ENGR 455 Final Project

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A buck converter steps down voltage and has built-in control systems to have the same Vout for a given load. This project explores how to design a buck converter for a given set of parameters. With an input of 5 volts, the buck converter needs to maintain a 1.8V at 5 amps with a ΔIL < 30% of Iout. The parts also must be chosen to such that Vout has a 1% ripple at full load and less than a 50mV peak to peak at that full load setting of Iout at 5 amps. The phase margin also needs to be greater than 50 degrees to prevent significant ringing from occurring and a 50mV transient droop when a load step of 2A-3Amps is given.

The first calculation is of the inductance needed for these parameters taking note that we want a series resistance less than 20mohns. The Vin is 5V and the Vout is 1.8 with these values we can get D the duty cycle of an ideal buck converter to be 0.36. The delta IL is then set to be 30% of Iout which calculates to 1.5Amps and a switching frequency predetermined to be 500khz. However, for our purposes, it's better to go with an even lower delta IL to increase the inductance since it has very few drawbacks and a lot of benefits. This was somewhat arbitrarily chosen to be using an Iout of 1.8 Amps. This creates a $\Delta\mathrm{That}$ is about 3 times smaller than the max value where the converter might reach a threshold of discontinuous conduction mode. The drawback to increasing the size of this inductor is decreased efficiency because larger inductors also have larger series resistances.

$$L = \frac{(V_{in}\text{-}V_{out})^{*}D}{\Delta I_L f_{sw}}$$

The final value is now given to around 4.3µH while the initial calculation gave us an inductor about 3 times as small. Nex step is the selection of Input and output capacitors. Ti has a WEBENCH Power designer software and that was used to aid with these parts. By specifying the converter and design parameters they automatically give you values that are tuned for your problem. These values were then chosen used as a reference point in the calculation of the next few sections. Inputting the chooses inductance among other things gave us a more accurate model for our design.

Using the Lt Spice simulation, the crossover frequency was found to be at 50Hz with a phase margin of 93 degrees at 0dBs seen in figure 3. However, using the simulator from TI a cross-over frequency of 35Khz and a significantly higher phase margin can be seen in figure 4. When choosing the feedback components, they were tuned to achieve a crossover frequency of around 50khz. The current results were determined to be the best because they roughly fit both simulators and were close enough to the parameters wanted.

