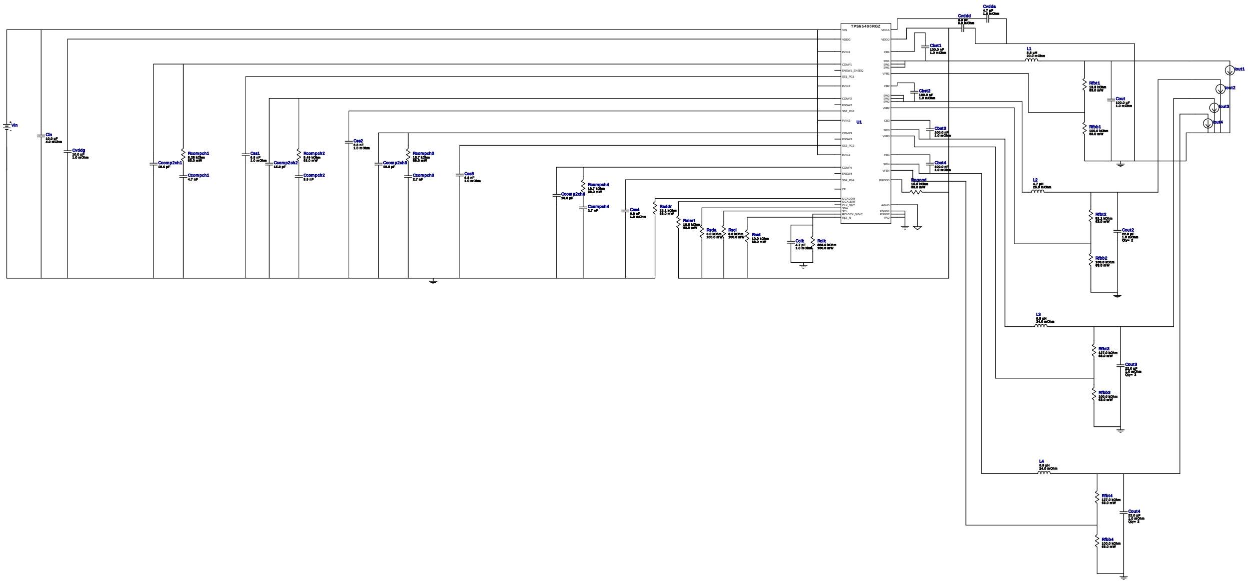
WEBENCH ® Design Report

VinMin = 12.0V
VinMax = 12.0V
Vout = 0.9V
Iout = 2.4A

Device = TPS65400RGZR
Topology = Buck
Created = 2024-12-09 01:20:31.717
BOM Cost = $3.72
BOM Count = 52
Total Pd = 0.99W

