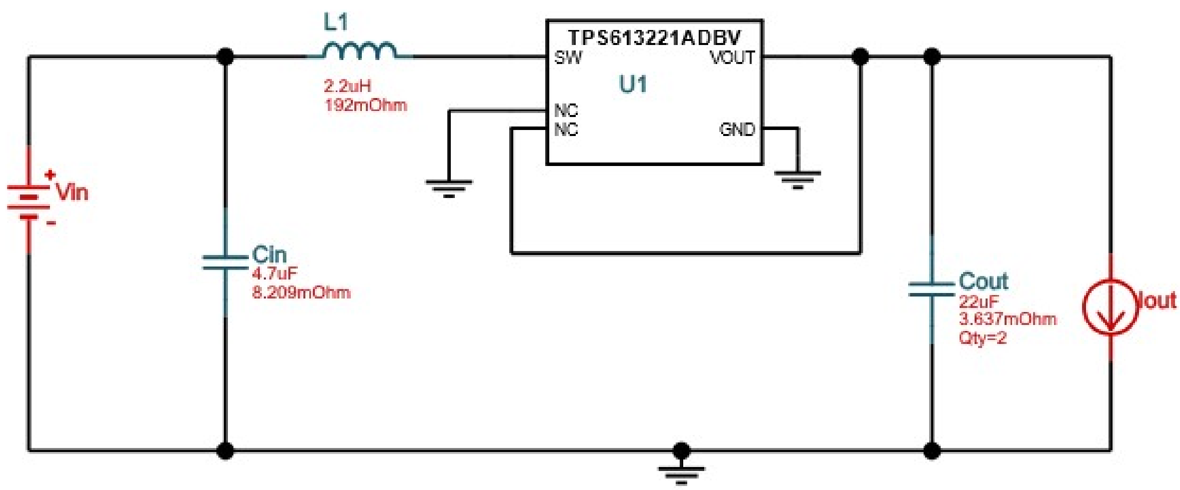
Assignment 2 – Yousef Awad

Section 1: My chosen regulators

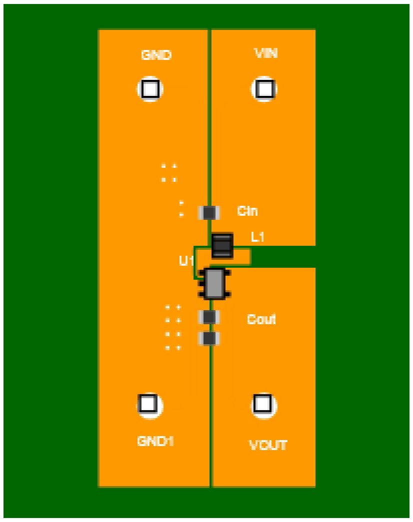
I chose the TPS613222ADBVR (5V regulator) and the TPS613221ADBVR (3.3V regulator). I chose this due to the fact that it was quite cheap per unit, as well as the fact that it has a large range of possible input voltages. Alongside this, the same applies for both regulators.

Section 2: 3.3V Regulator

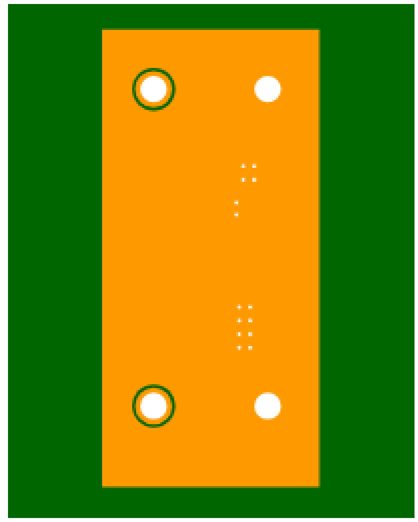
This is the schematic, from WEBench, for the 3.3V regulator:



This is the PCB layout from WEBench that I got:



Top



Bottom

This is the BOM for the Regulator:

Part	Manufacturer	Part Number	Quantity	Total Price ($)	Attribute	Total Footprint (mm²)	Top View
U1	Texas Instruments	TPS613221ADBVR	1	0.15		14.82	
Cin	Taiyo Yuden	MSAST21GAB5475MTNA01	1	0.03	Cap = 4.7 µF Total Derated Cap = 4.5 µF VDC = 25 V ESR = 8.21 mΩ Package = 0805	6.75	
L1	MuRata	1286AS-H-2R2M	1	0.15	L = 2.2 µH DCR = 192 mΩ IDC = 1.3 A	8.96	
Cout	Taiyo Yuden	MSASL219LB5226MTNA01	2	0.14	Cap = 22 µF Total Derated Cap = 23 µF VDC = 10 V ESR = 3.64 mΩ Package = 0805	13.5	