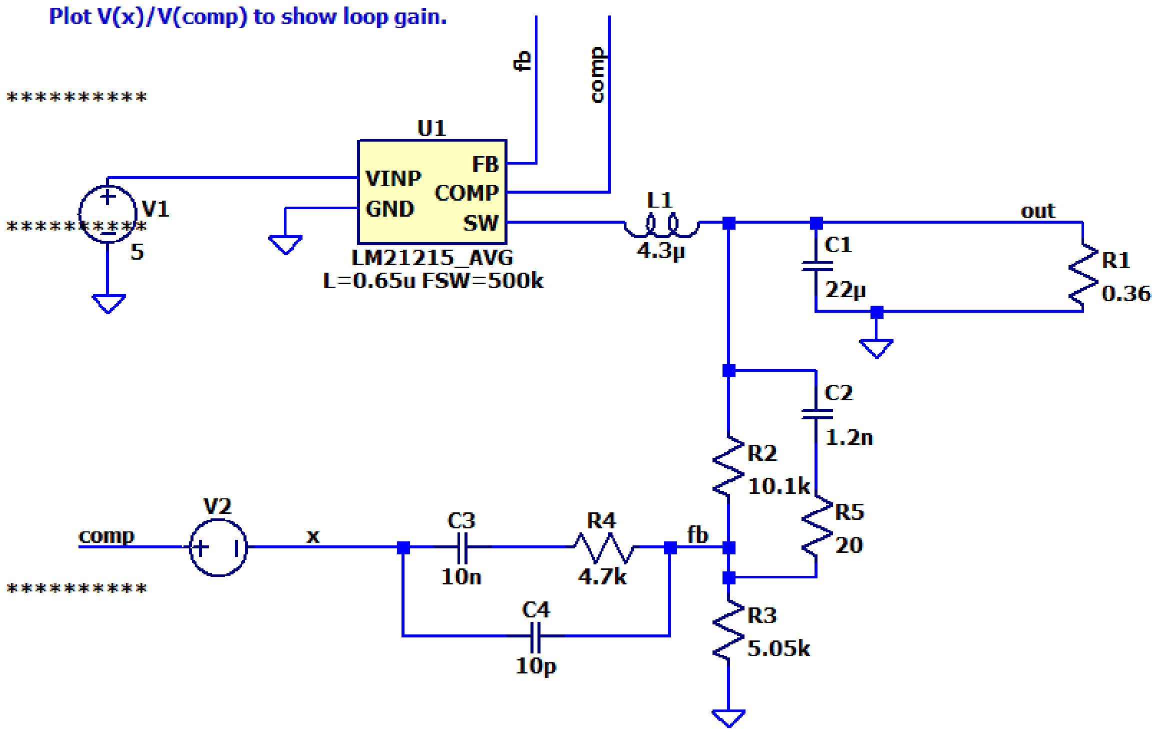


Figure 1 Loop gain simulation circuit

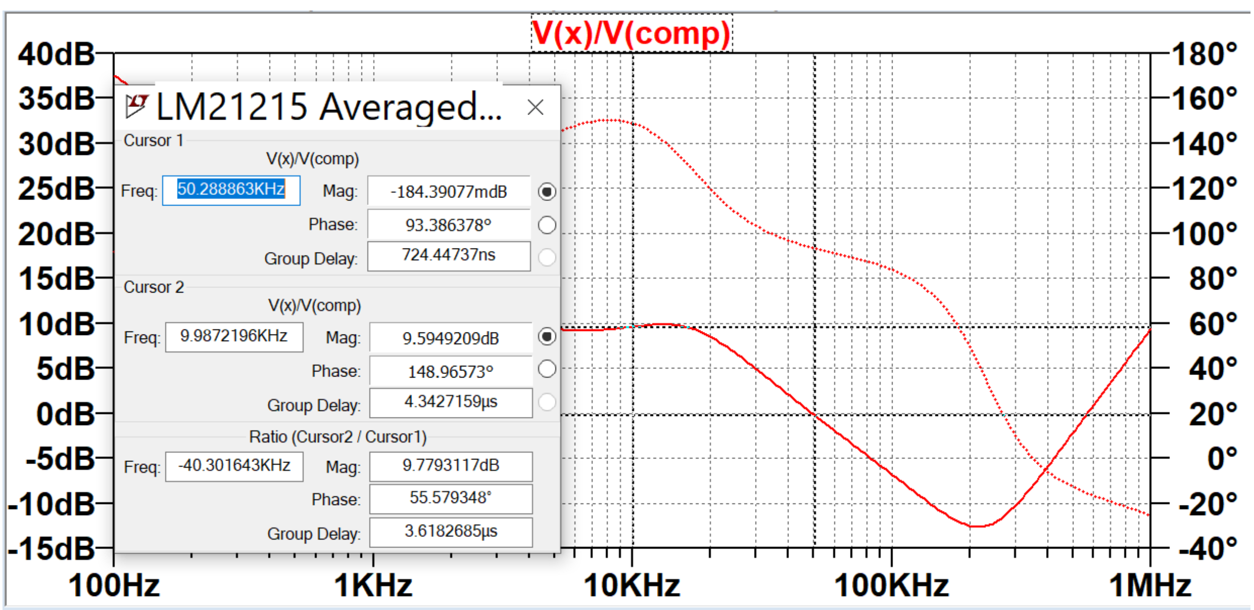


Figure 2 Cross over frequency/ phase margin

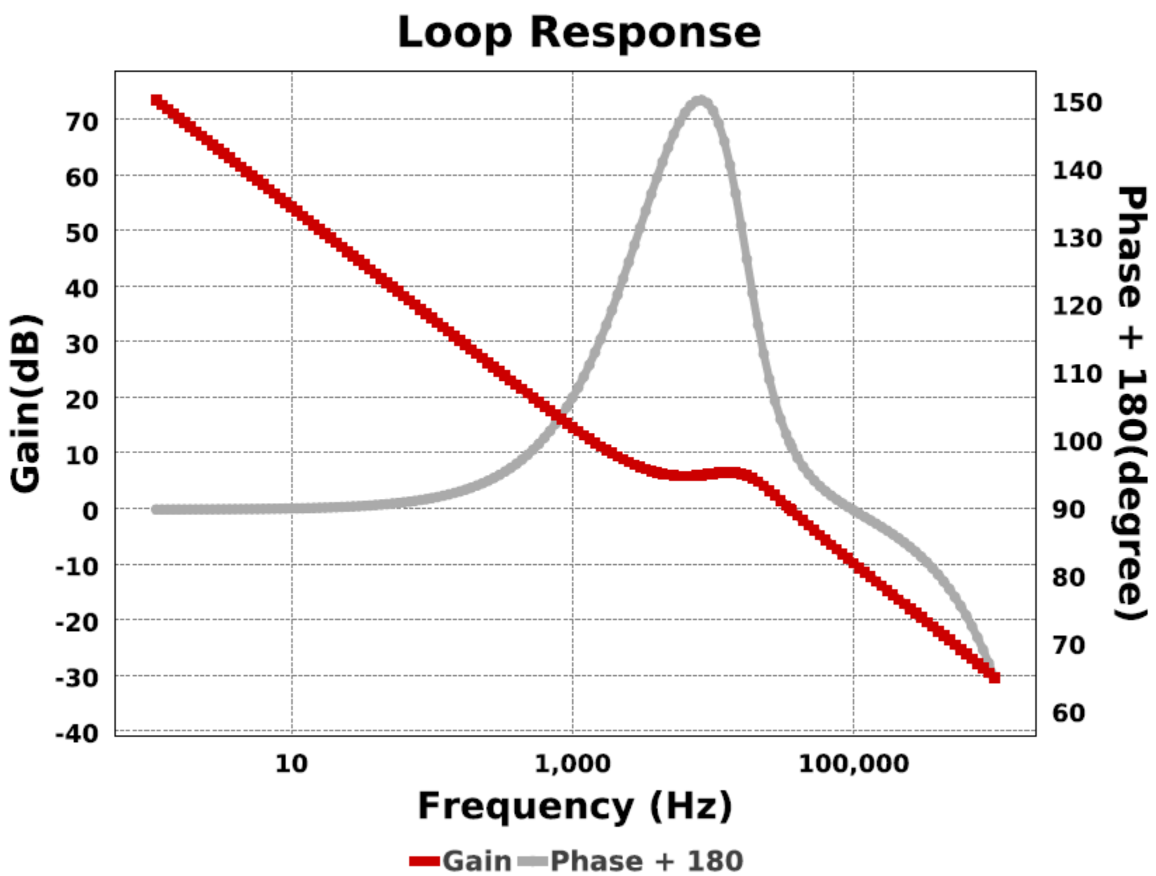


Figure 3 Crossover frequency and phase margin

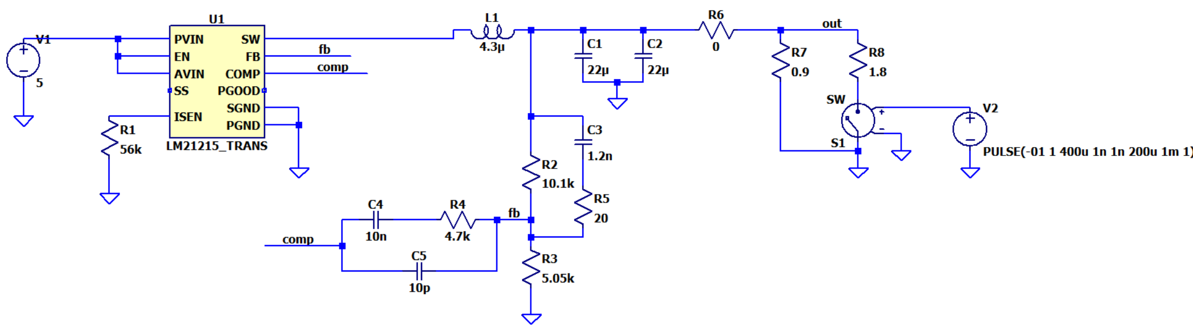


Figure 4 Load step simulation circuit

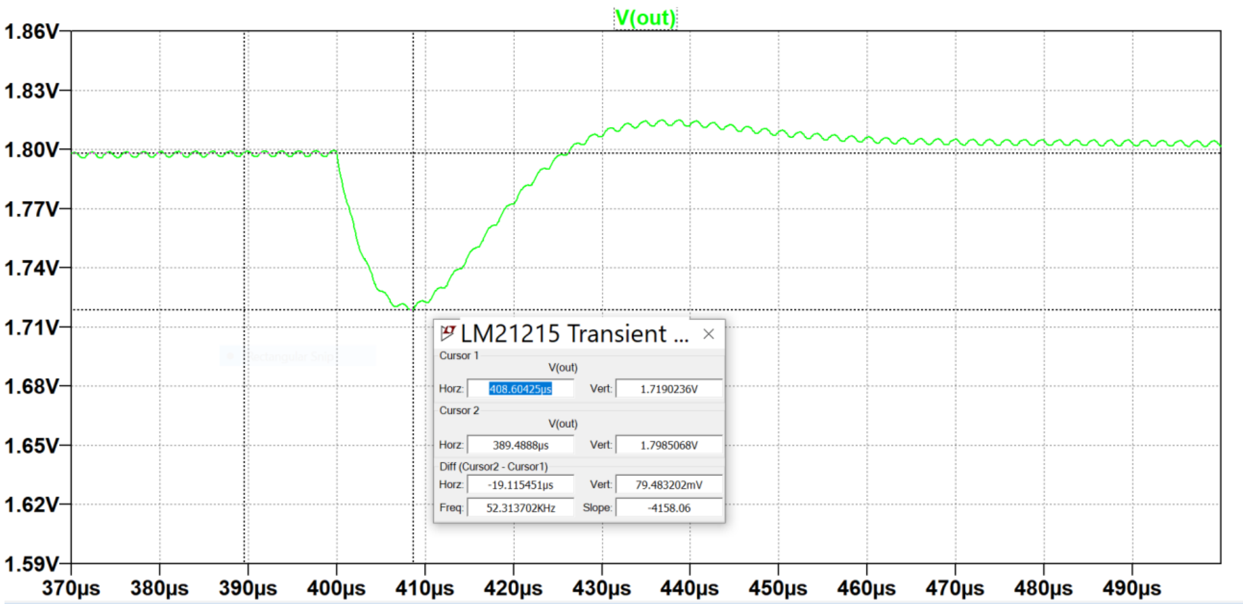


Figure 5 Vdroop size

With all the simulations accounted for the next step was to find physical parts on Mouser. And those can be seen in the appendix of this document under the BOM. The next stage was to start making the PCB. This was done with the use of eagle CAD. The layout of the schematic is normal and almost the same as the simulations done in LT spice. The PCB on the other hand has a very specific configuration that follows the guidelines made by TI. Take care to separate the feedback components and the Cin and Vout. Traces were also made to dissipate more power, when necessary, like in the case of Vout and Vin and a ground plane was placed where there was empty space throughout the PCB. To prevent heating, all the ground planes are tied together and there are many vias applied to the ground planes to make sure heat is dissipated effectively from the chip.