Design : 298 TPS65400RGZR
TPS65400RGZR 12V-12V to .90V @ 2.4A



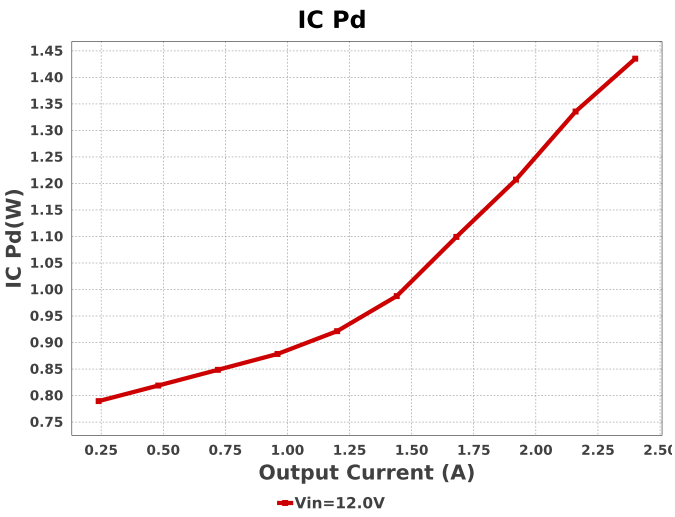
Electrical BOM

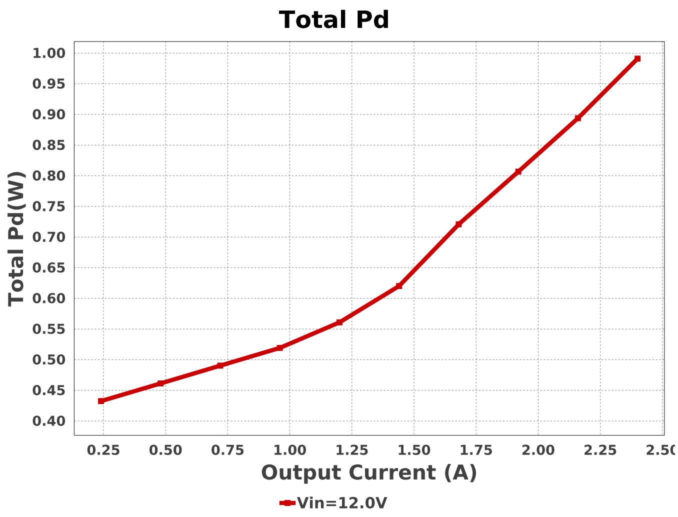
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cbst1	MuRata	GRM155R71A104KA01D Series= X7R	Cap= 100.0 nF ESR= 1.0 mOhm VDC= 10.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Cbst2	MuRata	GRM155R71A104KA01D Series= X7R	Cap= 100.0 nF ESR= 1.0 mOhm VDC= 10.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Cbst3	MuRata	GRM155R71A104KA01D Series= X7R	Cap= 100.0 nF ESR= 1.0 mOhm VDC= 10.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Cbst4	MuRata	GRM155R71A104KA01D Series= X7R	Cap= 100.0 nF ESR= 1.0 mOhm VDC= 10.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Cclk	MuRata	GRM1555C1H4R7CA01D Series= C0G/NP0	Cap= 4.7 pF ESR= 1.0 mOhm VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Ccomp2ch1	Yageo	CC0805JRNPO9BN180 Series= C0G/NP0	Cap= 18.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm^2
Ccomp2ch2	Yageo	CC0805JRNPO9BN150 Series= C0G/NP0	Cap= 15.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm^2
Ccomp2ch3	Yageo	CC0805JRNPO9BN100 Series= C0G/NP0	Cap= 10.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm^2
Ccomp2ch4	Yageo	CC0805JRNPO9BN100 Series= C0G/NP0	Cap= 10.0 pF VDC= 50.0 V IRMS= 0.0 A	1	$0.01	0805 7 mm^2

