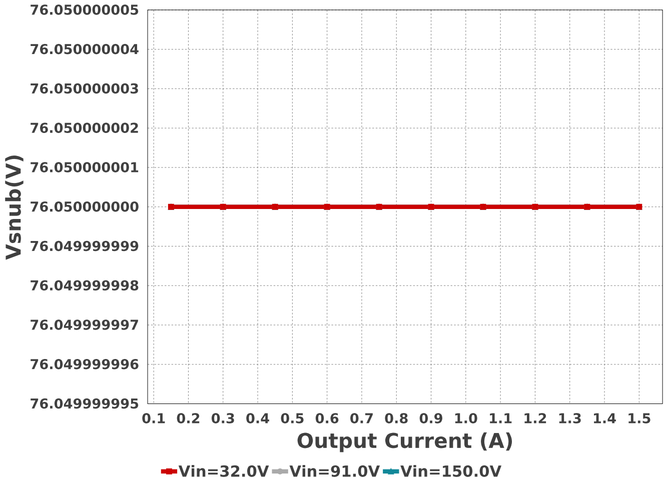

IC Pd
IC Pd(W)
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V


Cout1 IRMS
Cout1 IRMS(A)
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V

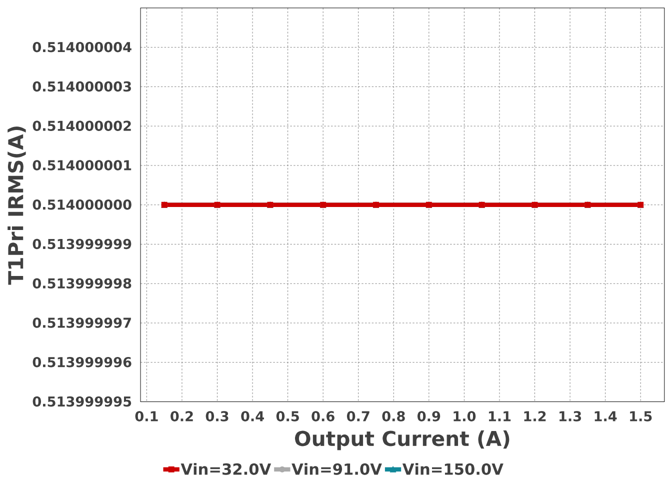

Dsec Vf
Dsec Vf(V)
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V


Ipri ripple pk-pk percentage
Ipri ripple pk-pk percentage(%)
Output Current (A)
Vin=32.0V Vin=91.0V Vin=150.0V