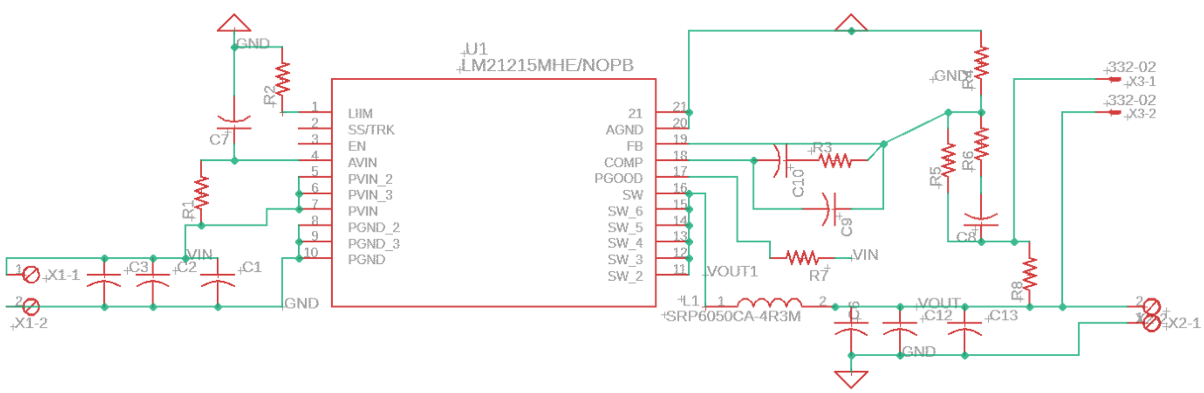


Figure 6 Schematic

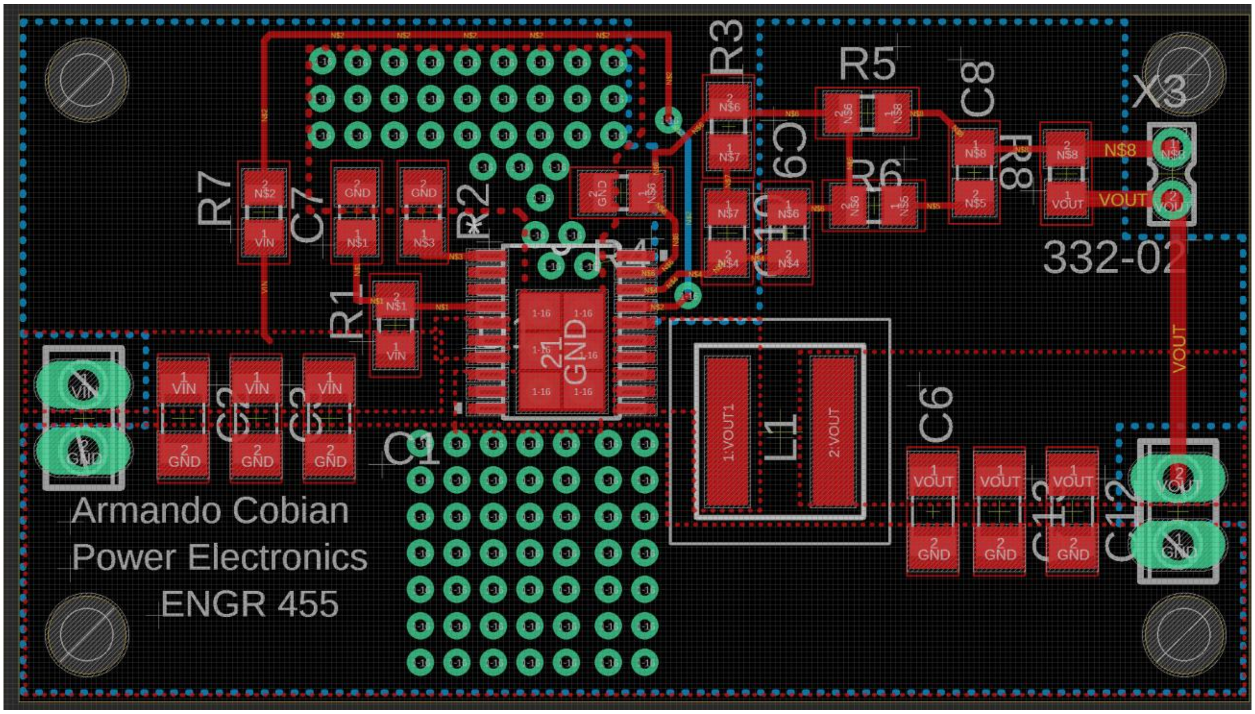


Figure 7 PCB

For this portion of the test, the stability of the system and the transient droop performance is taken into account. This is done but has a load step that draws a constant current of 2A to 3A and changes from both states at 100hz. Figure 6 shows us what this test and from the information provided it is clear that the system is not stable. The Vdroop is masked under the instability of the system since it doesn't ever zero out to a certain value. The main part that affects the Vdroop is the output capacitor and its series resistance. Having a lower higher Cout with a lower series resistance would have made this value smaller. Since 3 capacitors were set in parallel that was meant not only to increase the effective capacitance of Cout but also decrease the series resistance of Cout. As for instability increasing the board size and separating the feedback components from the output caps would have greatly helped to reduce the EMI. This can make the converter have poor regulation or lead to instability. So to sum up this shows a bigger Cout and further distancing of the feedback component would have helped the overall design.

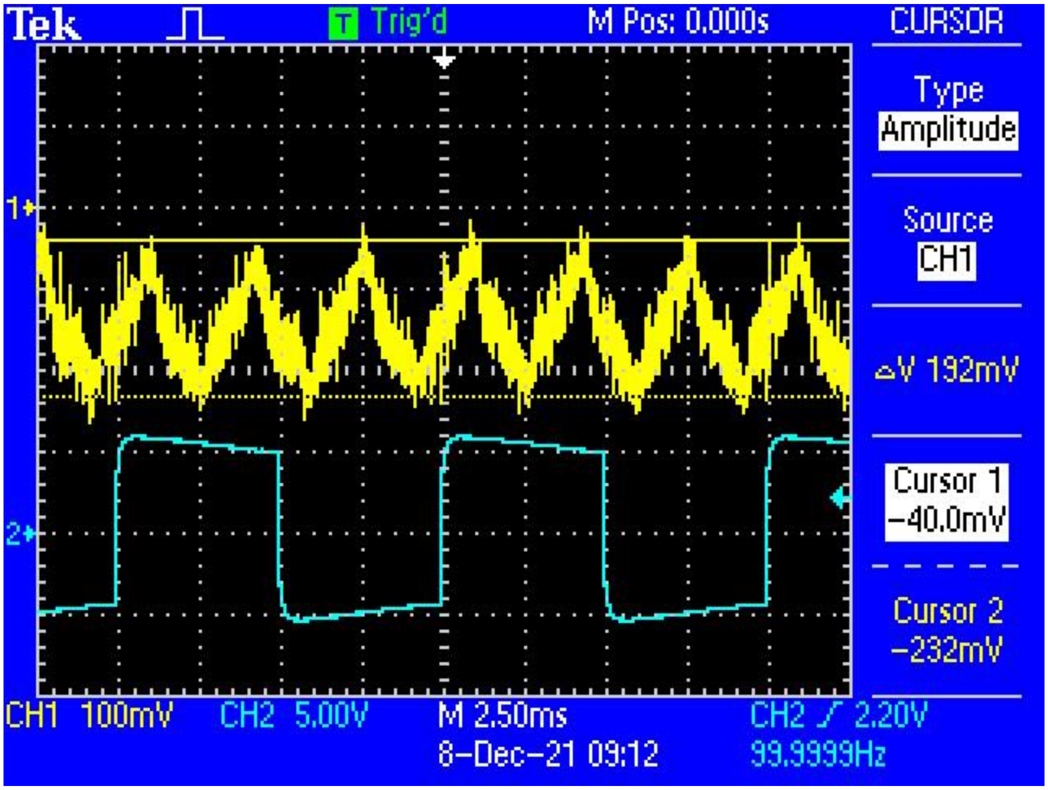


Figure 1 Step response/stability and droop performance

Here it is even more noticeable how unstable the system is when just testing at the full load condition. Under these conditions, the switching node, inductor current, and output ripple were to be measured. The observed output ripple can be seen to be 1V. This is extremely high and gives us an output ripple of about 50%. This would be affected by the inductor current and the output capacitors. A lower inductor current and a higher Cout would decrease this value. The test for the inductor current could not be completed since when the inductor was unsoldered to make a loop top measure the current one of the pads came off and a replacement was not available. However, the efficiency was calculated before this and with a Vin of 5V at 2.375A and at the output a 5amp draw with an initial measurement of 1.6V from the load voltage measurement. However, this was partly due to really long leads coming from the Vout to the load. If the Cout was read directly at the nodes leaving the PCB it did read 1.8V. This gives an efficiency of 75.78%.

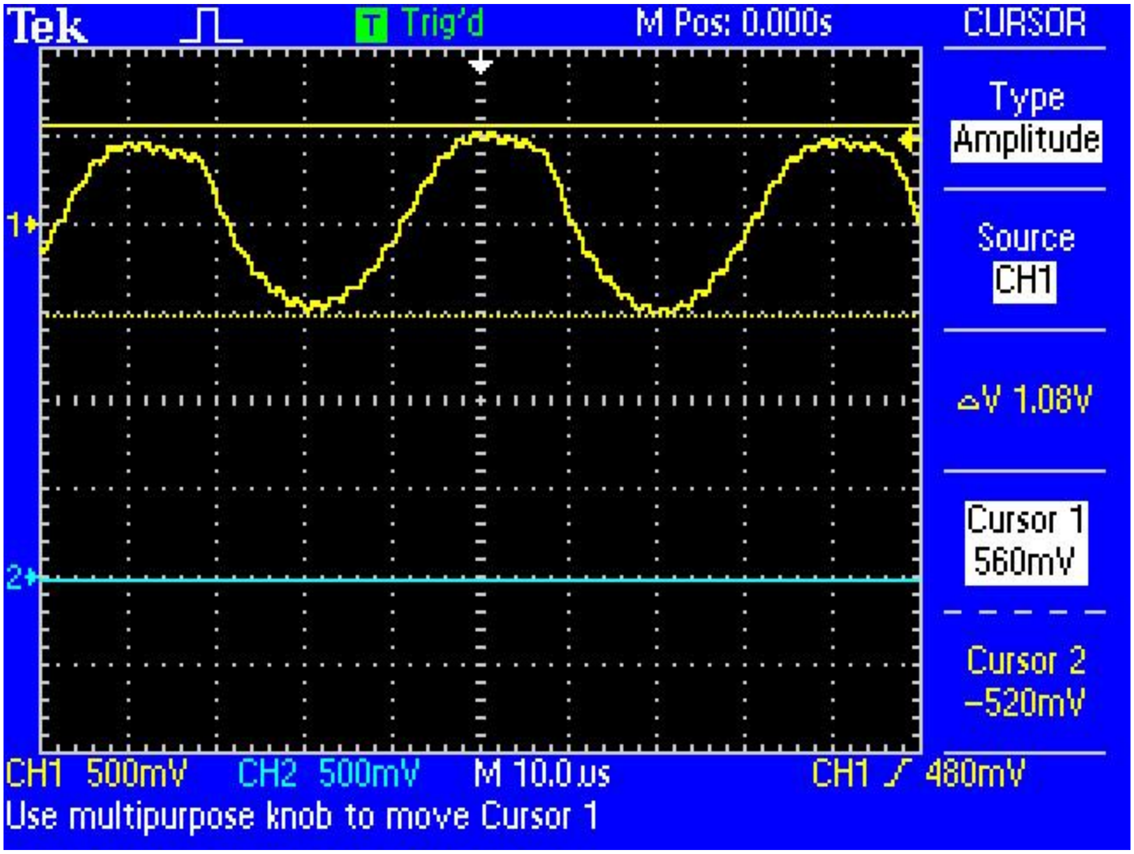


Figure 2 Full load

Conclusion

This project showed how to use simulations to validate hardware decisions than use that hardware to be able to reiterate a second design with better characteristics than the first. The PCB layout also was very informative in learning how to use planes instead of auto-tracing and making sure certain components are further away from others. A second iteration would also add more pins to read things like Vin and Vout with more ease. Another big thing was adding a current sensing loop to easily calculate the inductor current and not have to hard solder a loop to do so. As for the choice of the components, it is very apparent that the Cout needed to be increased and a smaller resistance for the capacitors was not able to be found in part selections then adding more in parallel to lower the effective resistance and increase the overall capacitance.

Appendix

MOUSER ELECTRONICS.

Products | Manufacturers | Services & Tools | Technical Resources | Help | Account & Orders

SHOPPING CART

This is not an invoice.