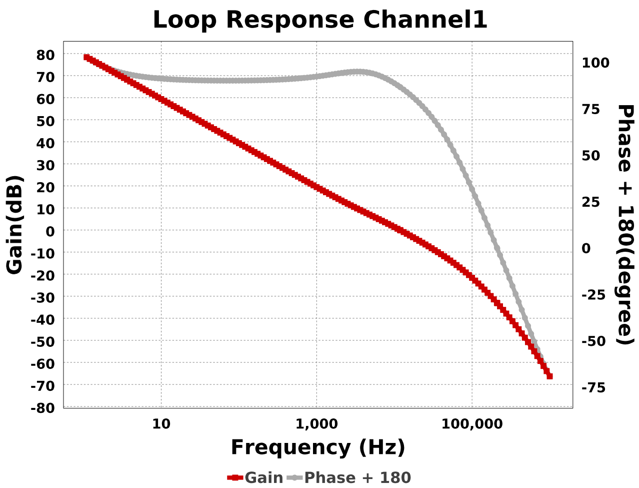
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Ccompch1	TDK	CGA4C2C0G1H472J060AA Series= C0G/NP0	Cap= 4.7 nF VDC= 50.0 V IRMS= 0.0 A	1	$0.04	0805 7 mm^2
Ccompch2	TDK	CGA4C2C0G1H392J060AA Series= C0G/NP0	Cap= 3.9 nF VDC= 50.0 V IRMS= 0.0 A	1	$0.04	0805 7 mm^2
Ccompch3	TDK	C2012C0G1H272J060AA Series= C0G/NP0	Cap= 2.7 nF VDC= 50.0 V IRMS= 0.0 A	1	$0.03	0805 7 mm^2
Ccompch4	TDK	C2012C0G1H272J060AA Series= C0G/NP0	Cap= 2.7 nF VDC= 50.0 V IRMS= 0.0 A	1	$0.03	0805 7 mm^2
Cin	MuRata	GRM21BR61E106MA73L Series= X5R	Cap= 10.0 uF ESR= 4.0 mOhm VDC= 25.0 V IRMS= 2.8 A	1	$0.04	0805 7 mm^2
Cout	MuRata	GRM32EC80J107ME20L Series= X6S	Cap= 100.0 uF ESR= 1.0 mOhm VDC= 6.3 V IRMS= 6.0 A	1	$0.17	1210_270 15 mm^2
Cout2	MuRata	GRM188R60J226MEA0D Series= X5R	Cap= 22.0 uF ESR= 1.0 mOhm VDC= 6.3 V IRMS= 6.0 A	2	$0.04	0603 5 mm^2
Cout3	MuRata	GRM188R60J226MEA0D Series= X5R	Cap= 22.0 uF ESR= 1.0 mOhm VDC= 6.3 V IRMS= 6.0 A	2	$0.04	0603 5 mm^2
Cout4	MuRata	GRM188R60J226MEA0D Series= X5R	Cap= 22.0 uF ESR= 1.0 mOhm VDC= 6.3 V IRMS= 6.0 A	2	$0.04	0603 5 mm^2
Css1	MuRata	GRM155R71E682KA01D Series= X7R	Cap= 6.8 nF ESR= 1.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Css2	MuRata	GRM155R71E682KA01D Series= X7R	Cap= 6.8 nF ESR= 1.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Css3	MuRata	GRM155R71E682KA01D Series= X7R	Cap= 6.8 nF ESR= 1.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Css4	MuRata	GRM155R71E682KA01D Series= X7R	Cap= 6.8 nF ESR= 1.0 mOhm VDC= 25.0 V IRMS= 0.0 A	1	$0.01	0402 3 mm^2
Cvdda	MuRata	GRM155R61A475MEAAD Series= X5R	Cap= 4.7 uF ESR= 1.0 mOhm VDC= 10.0 V IRMS= 0.0 A	1	$0.02	0402_065 3 mm^2
Cvddd	Kemet	C0805C335K8PACTU Series= X5R	Cap= 3.3 uF ESR= 5.0 mOhm VDC= 10.0 V IRMS= 8.13 A	1	$0.07	0805 7 mm^2
Cvddg	Taiyo Yuden	LMK212BJ106KG-T Series= X5R	Cap= 10.0 uF ESR= 1.0 mOhm VDC= 10.0 V IRMS= 0.0 A	1	$0.02	0805 7 mm^2
L1	TDK	VLP8040T-3R3N	L= 3.3 µH 20.0 mOhm	1	$0.22	VLP8040 113 mm^2

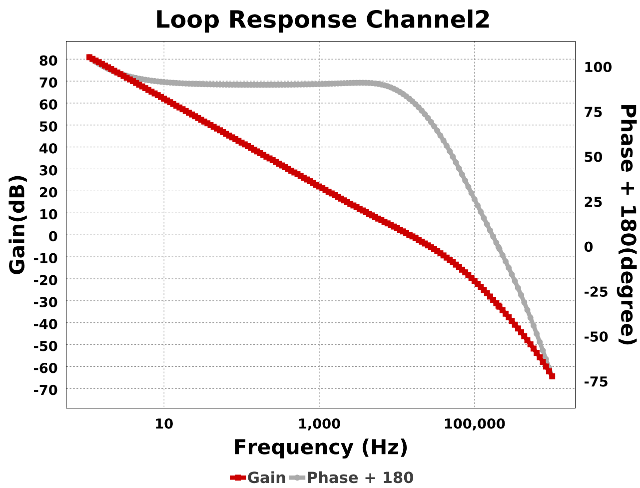
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
L2	TDK	VLP8040T-4R7M	L= 4.7 µH 25.0 mOhm	1	$0.22	VLP8040 113 mm^2
L3	TDK	VLP8040T-6R8M	L= 6.8 µH 24.0 mOhm	1	$0.22	VLP8040 113 mm^2
L4	TDK	VLP8040T-6R8M	L= 6.8 µH 24.0 mOhm	1	$0.22	VLP8040 113 mm^2
Raddr	Vishay-Dale	CRCW040222K1FKED Series= CRCW..e3	Res= 22.1 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Ralert	Vishay-Dale	CRCW040210K0FKED Series= CRCW..e3	Res= 10.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rclk	Yageo	RC0603FR-07383KL Series= ?	Res= 383.0 kOhm Power= 100.0 mW Tolerance= 1.0%	1	$0.01	0603 5 mm^2
Rcompch1	Vishay-Dale	CRCW04028K25FKED Series= CRCW..e3	Res= 8.25 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rcompch2	Vishay-Dale	CRCW04025K49FKED Series= CRCW..e3	Res= 5.49 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rcompch3	Vishay-Dale	CRCW040213K7FKED Series= CRCW..e3	Res= 13.7 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rcompch4	Vishay-Dale	CRCW040213K7FKED Series= CRCW..e3	Res= 13.7 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbb1	Vishay-Dale	CRCW0402100KFKED Series= CRCW..e3	Res= 100.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbb2	Vishay-Dale	CRCW0402100KFKED Series= CRCW..e3	Res= 100.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbb3	Vishay-Dale	CRCW0402100KFKED Series= CRCW..e3	Res= 100.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbb4	Vishay-Dale	CRCW0402100KFKED Series= CRCW..e3	Res= 100.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbt1	Vishay-Dale	CRCW040213K3FKED Series= CRCW..e3	Res= 13.3 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbt2	Vishay-Dale	CRCW040251K1FKED Series= CRCW..e3	Res= 51.1 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbt3	Vishay-Dale	CRCW0402127KFKED Series= CRCW..e3	Res= 127.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rfbt4	Vishay-Dale	CRCW0402127KFKED Series= CRCW..e3	Res= 127.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
Rpgood	Vishay-Dale	CRCW040210K0FKED Series= CRCW..e3	Res= 10.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2

