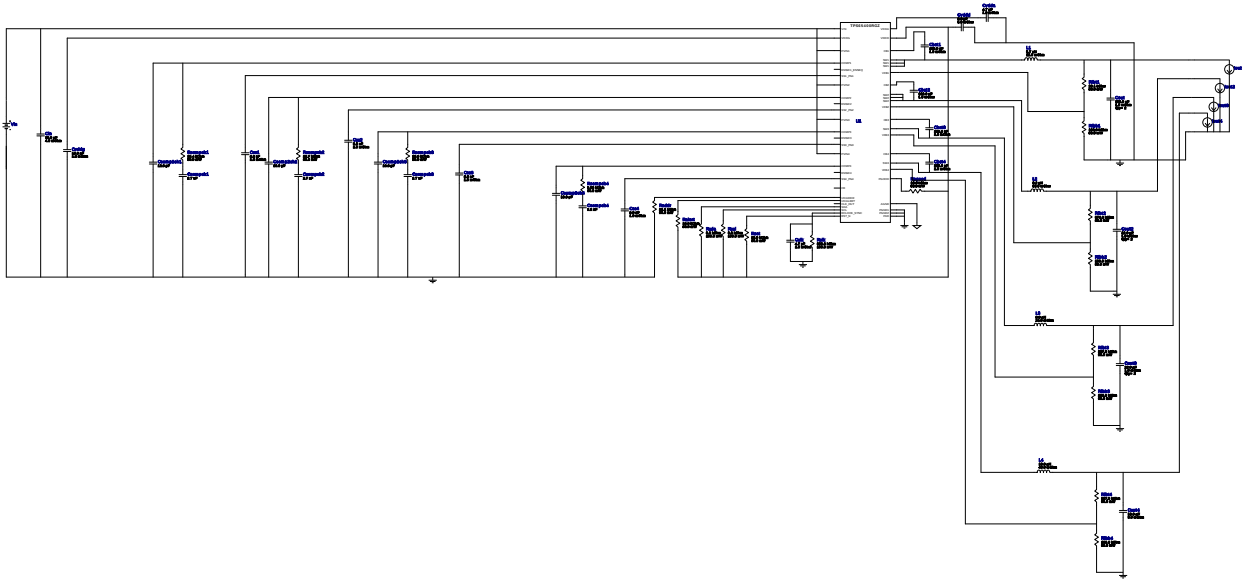


VinMin = 12.0V
VinMax = 12.0V
Vout = 1.0V
Iout = 4.0A

Device = TPS65400RGZR
Topology = Buck
Created = 2023-01-25 01:43:14.117
BOM Cost = \$4.41
BOM Count = 52
Total Pd = 2.72W

WEBENCH[®] Design Report

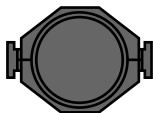
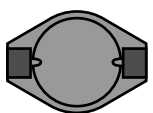
Design : 430 TPS65400RGZR
TPS65400RGZR 12V-12V to 1.00V @ 4A