Sort	Product Detail			Description	Quantity	Availability	Unit Price (USD)	Ext. Price (USD)
1		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	652-SRP6050CA-4R3M SRP6050CA-4R3M Bourns Customer #	Fixed Inductors 4.3uH 20% 9A RoHS Compliant	2 **Packaging:** **Cut Tape	2 Ships Now	$2.14	**$4.28**
2		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	80-C0805C103J3GAUTO C0805C103J3GACAUTO KEMET Customer #	Multilayer Ceramic Capacitors MLCC - SMD/SMT 25V 0.01uF C0G 0805 5% AEC-Q200 RoHS Compliant	2 **Packaging:** **Cut Tape	2 Ships Now	$0.41	**$0.82**
3		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	80-C0805X100J1GACTU C0805X100J1GACTU KEMET Customer #	Multilayer Ceramic Capacitors MLCC - SMD/SMT 100V 10pF C0G 0805 5% Flex Soft RoHS Compliant	2 **Packaging:** **Cut Tape	2 Ships Now	$0.40	**$0.80**
4		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	80-C0805C122J3HACTU C0805C122J3HACTU KEMET Customer #	Multilayer Ceramic Capacitors MLCC - SMD/SMT 25V 1200pF X8R 0805 5% RoHS Compliant	2 **Packaging:** **Cut Tape	2 Ships Now	$0.13	**$0.26**
5		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	81-GCJ31CR71A226KE1L GCJ31CR71A226KE01L Murata Customer #	Multilayer Ceramic Capacitors MLCC - SMD/SMT 22UF 10V 10% 1206 RoHS Compliant	6 **Packaging:** **Cut Tape	6 Ships Now	$1.03	**$6.18**
6		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	80-C1206X106J3R C1206X106J3RACTU KEMET Customer #	Multilayer Ceramic Capacitors MLCC - SMD/SMT 25V 10uF X7R 1206 5% Flex Soft RoHS Compliant	6 **Packaging:** **Cut Tape	6 Ships Now	$1.26	**$7.56**
7		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	80-C0805C104J3REAULR C0805C104J3RECAUTO7210 KEMET Customer #	Multilayer Ceramic Capacitors MLCC - SMD/SMT 25V 0.1uF X7R 0805 5% AEC-Q200 RoHS Compliant	2 **Packaging:** **Cut Tape	2 Ships Now	$0.36	**$0.72**
8		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	652-CHP0805AJW-100L CHP0805AJW-100ELF Bourns Customer #	Thick Film Resistors - SMD ResHighPowerA 0805 10R 5% 1/2W TC200 AEC-Q200 RoHS Compliant	2 **Packaging:** **Cut Tape	2 Ships Now	$0.55	**$1.10**

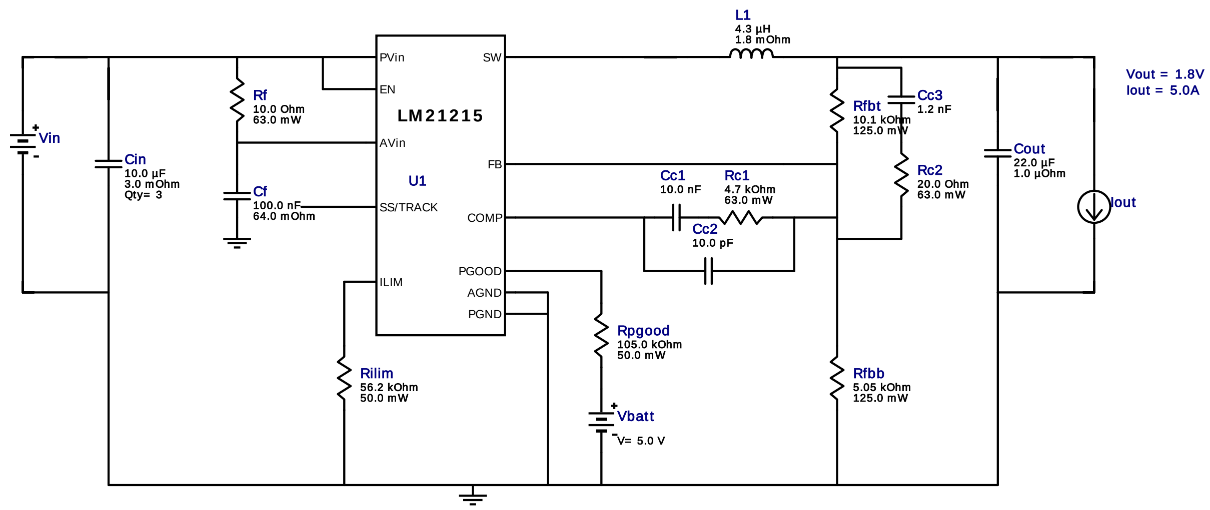
8		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	652-CHP0805AJW-100L CHP0805AJW-100ELF Bourns Customer #	Thick Film Resistors - SMD ResHighPowerA 0805 10R 5% 1/2W TC200 AEC-Q200 RoHS Compliant	2 **Packaging:** **Cut Tape	2 Ships Now	$0.55	**$1.10**
9		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	667-ERJ-P6WF5602V ERJ-P6WF5602V Panasonic Customer #	Thick Film Resistors - SMD 0805 56Kohms 1% Anti-Surge AEC-Q200 RoHS Compliant By Exemption	2 **Packaging:** **Cut Tape	2 Ships Now	$0.59	**$1.18**
10		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	652-CHP0805AFX1003EL CHP0805AFX-1003ELF Bourns Customer #	Thick Film Resistors - SMD ResHighPowerA 0805 100k 1% 1/2W TC100 RoHS Compliant	2	2 Ships Now	$0.65	**$1.30**
11		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	660-SG73G2ATTD4701D SG73G2ATTD4701D KOA Speer Customer #	Thick Film Resistors - SMD 4.7K ohm 0.5% 0.5W AEC-Q200 RoHS Compliant By Exemption	2 **Packaging:** **Cut Tape	2 Ships Now	$0.42	**$0.84**
12		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	667-ERJ-P6WF22R0V ERJ-P6WF22R0V Panasonic Customer #	Thick Film Resistors - SMD 0805 22ohms 1% Anti-Surge AEC-Q200 RoHS Compliant By Exemption	2 **Packaging:** **Cut Tape	2 Ships Now	$0.59	**$1.18**
13		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	652-CHP0805JW200ELF CHP0805-JW-200ELF Bourns Customer #	Thick Film Resistors - SMD 1/2W 20 ohms 5% 200ppm Ultra HP Chip RoHS Compliant By Exemption	2 **Packaging:** **Cut Tape	2 Ships Now	$0.37	**$0.74**
14		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	667-ERJ-P6WF5101V ERJ-P6WF5101V Panasonic Customer #	Thick Film Resistors - SMD 0805 5.1Kohms 1% Anti-Surge AEC-Q200 RoHS Compliant By Exemption	2 **Packaging:** **Cut Tape	2 Ships Now	$0.59	**$1.18**
15		**Mouser #:** **Mfr. #:** **Mfr.:** **Customer #:**	667-ERJ-P06F1022V ERJ-P06F1022V Panasonic Customer #	Thick Film Resistors - SMD 0805 10.2Kohms 0.5W 1% AEC-Q200 RoHS Compliant By Exemption	2 **Packaging:** **Cut Tape	2 Ships Now	$0.18	**$0.36**

VinMin = 5.0V
VinMax = 5.0V
Vout = 1.8V
Iout = 5.0A

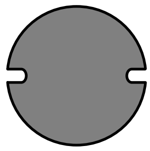
Device = LM21215MHX/NOPB
Topology = Buck
Created = 2021-11-28 00:13:20.141
BOM Cost = NA
BOM Count = 17
Total Pd = 0.53W

WEBENCH ® Design Report

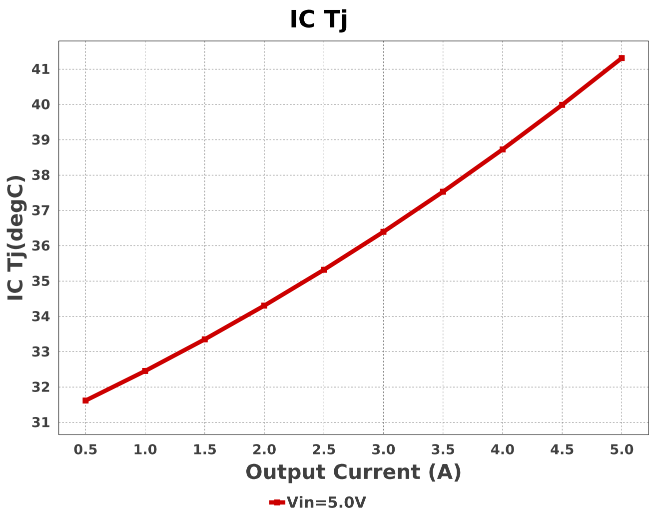
Design : 3 LM21215MHX/NOPB
LM21215MHX/NOPB 5V-5V to 1.80V @ 5A