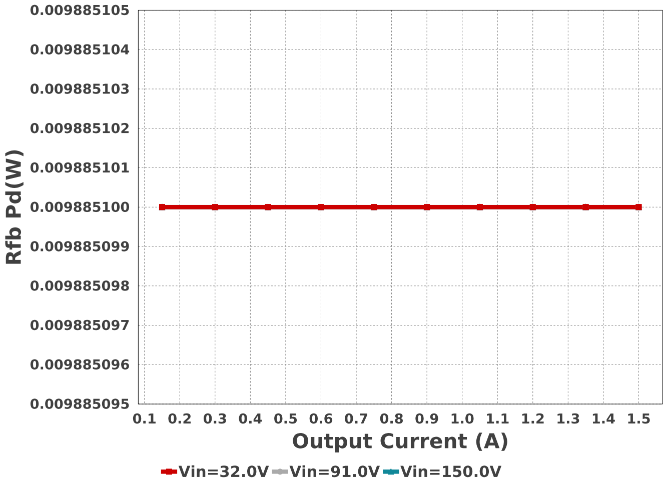
Vsnub



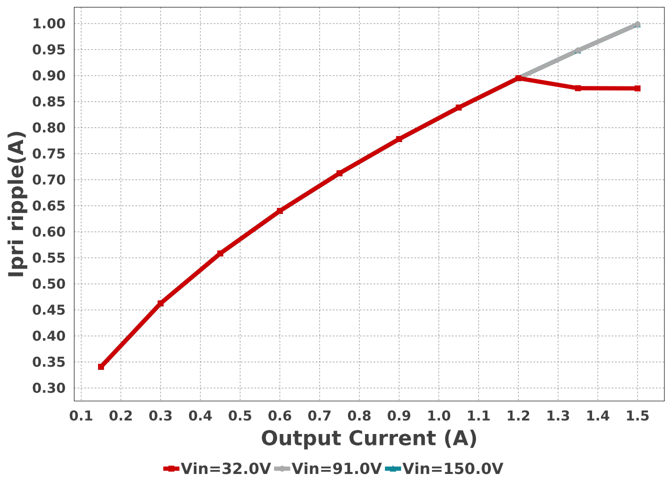
T1Pri IRMS



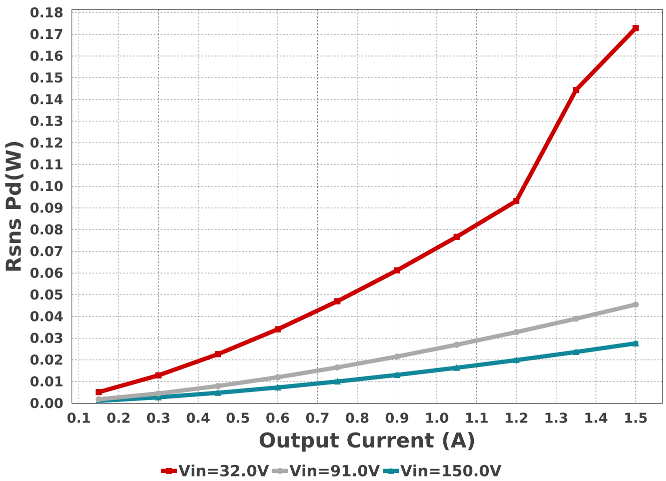
Rfb Pd



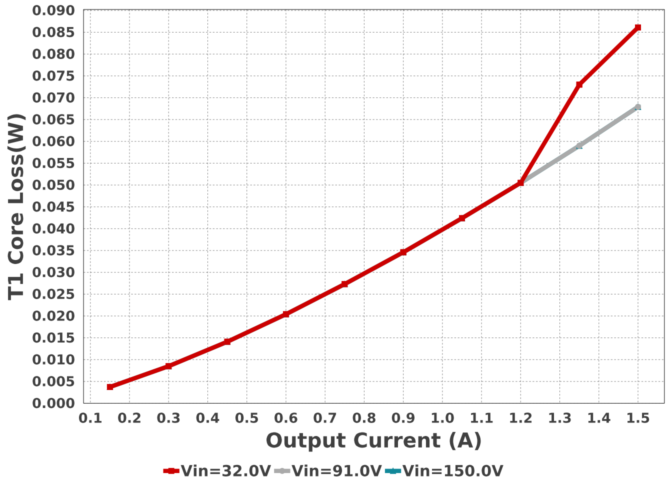
Ipri ripple

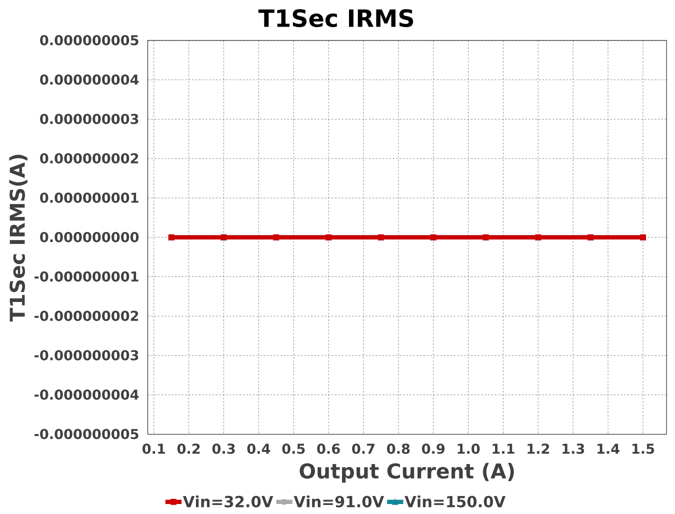


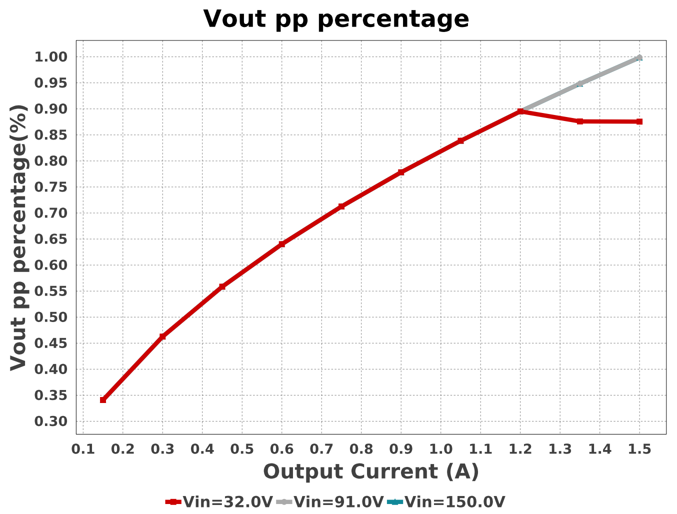
Rsns Pd

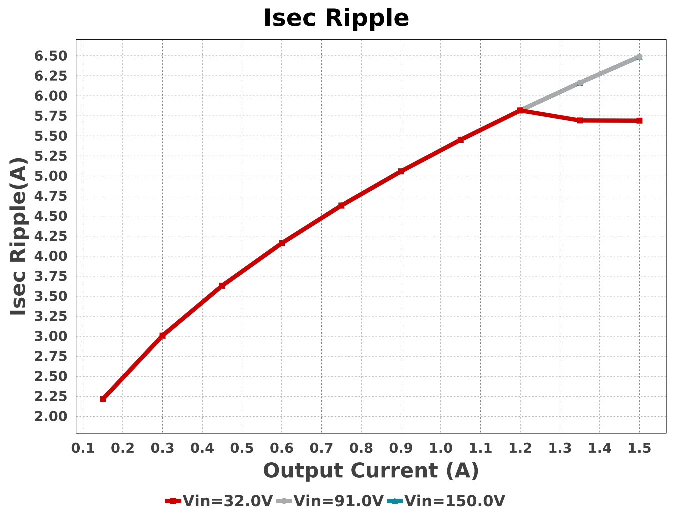


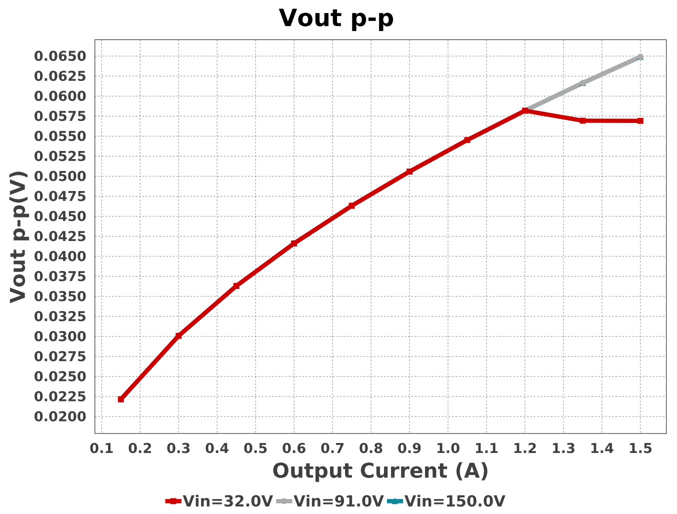
T1 Core Loss

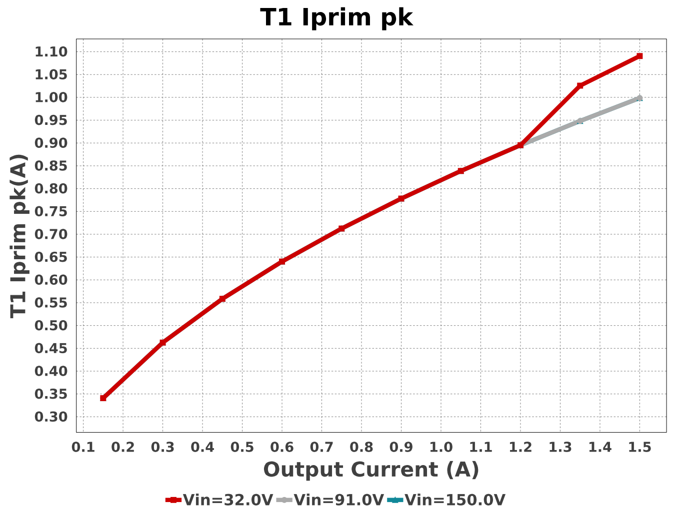












Operating Values

#	Name	Value	Category	Description
1.	Cin Pd	63.47 mW	Capacitor	Input capacitor power dissipation
2.	Cout1 IRMS	2.523 A	Capacitor	Output capacitor1 RMS ripple current
3.	Cout1 Pd	63.649 mW	Capacitor	Output capacitor1 power dissipation
4.	Daux trr	30.0 ns	Diode	Auxiliary Diode Reverse Recovery Time
5.	Dsec Pd	637.5 mW	Diode	Secondary Diode Power Dissipation
6.	Dsec Vf	850.0 mV	Diode	Effective Forward Voltage Drop at the Operating Current
7.	Dsec trr	0.0 ns	Diode	Output Diode Reverse Recovery Time
8.	Dsec2 Pd	637.5 mW	Diode	Secondary Diode Power Dissipation
9.	Dsec2 Vf	850.0 mV	Diode	Effective Forward Voltage Drop at the Operating Current
10.	Dsnub trr	35.0 ns	Diode	Snubber Diode Reverse Recovery Time
11.	IC Pd	65.072 mW	IC	IC power dissipation