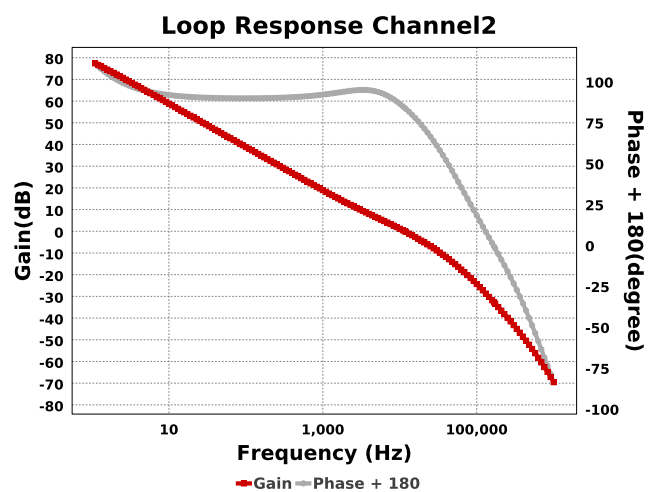
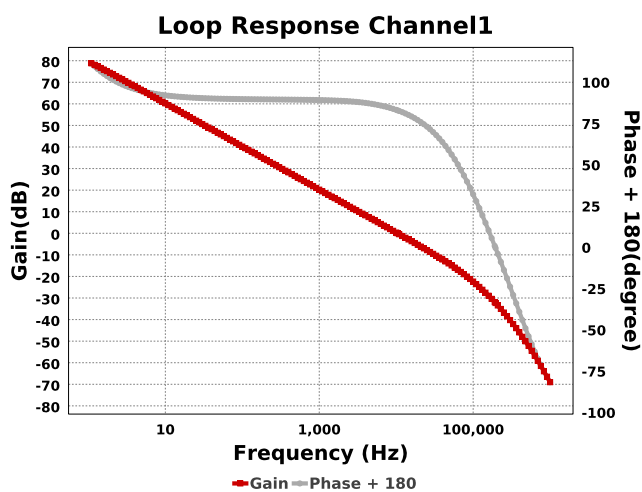
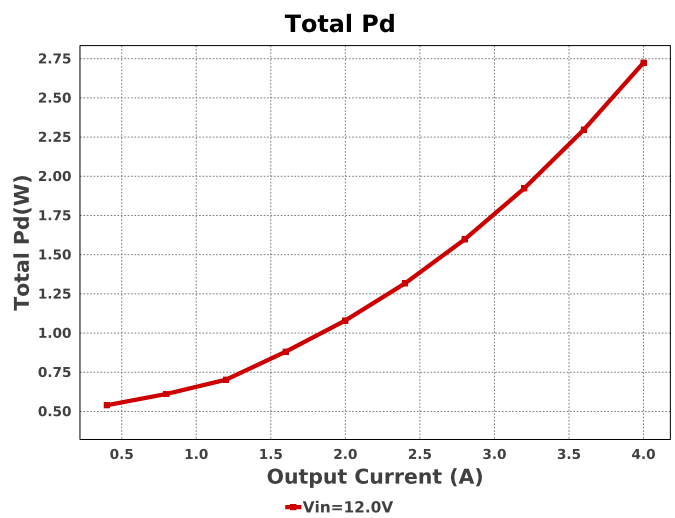
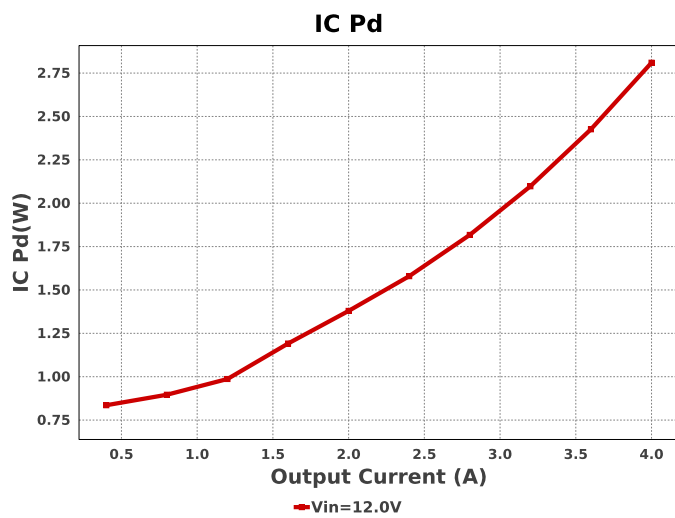
Electrical BOM