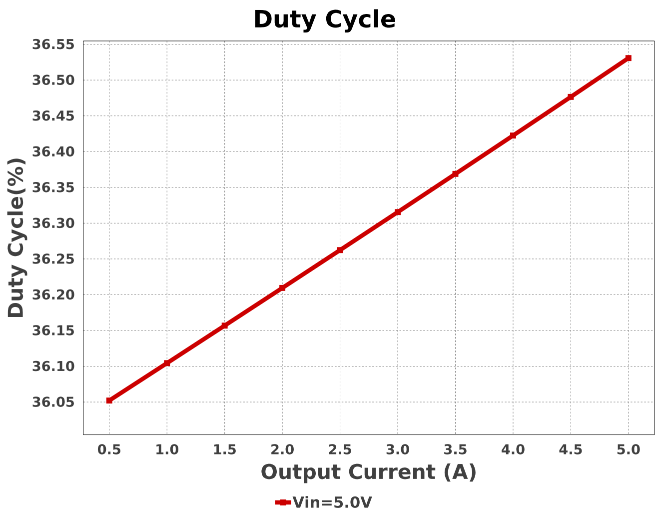


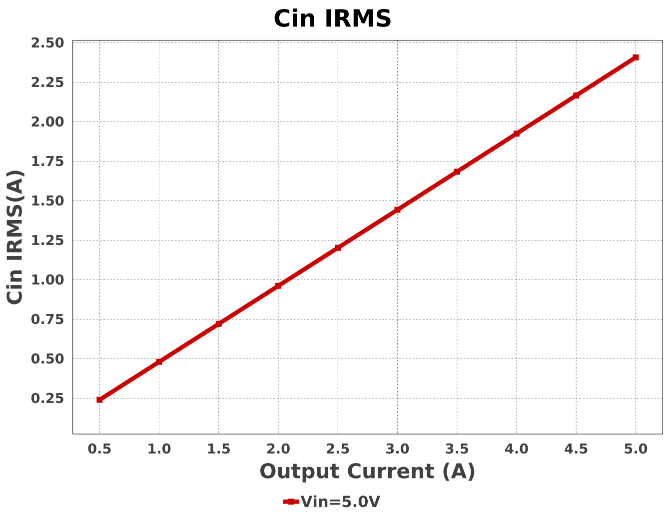
Electrical BOM

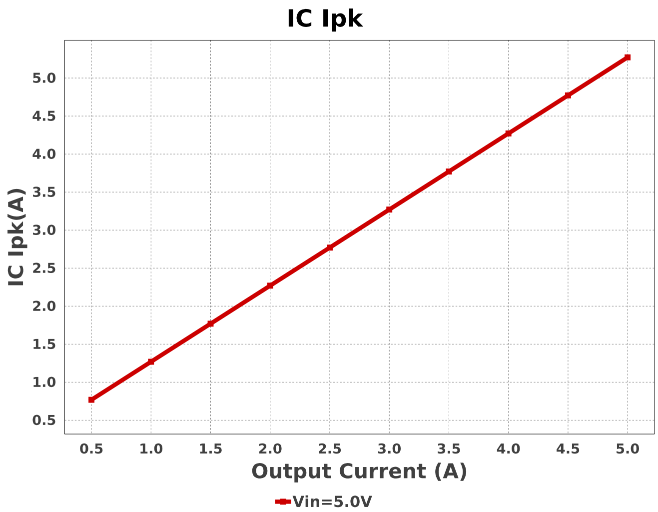
Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Cc1	CUSTOM	CUSTOM Series= C0G/NP0	Cap= 10.0 nF VDC= 50.0 V IRMS= 0.0 A	1	NA	0805 0 mm²
Cc2	CUSTOM	CUSTOM Series= C0G/NP0	Cap= 10.0 pF VDC= 50.0 V IRMS= 0.0 A	1	NA	0805 0 mm²
Cc3	CUSTOM	CUSTOM Series= C0G/NP0	Cap= 1.2 nF VDC= 50.0 V IRMS= 0.0 A	1	NA	0805 0 mm²
Cf	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 mm²
Cin	Kemet	C0805C106K8PACTU Series= X5R	Cap= 10.0 uF ESR= 3.0 mOhm VDC= 10.0 V IRMS= 11.43 A	3	$0.03	0805 7 mm²
Cout	CUSTOM	CUSTOM Series= X5R	Cap= 22.0 uF ESR= 1.0 uOhm VDC= 6.3 V IRMS= 4.4118 A	1	NA	1206_190 0 mm²
L1	CUSTOM	CUSTOM	L= 4.3 µH 1.8 mOhm	1	NA	 SDR1307 0 mm²
Rc1	CUSTOM	CUSTOM Series= CRCW..e3	Res= 4.7 kOhm Power= 63.0 mW Tolerance= 1.0%	1	NA	0402 0 mm²
Rc2	CUSTOM	CUSTOM Series= CRCW..e3	Res= 20.0 Ohm Power= 63.0 mW Tolerance= 1.0%	1	NA	0402 0 mm²

Name	Manufacturer	Part Number	Properties	Qty	Price	Footprint
Rf	Vishay-Dale	CRCW040210R0FKED Series= CRCW..e3	Res= 10.0 Ohm Power= 63.0 mW Tolerance= 1.0%	1	$0.01	0402 3 mm²
Rfbb	Yageo	RT0805BRD075K05L Series= ?	Res= 5.05 kOhm Power= 125.0 mW Tolerance= 0.1%	1	$0.06	0805 7 mm²
Rfbt	Yageo	RT0805BRD0710K1L Series= ?	Res= 10.1 kOhm Power= 125.0 mW Tolerance= 0.1%	1	$0.06	0805 7 mm²
Rilim	Yageo	RC0201FR-0756K2L Series= ?	Res= 56.2 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm²
Rpgood	Yageo	RC0201FR-07105KL Series= ?	Res= 105.0 kOhm Power= 50.0 mW Tolerance= 1.0%	1	$0.01	0201 2 mm²
U1	Texas Instruments	LM21215MHX/NOPB	Switcher	1	$3.08	MYB20AA 71 mm²