This right here is the Operating Point Table:

Name	Value	Category	Description
Vout	3.3 V	System Information	Operational Output Voltage
Cin IRMS	119.78 mA	Capacitor	Input capacitor RMS ripple current
Cin Pd	117.78 µW	Capacitor	Input capacitor power dissipation
Cout IRMS	138.81 mA	Capacitor	Output capacitor RMS ripple current
Cout Pd	35.04 µW	Capacitor	Output capacitor power dissipation
L Ipp	414.94	Inductor	Peak-to-peak inductor ripple current

	mA		
Ipp percentage	176.37 %	Inductor	Inductor ripple current percentage (with respect to average inductor current)
L Pd	11.07 mW	Inductor	Inductor power dissipation
Duty Cycle	32.30 %	System Information	Duty cycle
Efficiency	87.70 %	System Information	Steady state efficiency
Frequency	815.56 kHz	System Information	Switching frequency
IC Tj	41.08 °C	IC	IC junction temperature
ICThetaJA	189.7 °C/W	IC	IC junction-to-ambient thermal resistance
IC Pd	58.42 mW	IC	IC power dissipation
Pout	495 mW	System Information	Total output power
Iin Avg	235.27 mA	IC	Average input current
IC Ipk	415.59 mA	IC	Peak switch current in IC
Mode	CCM	System Information	Conduction Mode
Vout p-p	5.19 mV	System Information	Peak-to-peak output ripple voltage
Vin p-p	14.24 mV	System Information	Peak-to-peak input voltage
Rload_crit	40 Ω	System Information	Minimum Rload required during Start up
FootPrint	44 mm²	System Information	Total Foot Print Area of BOM components
Vin	2.4 V	System Information	Vin operating point
Iout	150 mA	System Information	Iout operating point
Cin Pd	117.78 µW	Power	Input capacitor power dissipation
Cout Pd	35.04 µW	Power	Output capacitor power dissipation
L Pd	11.07 mW	Power	Inductor power dissipation
IC Pd	58.42 mW	Power	IC power dissipation
Total BOM	$0.47	System Information	Total BOM Cost
Total Pd	69.64	Power	Total Power Dissipation

	mW		
BOM Count	5	System Information	Total Design BOM count

Here is the Log Efficiency Plot versus Current:

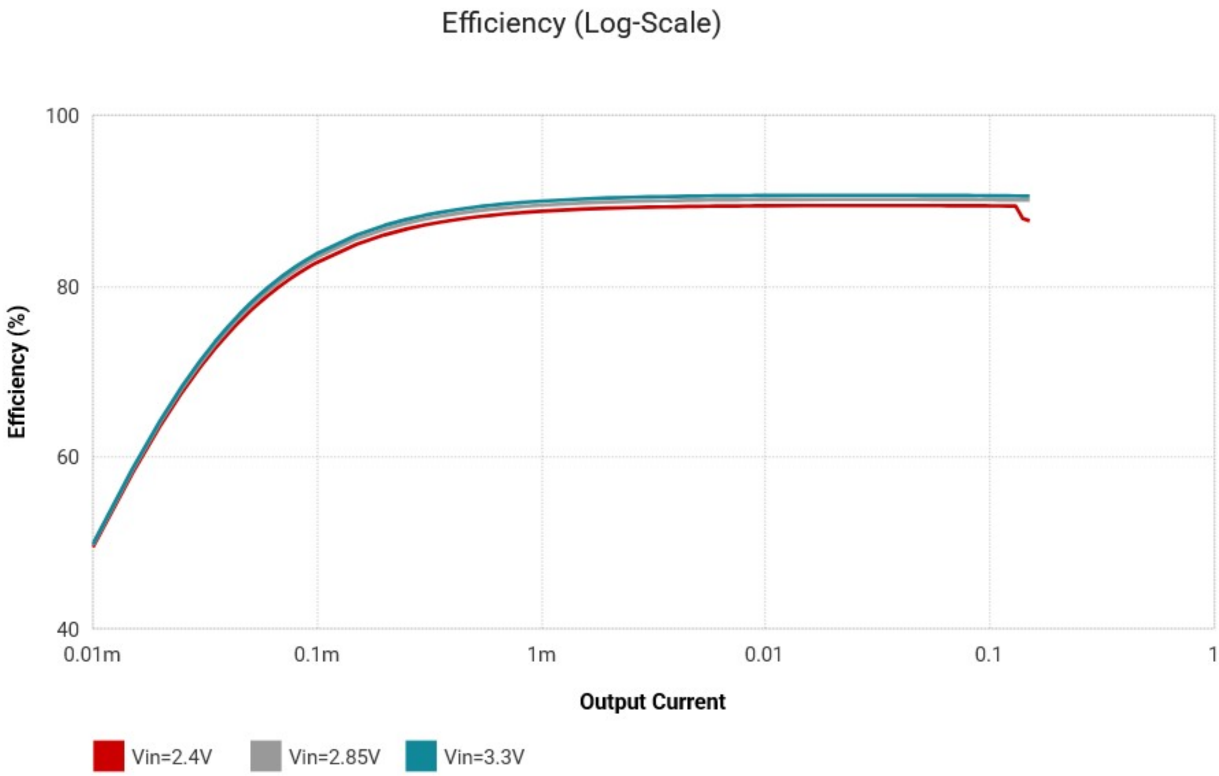


Table 2 (Fully Filled Out):

Output Voltage	Efficiency @ 150ma	BOM Cost (Total Parts Cost)	Footprint (PCB Area)	BOM Count (Parts Count)
5.0 VDC	88.8%	$0.43	43mm^2	5
3.3 VDC	87.7%	$0.47	44mm^2	5

For the following section I will be calculating stuff, so here's the math:

$$P_{out}=V_{out}*I_{out}=3.3*0.15=495\,mW$$

$$P_{regulator}=\frac{P_{out}*(1-Efficiency)}{Efficiency}=\frac{495*(1-0.877)}{0.877}=69.424\,mW$$

$$P_{in}=P_{regulator}+P_{out}=495+69.424=564.424\,mW$$

$$I_{in}=\frac{P_{in}}{V_{in}}=\frac{5.64424}{2.4}=235.18\,mA$$

$$T_j=P_d*R+T_a=.05842*189.7+28=39.08\,°C$$

Now, to compare, my calculations are above, and the actual values on the 3.3V Regulator is the following:

$$P_{out}=495\,mW$$

$$P_{regulator}=69.64\,mW$$

$$P_{in}=495+69.64=564.64\,mW$$

$$I_{in}=235.27\,mA$$

$$T_j=41.08\,°C$$

Now, my results are comparable to the ones that are given to me by WEBench, I assume the error on my hand on why it is not perfect is due to my assumptions and rounding that occurred over the course of the mathematics/algebra. Other than that, though, it aligns almost perfectly with the same-ish results.

Now, for the maximum junction temperature, from the data sheet, would be 120 degrees Celsius.

Now, with 2 Amps of current, the math is as follows:

$$P_{out}=3.3*2=6.6\,W$$

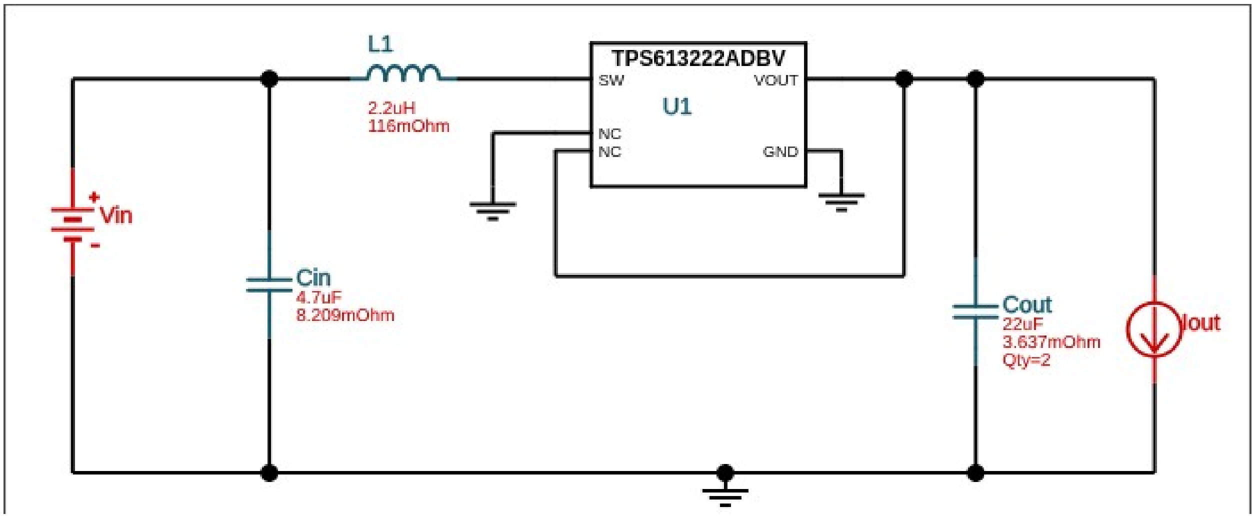
$$P_{regulator}=\frac{6.6*(1-0.877)}{0.877}=0.92566\,W$$