#	Name	Value	Category	Description
12.	IC Tj	88.388 degC	IC	IC junction temperature
13.	ICThetaJA	128.9 degC/W	IC	IC junction-to-ambient thermal resistance
14.	Iin Avg	358.1 mA	IC	Average input current
15.	M1 Pd	161.07 mW	Mosfet	M1 MOSFET total power dissipation
16.	M1 TjOP	90.905 degC	Mosfet	M1 MOSFET junction temperature
17.	Cin Pd	63.47 mW	Power	Input capacitor power dissipation
18.	Cout1 Pd	63.649 mW	Power	Output capacitor1 power dissipation
19.	Dsec Pd	637.5 mW	Power	Secondary Diode Power Dissipation
20.	Dsec2 Pd	637.5 mW	Power	Secondary Diode Power Dissipation
21.	IC Pd	65.072 mW	Power	IC power dissipation
22.	M1 Pd	161.07 mW	Power	M1 MOSFET total power dissipation
23.	Paux	23.459 mW	Power	Power Dissipation in Raux and Daux
24.	Pd Rstartup	4.64 mW	Power	Power Dissipation in Rstartup1 and Rstartup2
25.	Rdrv Pd	13.858 mW	Power	Power Dissipation in Gate Drive Resistor
26.	Rfb Pd	9.885 mW	Power	Rfb Power Dissipation
27.	Rsns Pd	190.6 mW	Power	Current Limit Sense Resistor Power Dissipation
28.	Snubber Pd	153.328 mW	Power	Snubber Power Dissipation
29.	T1 Copper Loss	244.12 mW	Power	Transformer Copper Loss Power Dissipation
30.	T1 Core Loss	78.6 mW	Power	Transformer Core Loss Power Dissipation
31.	T1 Pd	322.72 mW	Power	Estimated Losses in Transformer
32.	Total Pd	1.709 W	Power	Total Power Dissipation
33.	Pd Rstartup	4.64 mW	Resistor	Power Dissipation in Rstartup1 and Rstartup2
34.	Rdrv Pd	13.858 mW	Resistor	Power Dissipation in Gate Drive Resistor
35.	Rfb Pd	9.885 mW	Resistor	Rfb Power Dissipation
36.	Rsns Pd	190.6 mW	Resistor	Current Limit Sense Resistor Power Dissipation
37.	BOM Count	39	System Information	Total Design BOM count
38.	Duty Cycle	61.305 %	System Information	Duty cycle
39.	Efficiency	85.084 %	System Information	Steady state efficiency
40.	FootPrint	1.158 k mm^2	System Information	Total Foot Print Area of BOM components
41.	Frequency	176.23 kHz	System Information	Switching frequency
42.	Iout	1.5 A	System Information	Iout operating point
43.	Mode	CCM	System Information	Conduction Mode
44.	Pout	9.75 W	System Information	Total output power
45.	Tdead	0.0 ns	System Information	Approximate Dead Time of the Regulator
46.	Toff	1.931 us	System Information	Approximate Converter Off Time
47.	Ton Act	3.479 us	System Information	Approximate Converter On Time
48.	Total BOM	NA	System Information	Total BOM Cost
49.	Tsw	5.674 us	System Information	Switching Time Period
50.	Vin	32.0 V	System Information	Vin operating point
51.	Vout	6.5 V	System Information	Operational Output Voltage
52.	Vout p-p	58.328 mV	System Information	Peak-to-peak output ripple voltage
53.	Vout pp percentage	897.356 m%	System Information	Output Voltage ripple percentage
54.	Vsnub	76.05 V	System Information	Voltage Across the Snubber
55.	Ipri Avg	415.724 mA	Transformer	Average Current in Primary Winding over the complete Switching Period
56.	Ipri ripple	897.356 mA	Transformer	Ripple Current in the Primary Winding
57.	Ipri ripple pk-pk percentage	132.33 %	Transformer	Primary Current pk-pk ripple percentage(of Ipri avg during ton only)
58.	Isec Ripple	5.833 A	Transformer	Ripple Current in the Secondary Winding
59.	Paux	23.459 mW	Transformer	Power Dissipation in Raux and Daux
60.	T1 Copper Loss	244.12 mW	Transformer	Transformer Copper Loss Power Dissipation
61.	T1 Core Loss	78.6 mW	Transformer	Transformer Core Loss Power Dissipation
62.	T1 Iprim RMS	568.375 mA	Transformer	Transformer Primary RMS Current
63.	T1 Iprim pk	1.127 A	Transformer	Transformer Primary Peak Current
64.	T1 Is1 RMS	2.935 A	Transformer	Transformer Secondary1 RMS Current
65.	T1 Is1 pk	7.324 A	Transformer	Transformer Secondary1 Peak Current
66.	T1 Pd	322.72 mW	Transformer	Estimated Losses in Transformer
67.	T1Pri IRMS	514.403 mA	Transformer	Transformer Primary RMS Current