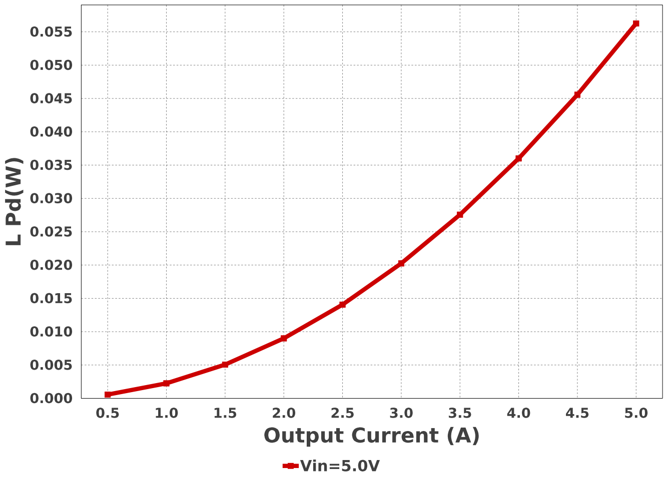




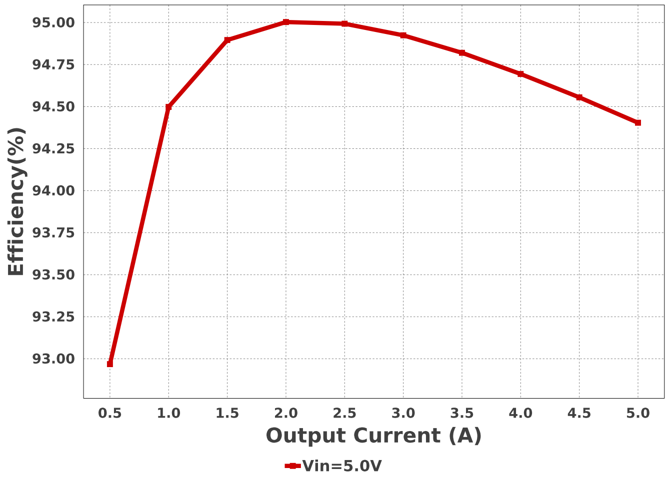




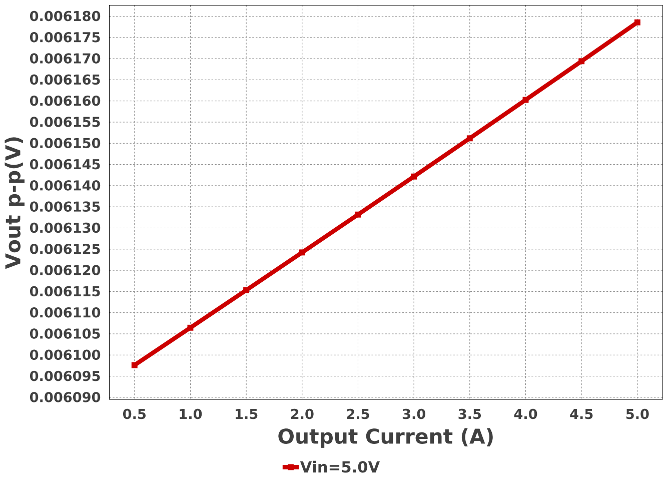
L Pd



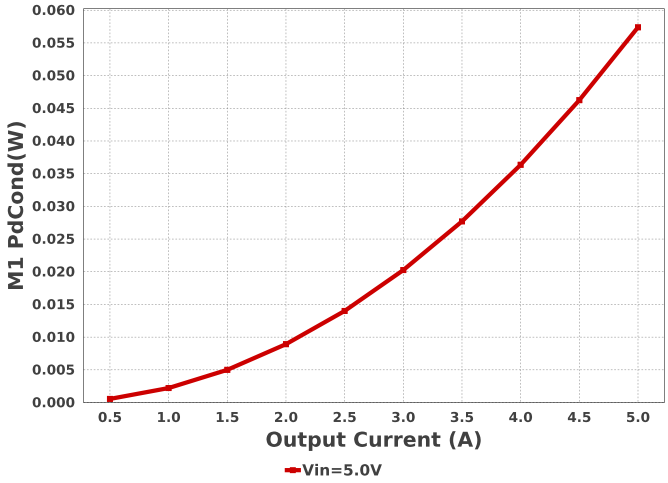
Efficiency



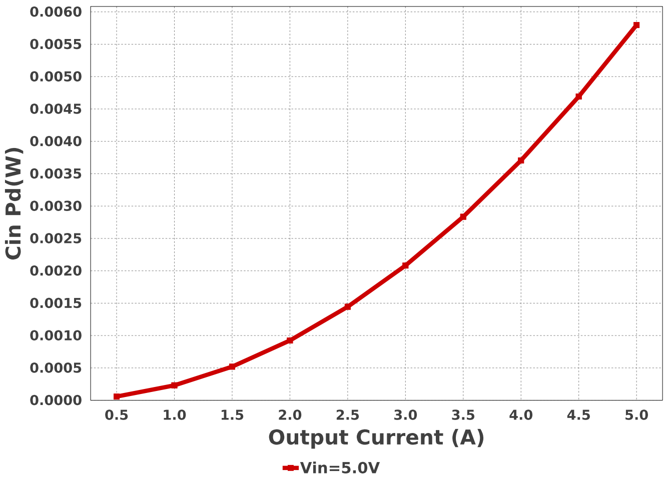
Vout p-p



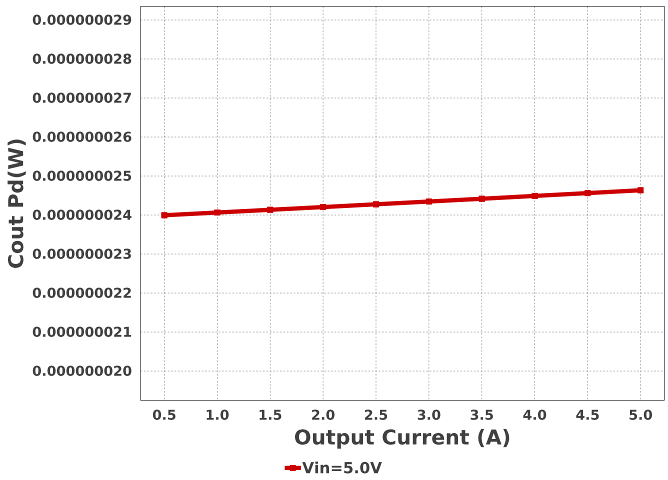
M1 PdCond

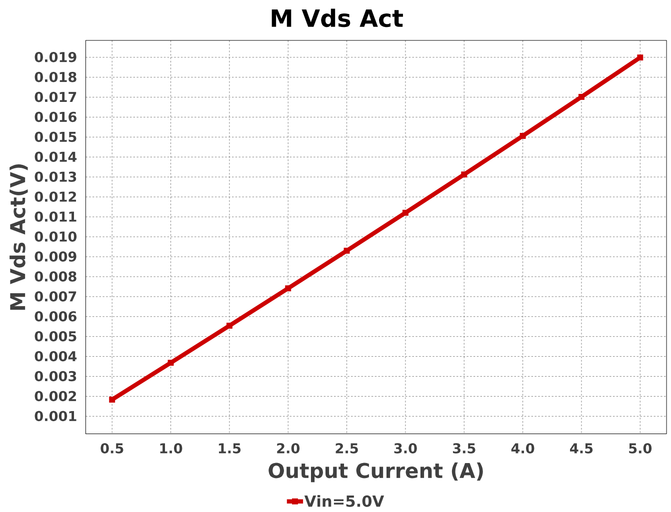


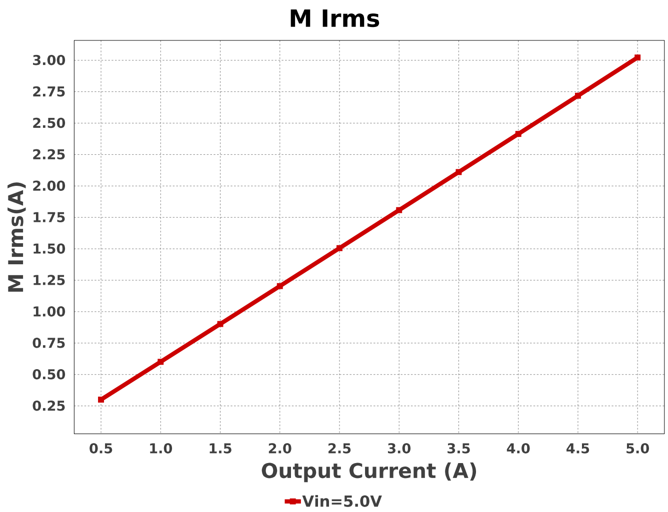
Cin Pd

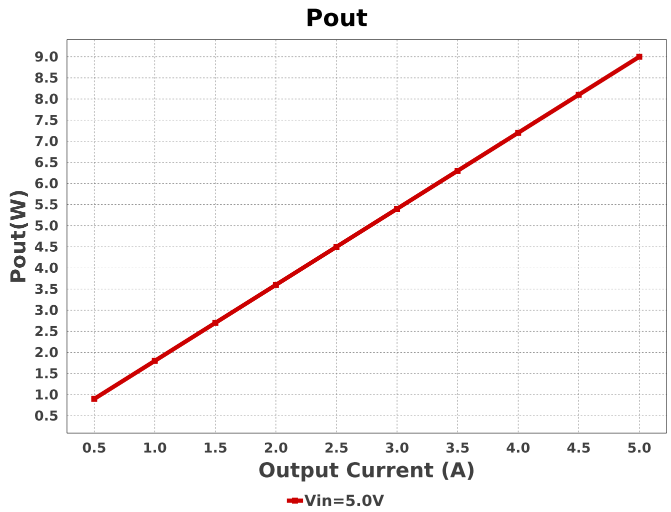


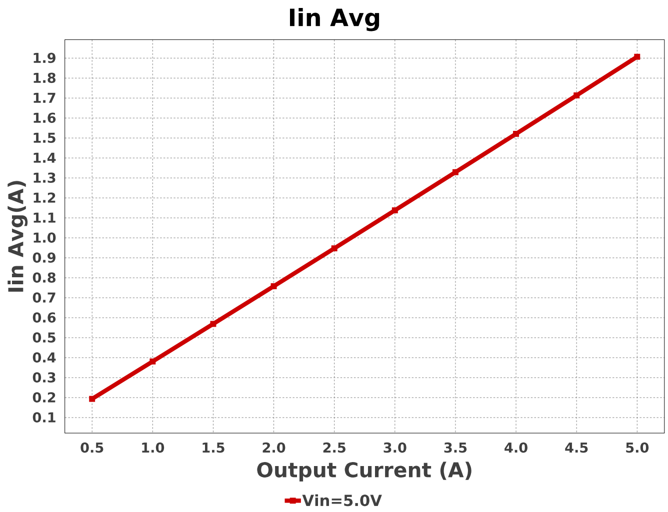
Cout Pd

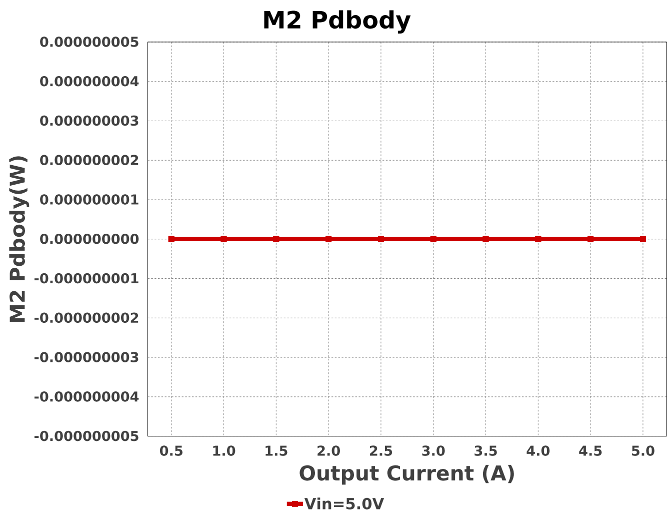


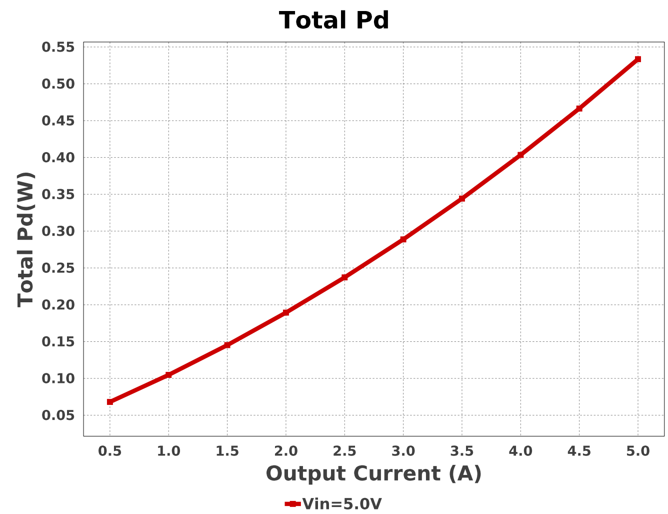

M Vds Act
M Vds Act(V)
0.019
0.018
0.017
0.016
0.015
0.014
0.013
0.012
0.011
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=5.0V