$$T_j=0.92566*189.7+28=203.60\,°C$$

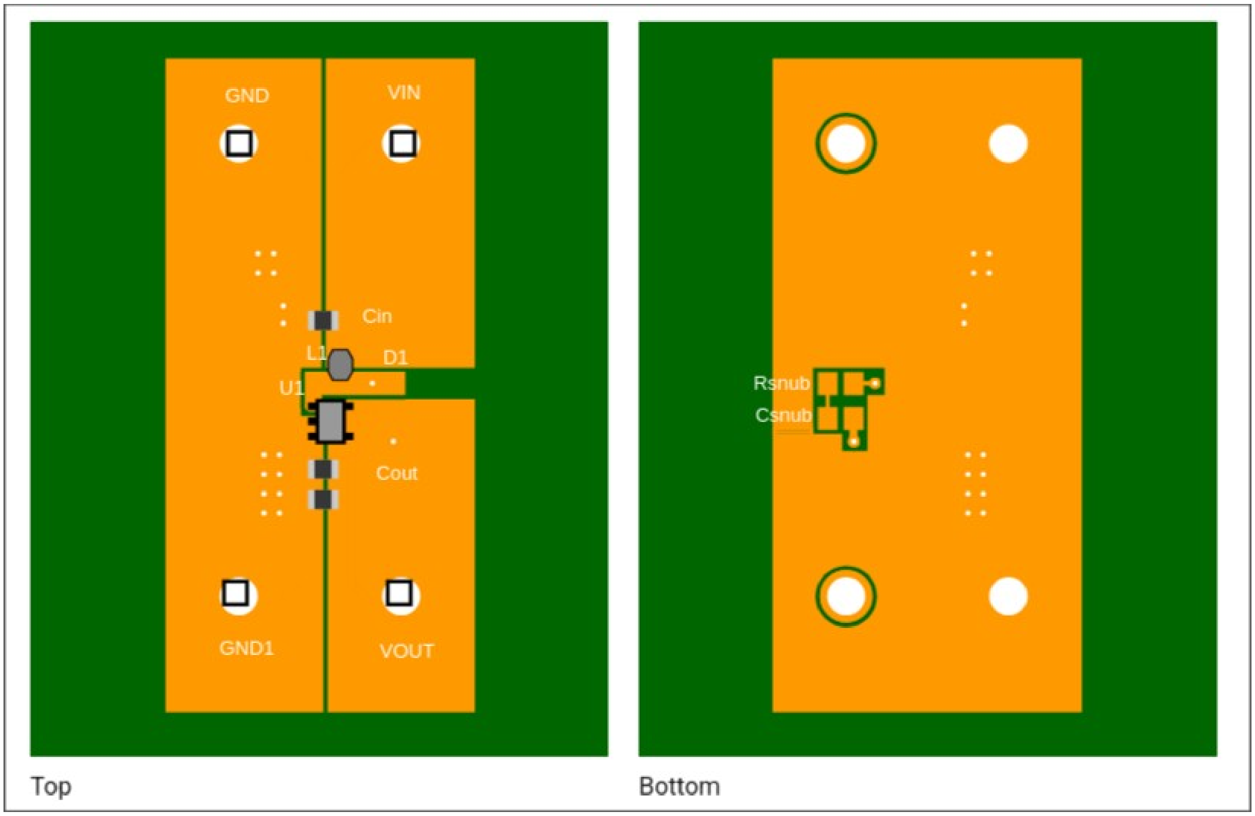
The current limit from the datasheet is between 0.75 and 1.60 Amps, with a typical value of 1.20 Amps.