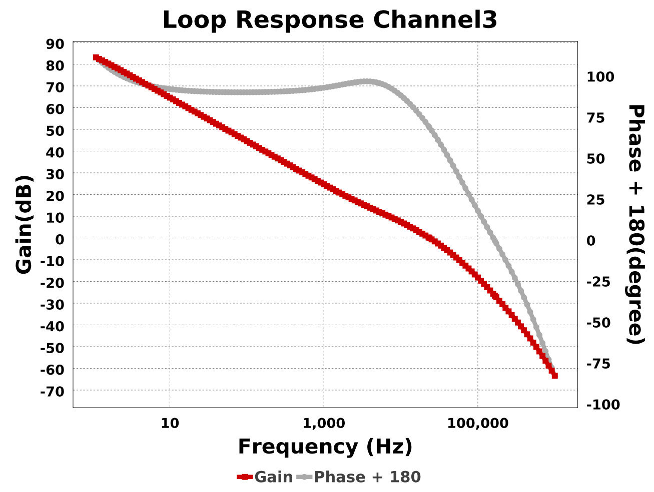
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Rscl	Yageo	RC0603FR-073KL Series= ?	Res= 3.0 kOhm Power= 100.0 mW Tolerance= 1.0%	1	$0.01	0603 5 mm^2
Rsda	Yageo	RC0603FR-073KL Series= ?	Res= 3.0 kOhm Power= 100.0 mW Tolerance= 1.0%	1	$0.01	0603 5 mm^2
Rset	Vishay-Dale	CRCW040210K0FKED Series= CRCW..e3	Res= 10.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm^2
U1	Texas Instruments	TPS65400RGZR	Switcher	1	$1.82	RGZ0048B 81 mm^2