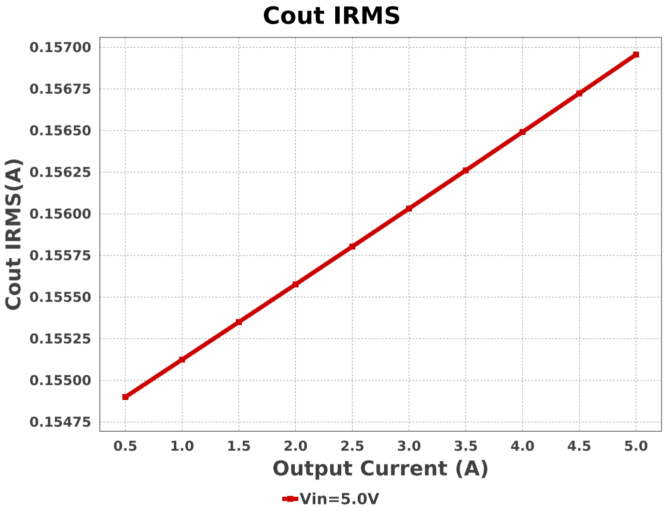

M Irms
M Irms(A)
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=5.0V

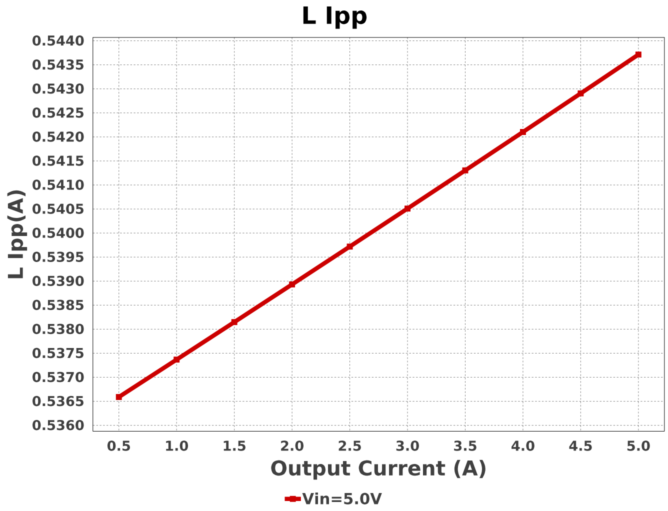

Pout
Pout(W)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=5.0V

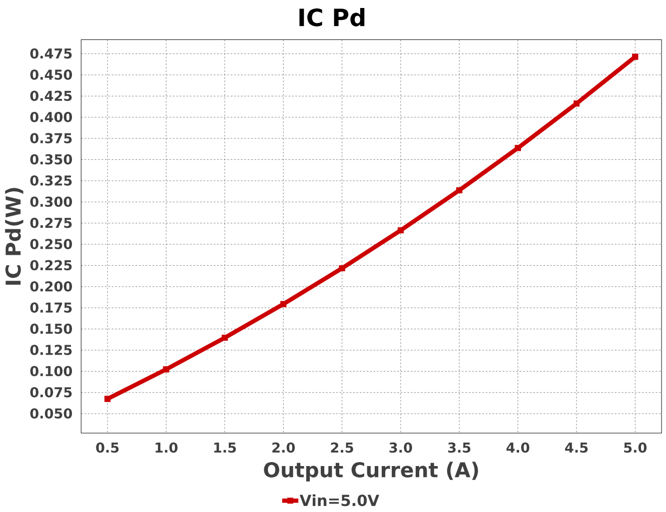

Iin Avg
Iin Avg(A)
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=5.0V

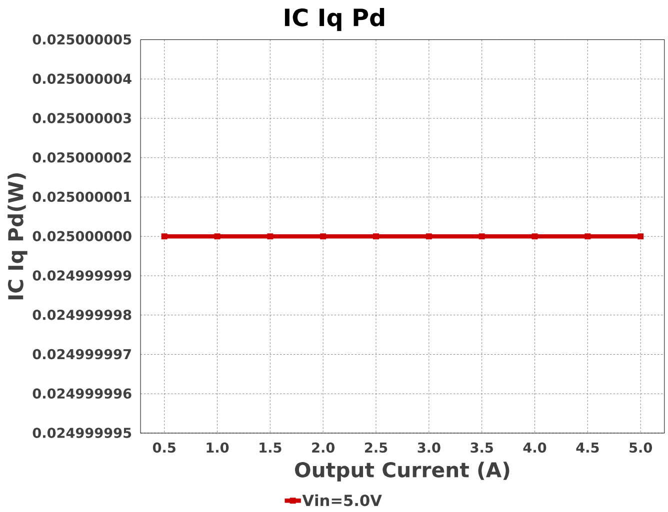

M2 Pdbody
M2 Pdbody(W)
0.000000005
0.000000004
0.000000003
0.000000002
0.000000001
0.000000000
-0.000000001
-0.000000002
-0.000000003
-0.000000004
-0.000000005
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=5.0V

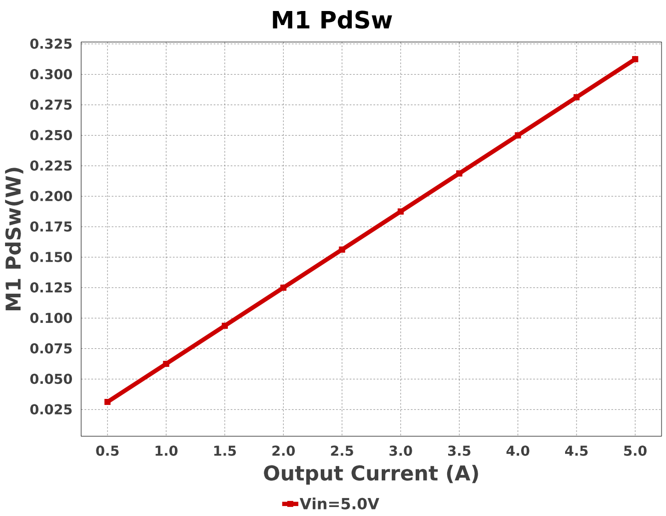

Total Pd
Total Pd(W)
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Output Current (A)
Vin=5.0V