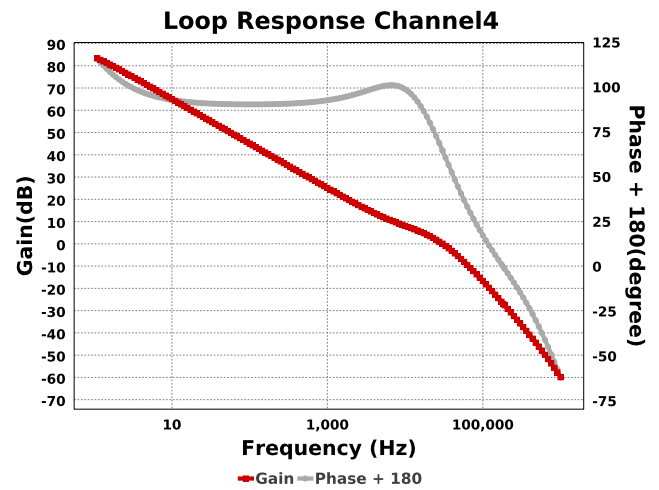
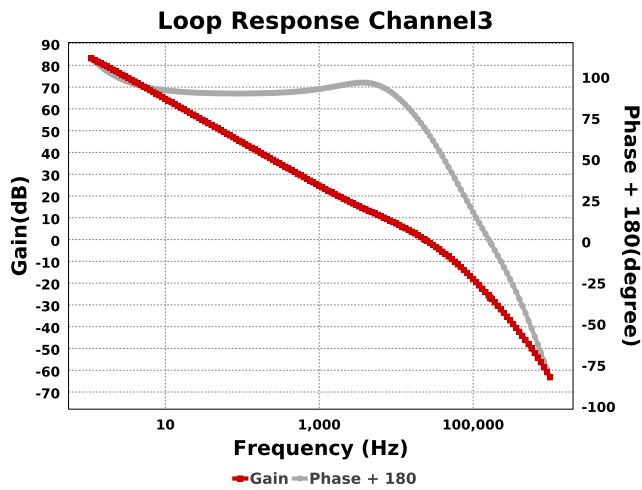
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cbst1	MuRata	GRM155R71A104KA01D Series= X7R	Cap= 100.0 nF ESR= 1.0 mOhm VDC= 10.0 V IRMS= 0.0 A	1	\$0.01	0402 3 mm ²
Cbst2	MuRata	GRM155R71A104KA01D Series= X7R	Cap= 100.0 nF ESR= 1.0 mOhm VDC= 10.0 V IRMS= 0.0 A	1	\$0.01	0402 3 mm ²
Cbst3	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
Ccomp2ch1Yageo		CC0805JRNPO9BN120 Series= C0G/NP0	Cap= 12.0 pF VDC= 50.0 V IRMS= 0.0 A	1	\$0.01	0805 7 mm ²
Ccomp2ch2Yageo		CC0805JRNPO9BN100 Series= C0G/NP0	Cap= 10.0 pF VDC= 50.0 V IRMS= 0.0 A	1	\$0.01	0805 7 mm ²
Ccomp2ch3Yageo		CC0805JRNPO9BN100 Series= C0G/NP0	Cap= 10.0 pF VDC= 50.0 V IRMS= 0.0 A	1	\$0.01	0805 7 mm ²
Ccomp2ch4Yageo		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	C2012C0G1H272J060AA Series= C0G/NP0	Cap= 2.7 nF VDC= 50.0 V IRMS= 0.0 A	1	\$0.03	 0805 7 mm ²
Ccompch2	TDK	C2012C0G1H272J060AA Series= C0G/NP0	Cap= 2.7 nF VDC= 50.0 V IRMS= 0.0 A	1	\$0.03	 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	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	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	2	\$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	Kemet	C0805C106K8PACTU Series= X5R	Cap= 10.0 uF ESR= 3.0 mOhm VDC= 10.0 V IRMS= 11.43 A	1	\$0.03	 0805 7 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

Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
L1	NIC Components	NPI31P2R7MTRF	L= 2.7 μ H 12.0 mOhm	1	\$0.17	 IND_NPI31P 185 mm ²
L2	Vishay-Dale	IHLP2525CZER8R2M01	L= 8.2 μ H 68.0 mOhm	1	\$0.61	 IHLP-2525CZ 75 mm ²
L3	TDK	VLP8040T-6R8M	L= 6.8 μ H 24.0 mOhm	1	\$0.22	 VLP8040 113 mm ²
L4	NIC Components	NPI34W100MTRF	L= 10.0 μ H 40.0 mOhm	1	\$0.25	 IND_NPI34W 172 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	Yageo	RC0201FR-0715K4L Series= ?	Res= 15.4 kOhm Power= 50.0 mW Tolerance= 1.0%	1	\$0.01	 0201 2 mm ²
Rcompch2	Vishay-Dale	CRCW040213K7FKED Series= CRCW..e3	Res= 13.7 kOhm Power= 63.0 mW Tolerance= 1.0%	1	\$0.01	 0402 3 mm ²
Rcompch3	Vishay-Dale	CRCW040213K3FKED Series= CRCW..e3	Res= 13.3 kOhm Power= 63.0 mW Tolerance= 1.0%	1	\$0.01	 0402 3 mm ²
Rcompch4	Vishay-Dale	CRCW04029K53FKED Series= CRCW..e3	Res= 9.53 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	CRCW040226K1FKED Series= CRCW..e3	Res= 26.1 kOhm Power= 63.0 mW Tolerance= 1.0%	1	\$0.01	 0402 3 mm ²
Rfbt2	Vishay-Dale	CRCW0402374KFKED Series= CRCW..e3	Res= 374.0 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

Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Rfbt4	Vishay-Dale	CRCW0402127KFKED Series= CRCW..e3	Res= 127.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	\$0.01	 0402 3 mm²
Rpgood	Vishay-Dale	CRCW040210K0FKED Series= CRCW..e3	Res= 10.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	\$0.01	 0402 3 mm²
Rslcl	Yageo	RC0603FR-073KL Series= ?	Res= 3.0 kOhm Power= 100.0 mW Tolerance= 1.0%	1	\$0.01	 0603 5 mm²
Rsda	Yageo	RC0603FR-073KL Series= ?	Res= 3.0 kOhm Power= 100.0 mW Tolerance= 1.0%	1	\$0.01	 0603 5 mm²
Rset	Vishay-Dale	CRCW040210K0FKED Series= CRCW..e3	Res= 10.0 kOhm Power= 63.0 mW Tolerance= 1.0%	1	\$0.01	 0402 3 mm²
U1	Texas Instruments	TPS65400RGZR	Switcher	1	\$2.05	 RGZ0048B 81 mm²





Operating Values

#	Name	Value	Category	Description
1.	Cout_ch1 IRMS	241.206 mA	Capacitor	Output Channel 1 Capacitor RMS ripple current
2.	Cout_ch2 IRMS	195.826 mA	Capacitor	Output Channel 2 Capacitor RMS ripple current
3.	Cout_ch3 IRMS	140.413 mA	Capacitor	Output Channel 3 Capacitor RMS ripple current
4.	Cout_ch4 IRMS	144.515 mA	Capacitor	Output Channel 4 Capacitor RMS ripple current
5.	IC Pd	2.81 W	IC	IC power dissipation
6.	IC Tj	83.049 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	2.677 A	IC	Average input current
10.	L1 Ipp	835.56 mA	Inductor	Inductor 1 peak to peak current
11.	L2Ipp	678.361 mA	Inductor	Channel 2 Inductor Peak to peak Current
12.	L3 Ipp	486.404 mA	Inductor	Inductor 3 peak to peak current
13.	L4 Ipp	500.614 mA	Inductor	Inductor 4 peak to peak current
14.	Cross Freq Ch1	10.42 kHz	Loop	Bode plot crossover frequency
15.	Cross Freq Ch2	11.603 kHz	Loop	Bode plot crossover frequency
16.	Cross Freq Ch3	23.618 kHz	Loop	Bode plot crossover frequency
17.	Cross Freq Ch4	30.257 kHz	Loop	Bode plot crossover frequency
18.	Gain Marg Ch1	-32.331 dB	Loop	Bode Plot Gain Margin
19.	Gain Marg Ch2	-32.788 dB	Loop	Bode Plot Gain Margin
20.	Gain Marg Ch3	-26.642 dB	Loop	Bode Plot Gain Margin
21.	Gain Marg Ch4	-26.963 dB	Loop	Bode Plot Gain Margin
22.	Low Freq Gain Ch1	78.779 dB	Loop	Gain at 1Hz
23.	Low Freq Gain Ch2	77.392 dB	Loop	Gain at 1Hz
24.	Low Freq Gain Ch3	83.162 dB	Loop	Gain at 1Hz
25.	Low Freq Gain Ch4	83.282 dB	Loop	Gain at 1Hz
26.	Phase Marg Ch1	83.416 deg	Loop	Bode Plot Phase Margin
27.	Phase Marg Ch2	84.686 deg	Loop	Bode Plot Phase Margin
28.	Phase Marg Ch3	69.313 deg	Loop	Bode Plot Phase Margin
29.	Phase Marg Ch4	64.89 deg	Loop	Bode Plot Phase Margin
30.	Cout_ch1 Pd	29.09 μ	Power	Output channel 1 capacitor power dissipation
31.	Cout_ch2 Pd	19.174 μ	Power	Output channel 2 capacitor power dissipation
32.	Cout_ch3 Pd	9.858 μ	Power	Output channel 3 capacitor power dissipation
33.	Cout_ch4 Pd	62.654 μ	Power	Output channel 3 capacitor power dissipation
34.	IC Pd	2.81 W	Power	IC power dissipation
35.	L1 Pd	192.698 m	Power	Inductor1 power loss
36.	L2 Pd	1.091	Power	Inductor2 power loss