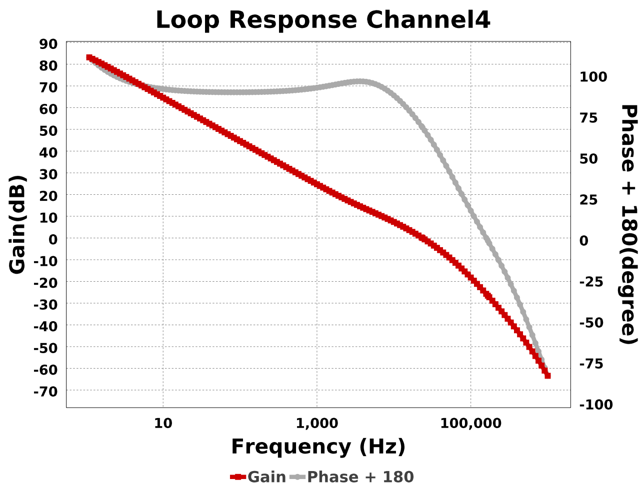












Operating Values

#	Name	Value	Category	Description
1.	Cout_ch1 IRMS	170.039 mA	Capacitor	Output Channel 1 Capacitor RMS ripple current
2.	Cout_ch2 IRMS	147.905 mA	Capacitor	Output Channel 2 Capacitor RMS ripple current
3.	Cout_ch3 IRMS	139.638 mA	Capacitor	Output Channel 3 Capacitor RMS ripple current
4.	Cout_ch4 IRMS	139.638 mA	Capacitor	Output Channel 4 Capacitor RMS ripple current
5.	IC Pd	1.435 W	IC	IC power dissipation
6.	IC Tj	52.101 degC	IC	IC junction temperature
7.	IC Tolerance	10.0 mV	IC	IC Feedback Tolerance
8.	ICThetaJA Effective	18.88 degC/W	IC	Effective IC Junction-to-Ambient Thermal Resistance
9.	Iin Avg	1.063 A	IC	Average input current
10.	L1 Ipp	589.033 mA	Inductor	Inductor 1 peak to peak current
11.	L2Ipp	512.356 mA	Inductor	Channel 2 Inductor Peak to peak Current
12.	L3 Ipp	483.722 mA	Inductor	Inductor 3 peak to peak current
13.	L4 Ipp	483.722 mA	Inductor	Inductor 4 peak to peak current
14.	Cross Freq Ch1	11.805 kHz	Loop	Bode plot crossover frequency
15.	Cross Freq Ch2	14.561 kHz	Loop	Bode plot crossover frequency
16.	Cross Freq Ch3	23.547 kHz	Loop	Bode plot crossover frequency
17.	Cross Freq Ch4	23.547 kHz	Loop	Bode plot crossover frequency
18.	Gain Marg Ch1	-33.163 dB	Loop	Bode Plot Gain Margin
19.	Gain Marg Ch2	-32.24 dB	Loop	Bode Plot Gain Margin
20.	Gain Marg Ch3	-26.55 dB	Loop	Bode Plot Gain Margin
21.	Gain Marg Ch4	-26.55 dB	Loop	Bode Plot Gain Margin
22.	Low Freq Gain Ch1	78.34 dB	Loop	Gain at 1Hz
23.	Low Freq Gain Ch2	80.873 dB	Loop	Gain at 1Hz
24.	Low Freq Gain Ch3	83.157 dB	Loop	Gain at 1Hz
25.	Low Freq Gain Ch4	83.157 dB	Loop	Gain at 1Hz
26.	Phase Marg Ch1	87.025 deg	Loop	Bode Plot Phase Margin
27.	Phase Marg Ch2	82.366 deg	Loop	Bode Plot Phase Margin
28.	Phase Marg Ch3	69.134 deg	Loop	Bode Plot Phase Margin
29.	Phase Marg Ch4	69.134 deg	Loop	Bode Plot Phase Margin
30.	Cout_ch1 Pd	28.913 µ	Power	Ouput channel 1 capacitor power dissipation
31.	Cout_ch2 Pd	10.938 µ	Power	Ouput channel 2 capacitor power dissipation
32.	Cout_ch3 Pd	9.749 µ	Power	Ouput channel 3 capacitor power dissipation
33.	Cout_ch4 Pd	9.749 µ	Power	Ouput channel 3 capacitor power dissipation
34.	IC Pd	1.435 W	Power	IC power dissipation
35.	L1 Pd	115.778 m	Power	Inductor1 power loss
36.	L2 Pd	100.547 m	Power	Inductor2 power loss