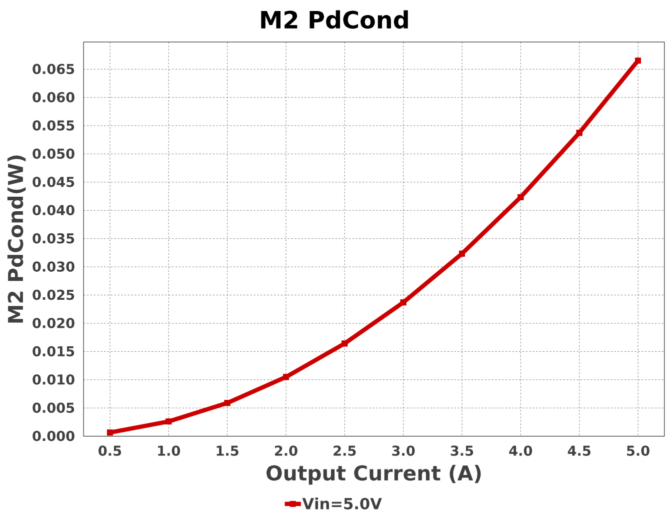

Cout IRMS
Cout IRMS(A)
Output Current (A)
Vin=5.0V

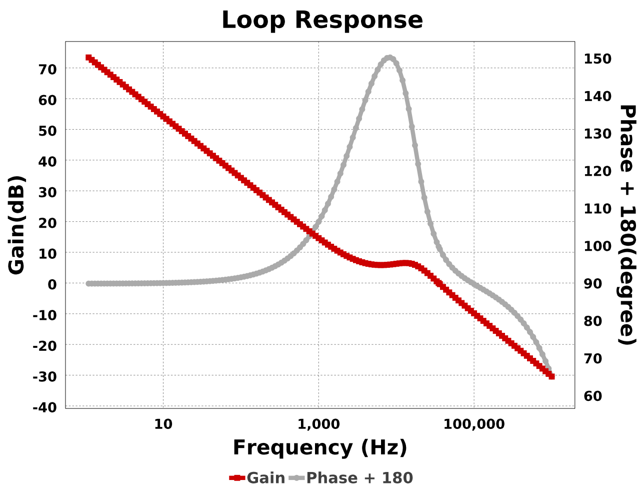

L Ipp
L Ipp(A)
Output Current (A)
Vin=5.0V


IC Pd
IC Pd(W)
Output Current (A)
Vin=5.0V


IC Iq Pd
IC Iq Pd(W)
Output Current (A)
Vin=5.0V


M1 PdSw
M1 PdSw(W)
Output Current (A)
Vin=5.0V


M2 PdCond
M2 PdCond(W)
Output Current (A)
Vin=5.0V



Operating Values

#	Name	Value	Category	Description
1.	BOM Count	17		Total Design BOM count
2.	Total BOM	NA		Total BOM Cost
3.	Cin IRMS	2.408 A	Capacitor	Input capacitor RMS ripple current
4.	Cin Pd	5.796 mW	Capacitor	Input capacitor power dissipation
5.	Cout IRMS	156.957 mA	Capacitor	Output capacitor RMS ripple current
6.	Cout Pd	24.635 nW	Capacitor	Output capacitor power dissipation
7.	IC Ipk	5.272 A	IC	Peak switch current in IC
8.	IC Iq Pd	25.0 mW	IC	IC Iq Pd
9.	IC Pd	471.41 mW	IC	IC power dissipation
10.	IC Tj	41.314 degC	IC	IC junction temperature
11.	IC Tolerance	6.0 mV	IC	IC Feedback Tolerance
12.	ICThetaJA	24.0 degC/W	IC	IC junction-to-ambient thermal resistance
13.	Iin Avg	1.907 A	IC	Average input current
14.	L Ipp	543.713 mA	Inductor	Peak-to-peak inductor ripple current
15.	L Pd	56.25 mW	Inductor	Inductor power dissipation
16.	M1 Irms	3.022 A	Mosfet	Q Iavg
17.	M Vds Act	18.99 mV	Mosfet	Voltage drop across the MosFET
18.	M1 PdCond	57.389 mW	Mosfet	M1 MOSFET switching losses
19.	M1 PdSw	312.5 mW	Mosfet	M1 MOSFET switching losses
20.	M1 PdCond	66.524 mW	Mosfet	M2 MOSFET switching losses
21.	M2 Pdbody	0.0 W	Mosfet	Power dissipation through lower FET
22.	Cin Pd	5.796 mW	Power	Input capacitor power dissipation
23.	Cout Pd	24.635 nW	Power	Output capacitor power dissipation
24.	IC Pd	471.41 mW	Power	IC power dissipation
25.	L Pd	56.25 mW	Power	Inductor power dissipation
26.	M1 PdCond	57.389 mW	Power	M1 MOSFET switching losses
27.	M1 PdSw	312.5 mW	Power	M1 MOSFET switching losses
28.	M1 PdCond	66.524 mW	Power	M2 MOSFET switching losses
29.	M2 Pdbody	0.0 W	Power	Power dissipation through lower FET
30.	Total Pd	533.495 mW	Power	Total Power Dissipation
31.	Cross Freq	35.023 kHz	System Information	Bode plot crossover frequency
32.	Duty Cycle	36.531 %	System Information	Duty cycle
33.	Efficiency	94.404 %	System Information	Steady state efficiency
34.	FootPrint	383.0 mm^2	System Information	Total Foot Print Area of BOM components
35.	Frequency	500.0 kHz	System Information	Switching frequency
36.	Gain Marg	-45.844 dB	System Information	Bode Plot Gain Margin
37.	Iout	5.0 A	System Information	Iout operating point
38.	Low Freq Gain	73.413 dB	System Information	Gain at 1Hz
39.	Mode	CCM	System Information	Conduction Mode
40.	Phase Marg	99.904 deg	System Information	Bode Plot Phase Margin
41.	Pout	9.0 W	System Information	Total output power

#	Name	Value	Category	Description
42.	Vin	5.0 V	System Information	Vin operating point
43.	Vout	1.8 V	System Information	Operational Output Voltage
44.	Vout Actual	1.8 V	System Information	Vout Actual calculated based on selected voltage divider resistors
45.	Vout Tolerance	1.135 %	System Information	Vout Tolerance based on IC Tolerance (no load) and voltage divider resistors if applicable
46.	Vout p-p	6.179 mV	System Information	Peak-to-peak output ripple voltage

Design Inputs

Name	Value	Description
Iout	5.0	Maximum Output Current
SoftStart	0.5 ms	Soft Start Time (ms)
VinMax	5.0	Maximum input voltage
VinMin	5.0	Minimum input voltage
Vout	1.8	Output Voltage
base_pn	LM21215	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

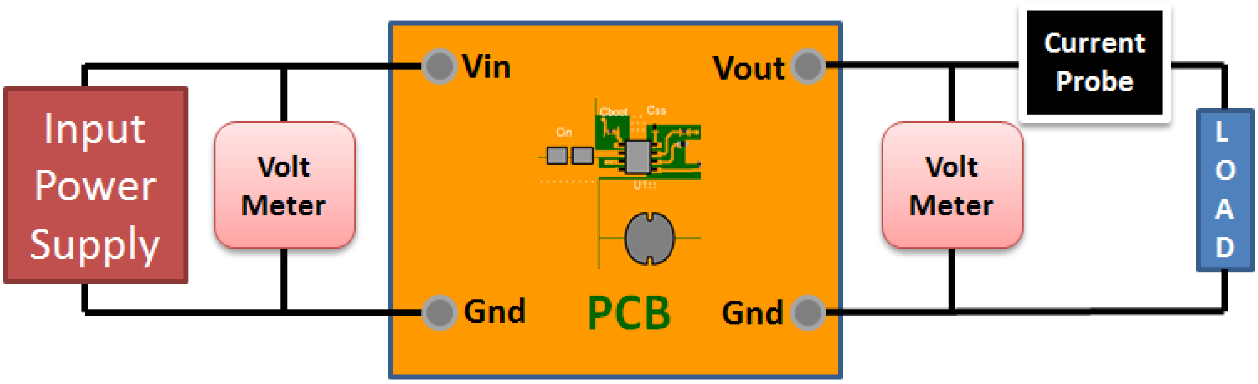
If board assembly is done in house it is best to tack down one terminal of a component on the board then solder the other terminal. For surface mount parts with large tabs, such as the DPAK, the tab on the back of the package should be pre-tinned with solder, then tacked into place by one of the pins.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

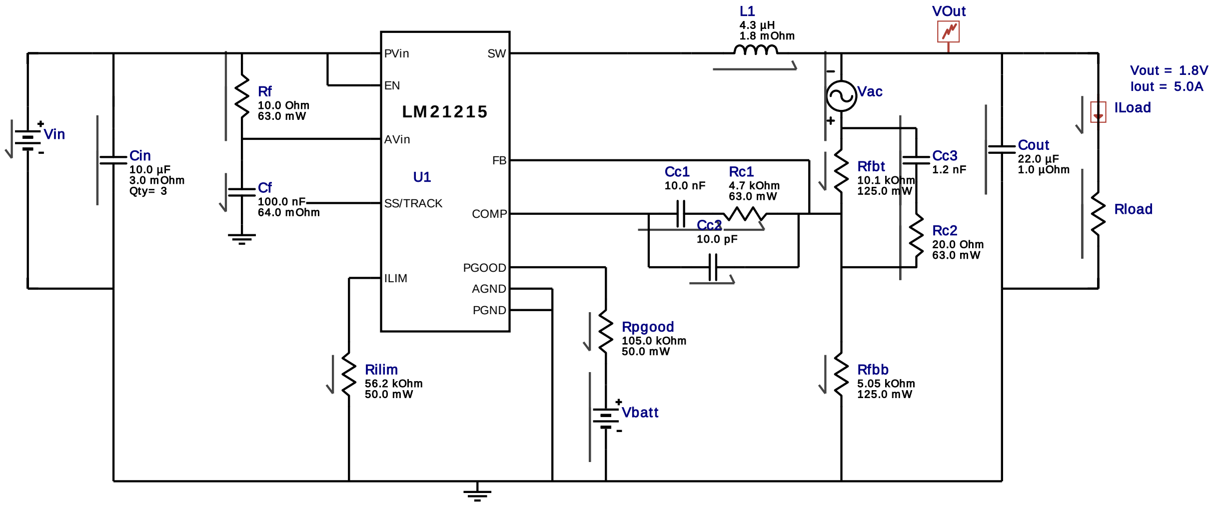


WEBENCH® Electrical Simulation Report

Design Id = 3

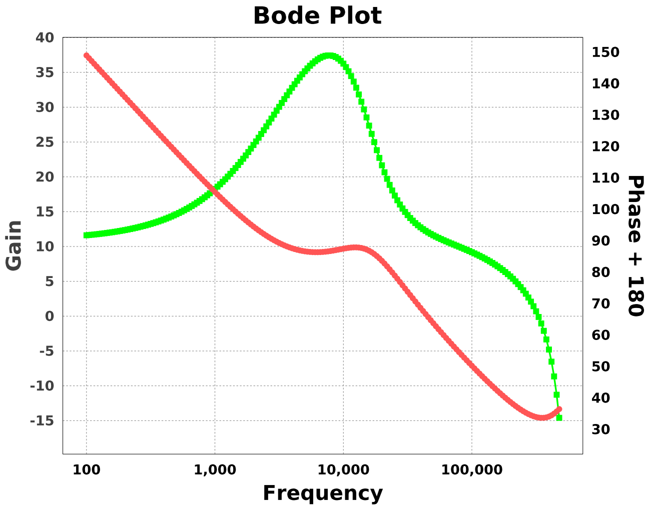
sim_id = 3

Simulation Type = Bode Plot



Simulation Parameters

#	Name	Parameter Name	Description	Values
1.	Cinj	C	Injection Isolation Capacitance	10 F
2.	Linj	L	Injection Isolation Inductance	10 H
3.	Vinj	AC	AC Voltage Source Amplitude	1 V
4.	Rload	R	Load Resistance	0.36 Ohm



Design Assistance

1. The LM21K series has simple to use low voltage and high current voltage regulators. The LM21215 is available in fixed frequency option, but with an adjustable current limit.

2. Master key : 16460E6DCD6D8EE8[v1]

3. **LM21215** Product Folder : http://www.ti.com/product/LM21215 : contains the data sheet and other resources.