#	Name	Value	Category	Description
37.	L3 Pd	96.473 m	Power	Inductor3 power loss
38.	L4 Pd	160.835 m	Power	Inductor3 power loss
39.	Total Pd	2.724 W	Power	Total Power Dissipation
40.	BOM Count	52	System Information	Total Design BOM count
41.	Duty Cycle 1	10.386 %	System Information	Duty cycle for Channel 1
42.	Duty Cycle 2	35.677 %	System Information	Duty cycle for Channel 2
43.	Duty Cycle 3	16.261 %	System Information	Duty cycle for Channel 3
44.	Duty Cycle 4	29.047 %	System Information	Duty Cycle channel 4
45.	Efficiency	91.519 %	System Information	Steady state efficiency
46.	FootPrint	847.0 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	4.0 A	System Information	Iout1 operating point
52.	Iout2	4.0 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	4.0 W	System Information	Total output power
60.	Pout2	15.2 W	System Information	Total output power
61.	Pout3	3.6 W	System Information	Total output power
62.	Pout4	6.6 W	System Information	Total output power
63.	Total BOM	\$4.41	System Information	Total BOM Cost
64.	Vin	12.0 V	System Information	Vin operating point
65.	Vout Tolerance	1.673 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
66.	Vout1	1.0 V	System Information	Operational Voltage 1
67.	Vout1_Actual	1.009 V	System Information	Vout Actual calculated based on selected voltage divider resistors
68.	Vout2	3.8 V	System Information	Operational Voltage 2
69.	Vout2Tolerance	2.864 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
70.	Vout2_Actual	3.792 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	3.3 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	4.0	Maximum Output Current
Iout1	4.0	Output Current #1
Iout2	4.0	Output Current #2
VinMax	12.0	Maximum input voltage
VinMin	12.0	Minimum input voltage
Vout	1.0	Output Voltage
Vout1	1.0	Output Voltage #1
Vout2	3.8	Output Voltage #2
base_pn	TPS65400	Base Product Number
source	DC	Input Source Type
Ta	30.0	Ambient temperature
UserFsw	493.0 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 C_{in} and C_{out} , 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

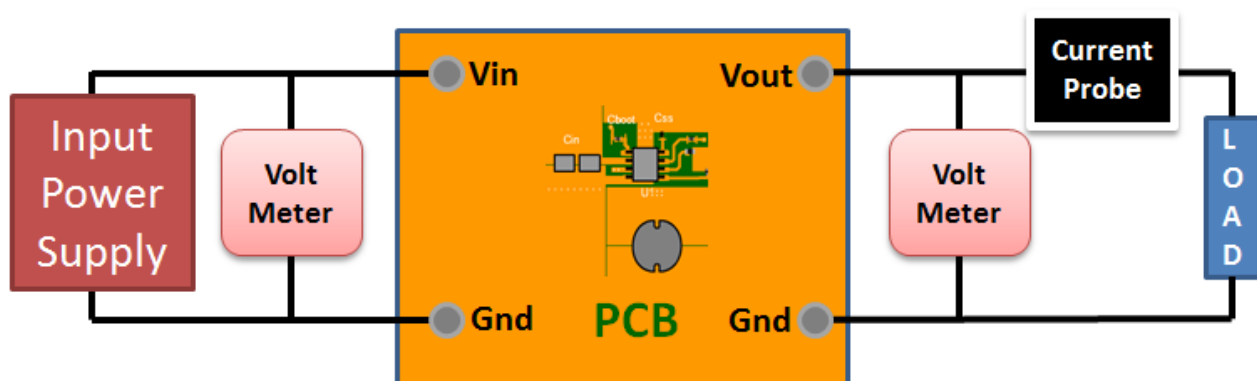
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins. To solder the tab down 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 V_{in} and GND. Connect a digital volt meter and a load if needed to set the minimum load of the design from V_{out} 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 V_{in} and GND, a load is connected between V_{out} and GND and a current meter is connected in series between V_{out} 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 : DB0578CF46F09962[v1]
2. **TPS65400** Product Folder : <http://www.ti.com/product/TPS65400> : contains the data sheet and other resources.

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