#	Name	Value	Category	Description
37.	L3 Pd	96.468 m	Power	Inductor3 power loss
38.	L4 Pd	96.468 m	Power	Inductor3 power loss
39.	Total Pd	991.023 mW	Power	Total Power Dissipation
40.	BOM Count	52	System Information	Total Design BOM count
41.	Duty Cycle 1	8.776 %	System Information	Duty cycle for Channel 1
42.	Duty Cycle 2	11.159 %	System Information	Duty cycle for Channel 2
43.	Duty Cycle 3	16.15 %	System Information	Duty cycle for Channel 3
44.	Duty Cycle 4	16.15 %	System Information	Duty Cycle channel 4
45.	Efficiency	92.228 %	System Information	Steady state efficiency
46.	FootPrint	744.0 mm^2	System Information	Total Foot Print Area of BOM components
47.	Frequency	493.277 kHz	System Information	Switching frequency
48.	Frequency Ch2	493.277 kHz	System Information	Switching frequency
49.	Frequency Ch3	493.277 kHz	System Information	Switching frequency
50.	Frequency Ch4	493.277 kHz	System Information	Switching frequency
51.	Iout1	2.4 A	System Information	Iout1 operating point
52.	Iout2	2.0 A	System Information	Iout2 operating point
53.	Iout3	2.0 A	System Information	Output Current channel 3
54.	Iout4	2.0 A	System Information	Output Current channel 4
55.	Ch1 Mode	CCM	System Information	Channel 1 Conduction Mode
56.	Ch2 Mode	CCM	System Information	Channel 2 Conduction Mode
57.	Mode	CCM	System Information	Channel 3 Conduction Mode
58.	Mode	CCM	System Information	Channel 4 Conduction Mode
59.	Pout1	2.16 W	System Information	Total output power
60.	Pout2	2.4 W	System Information	Total output power
61.	Pout3	3.6 W	System Information	Total output power
62.	Pout4	3.6 W	System Information	Total output power
63.	Total BOM	$3.72	System Information	Total BOM Cost
64.	Vin	12.0 V	System Information	Vin operating point
65.	Vout Tolerance	1.49 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
66.	Vout1	900.0 mV	System Information	Operational Voltage 1
67.	Vout1_Actual	906.4 mV	System Information	Vout Actual calculated based on selected voltage divider resistors
68.	Vout2	1.2 V	System Information	Operational Voltage 2
69.	Vout2Tolerance	1.942 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
70.	Vout2_Actual	1.209 V	System Information	Vout Actual calculated based on selected voltage divider resistors
71.	Vout3	1.8 V	System Information	Operational Voltage 3
72.	Vout3Tolerance	2.394 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
73.	Vout3_Actual	1.816 V	System Information	Vout Actual calculated based on selected voltage divider resistors
74.	Vout4	1.8 V	System Information	Operational Voltage 4
75.	Vout4Tolerance	2.394 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable

#	Name	Value	Category	Description
76.	Vout4_Actual	1.816 V	System Information	Vout Actual calculated based on selected voltage divider resistors

Design Inputs

Name	Value	Description
Iout	2.4	Maximum Output Current
Iout1	2.4	Output Current #1
Iout2	2.0	Output Current #2
VinMax	12.0	Maximum input voltage
VinMin	12.0	Minimum input voltage
Vout	900.0 m	Output Voltage
Vout1	900.0 m	Output Voltage #1
Vout2	1.2	Output Voltage #2
base_pn	TPS65400	Base Product Number
source	DC	Input Source Type
Ta	25.0	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

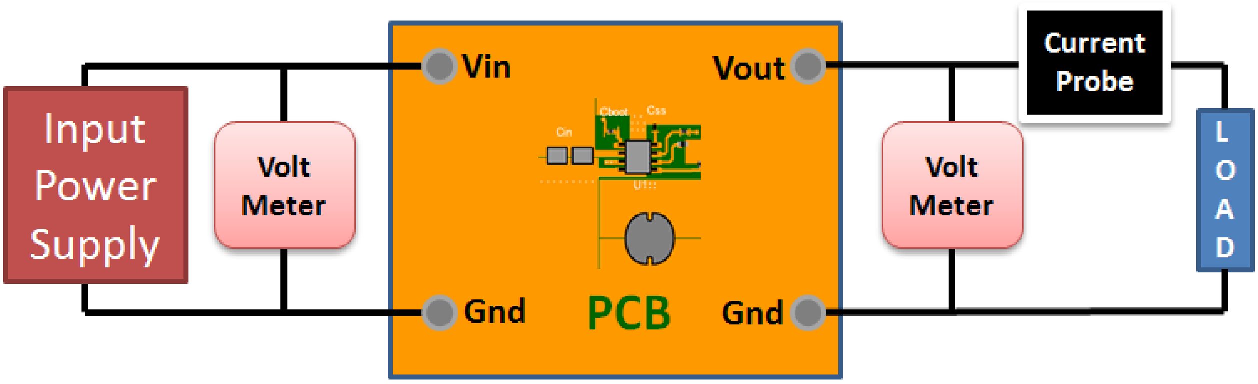
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. 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 12.0V 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 : 3AC91911FABB984D[v1]

2. **TPS65400** Product Folder : http://www.ti.com/product/TPS65400 : contains the data sheet and other resources.

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