#	Name	Value	Category	Description
68.	T1Sec IRMS	2.674 A	Transformer	Transformer Secondary RMS Current
69.	Vaux	12.075 V	Transformer	Auxiliary Voltage

Design Inputs

Name	Value	Description
Iout	1.5	Maximum Output Current
VinMax	150.0	Maximum input voltage
VinMin	32.0	Minimum input voltage
Vout	6.5	Output Voltage
base_pn	UCC28C50	Base Product Number
source	DC	Input Source Type
Ta	80.0	Ambient temperature
UserFsw	176.0 k	Customer Selected Frequency

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

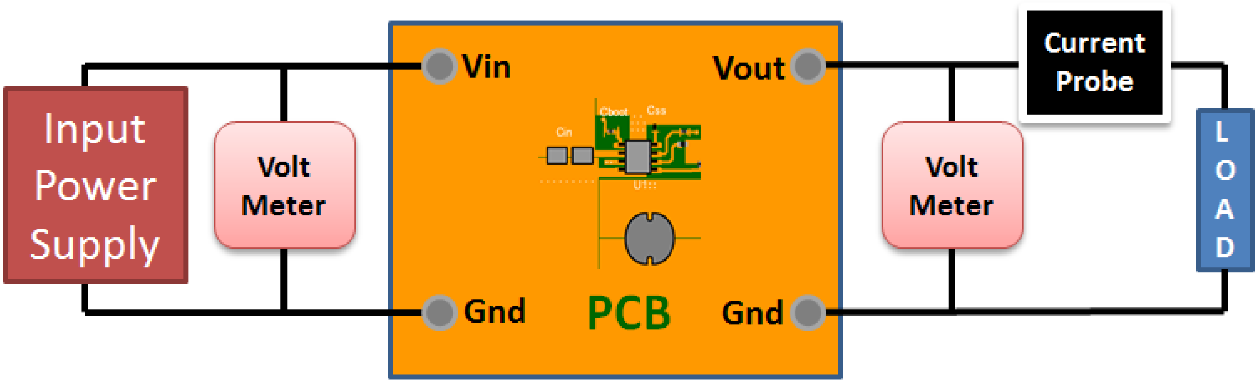
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. 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 32.0V 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	B65805P0000R049
2.	Core Manufacturer	TDK
3.	Coil Former Part Number	B65806P1008D001
4.	Coil Former Manufacturer	TDK

Transformer Electrical Diagram

Primary

Turns	26.0
AWG	29.0
Layers	2.0
Strands	1.0
Insulation Type	Heavy Insulated Magnet Wire

Secondary

Turns	4.0
AWG	31.0
Layers	1.0
Strands	2.0
Insulation Type	Triple Insulated

Auxiliary

Turns	7.0
AWG	28.0
Layers	1.0
Strands	1.0
Insulation Type	Heavy Insulated Magnet Wire

Transformer Construction Diagram

Winding Instruction

Winding	AWG	Turns	Winding Orientation
Primary First 1/2.0	29.0	13	Clockwise
Auxiliary	28.0	7.0	Counter Clockwise
Triple Insulated Secondary	31.0	4.0	Counter Clockwise
Primary Second 1/2.0	29.0	13	Clockwise

Transformer Parameters

#	Name	Value
1.	Lpri	1.2E-4H
2.	Inductance Factor(Al)	178.0nH
3.	Npri	26.0
4.	Nsec	4.0
5.	Naux	7.0
6.	Core Type	RM5
7.	Core Material	N49

#	Name	Value
8.	Bmax	0.20T
9.	Switching Frequency	176.23kHz
10.	DMax	0.6
11.	Ipk(Primary)	1.06A
12.	Irms(Primary)	0.51A
13.	Ipk(Secondary)	6.87A
14.	Irms(Secondary)	2.73A

Design Assistance

1. Master key : 1AD222A1559261CA2AA0AE2AC4EE8396[v1]
2. **UCC28C50** Product Folder : https://www.ti.com/product/UCC28C50 : contains the data sheet and other resources.