Section 3: 5V Regulator

Here is the schematic from WeBench for the 5V regulator.



And here is the subsequent pcb layout that WeBench shows me:



Here is the Bill of Materials (BOM) that WeBench shows me:

Part	Manufacturer	Part Number	Quantity	Total Price ($)	Attribute	Total Footprint (mm²)	Top View
U1	Texas Instruments	TPS613222ADBVR	1	0.15		14.82	
Cin	Taiyo Yuden	MSAST21GAB5475MTNA01	1	0.03	Cap = 4.7 µF Total Derated Cap = 4.5 µF VDC = 25 V ESR = 8.21 mΩ Package = 0805	6.75	
L1	MuRata	DFE201612E-2R2M=P2	1	0.11	L = 2.2 µH DCR = 116 mΩ IDC = 1.8 A	7.8	
Cout	Taiyo Yuden	MSASL219LB5226MTNA01	2	0.14	Cap = 22 µF Total Derated Cap = 15 µF VDC = 10 V ESR = 3.64 mΩ Package = 0805	13.5	

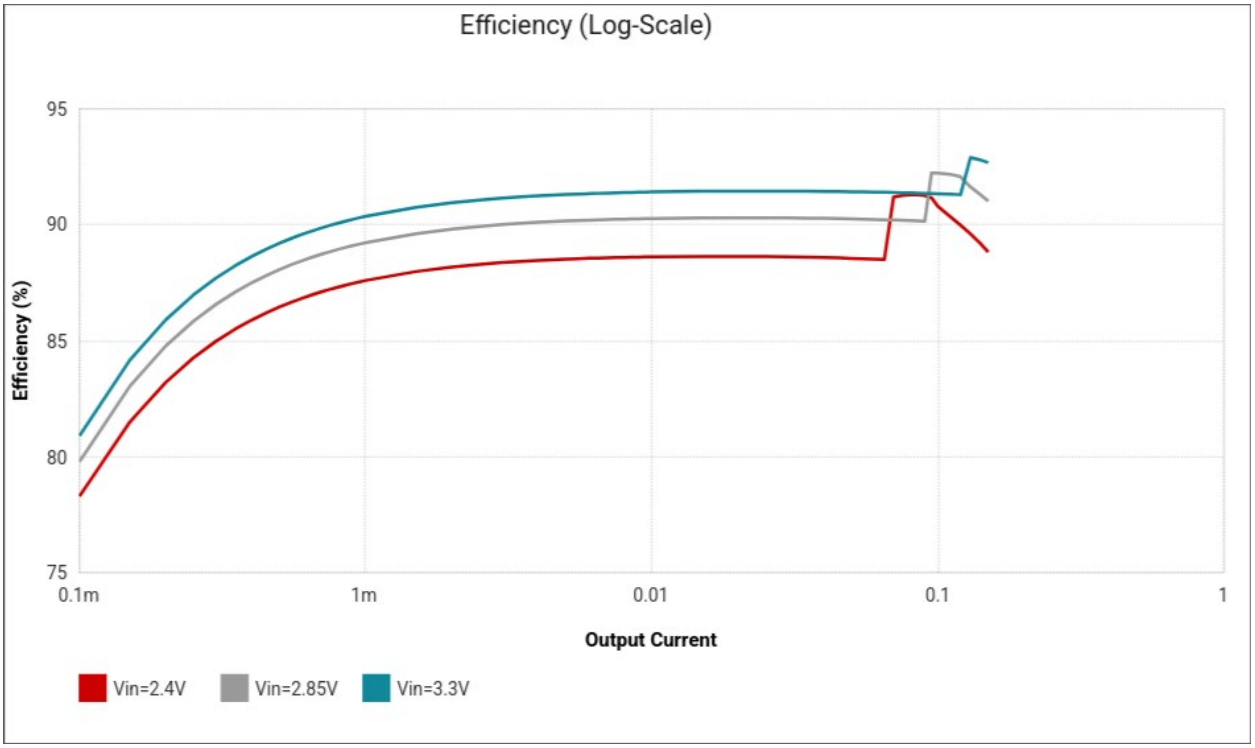
And here is the subsequent operating point table that it gives me:

Name	Value	Category	Description
Vout	5 V	System Information	Operational Output Voltage
Cin IRMS	115.21 mA	Capacitor	Input capacitor RMS ripple current
Cin Pd	108.95 µW	Capacitor	Input capacitor power dissipation
Cout IRMS	174.45 mA	Capacitor	Output capacitor RMS ripple current
Cout Pd	55.34 µW	Capacitor	Output capacitor power dissipation
L Ipp	399.08 mA	Inductor	Peak-to-peak inductor ripple current
Ipp percentage	113.44%	Inductor	Inductor ripple current percentage (with respect to average inductor current)
L Pd	13.07 mW	Inductor	Inductor power dissipation
Duty Cycle	56.20%	System Information	Duty cycle
Efficiency	88.8%	System Information	Steady state efficiency
Frequency	1.43 MHz	System Information	Switching frequency
IC Tj	45.39 °C	IC	IC junction temperature

ICThetaJA	189.7 °C/W	IC	IC junction-to-ambient thermal resistance
IC Pd	81.1 mW	IC	IC power dissipation
Pout	750 mW	System Information	Total output power
Iin Avg	351.81 mA	IC	Average input current
IC Ipk	514.88 mA	IC	Peak switch current in IC
Mode	CCM	System Information	Conduction Mode
Vout p-p	5.71 mV	System Information	Peak-to-peak output ripple voltage
Vin p-p	8.02 mV	System Information	Peak-to-peak input voltage
Rload_crit	500 Ω	System Information	Minimum Rload required during Start up
FootPrint	43 mm^2	System Information	Total Foot Print Area of BOM components
Vin	2.4 V	System Information	Vin operating point
Iout	150 mA	System Information	Iout operating point
Cin Pd	108.95 µW	Power	Input capacitor power dissipation
Cout Pd	55.34 µW	Power	Output capacitor power dissipation
L Pd	13.07 mW	Power	Inductor power dissipation
IC Pd	81.1 mW	Power	IC power dissipation
Total BOM	$0.43	System Information	Total BOM Cost
Total Pd	94.35 mW	Power	Total Power Dissipation

BOM Count	5	System Information	Total Design BOM count

Here is the respective Log Efficiency plot versus the current:



And here is the table 2 that I filled out previously in section 2 (since it is the same exact data):

Output Voltage	**Efficiency @ 150ma**	**BOM Cost (Total Parts Cost)**	**Footprint (PCB Area)**	**BOM Count (Parts Count)**
5.0 VDC	88.8%	$0.43	43mm^2	5
3.3 VDC	87.7%	$0.47	44mm^2	5

For the following section I will be calculating stuff, so here's the math:

$$P_{out} = V_{out} * I_{out} = 5 * 0.15 = 750\, mW$$

$$P_{regulator} = \frac{P_{out} * (1 - Efficiency)}{Efficiency} = \frac{750 * (1 - 0.888)}{0.888} = 95\, mW$$

$$P_{in} = P_{regulator} + P_{out} = 750 + 95 = 845\, mW$$

$$I_{in} = \frac{P_{in}}{V_{in}} = \frac{0.845}{2.4} = 352\,mA$$

$$T_j = P_d * R + T_a = .095 * 189.7 + 28 = 46.02\,°C$$

Now, to compare my results with the operating table that was given to me by WeBench, I can see that my results are almost exactly the same as to which the operating table shows! The only difference is that in my Temperature at the Junction value, the Power dissipated was slightly different but did not, thankfully, effect my calculations.

Now, from the data sheet, it showed a maximum junction temperature of 150 degrees centigrade, and 125 degrees centigrade for the recommended maximum.

Given that the current out would be 2 Amps, the junction temperature math would be the following:

$$T_j = P_d * R + T_a = (5 * 2 * 11.2\,\%) * 189.7 + 28 = 240.46\,°C$$

Of which, would be a tad too hot compared to the limit of 125 degrees centigrade.

Section 4: Summary

In summary, in this report, I learned of the uses and what is WEBench, as well as how it is used to create designs for DC/DC circuits (and of the fact that it has AC/DC circuits as well). Alongside this, I also learned how to test, simulate, and analyze, the different designs that you can create within WEBench as well as reading the data that it has in it. From that, I learned how the data is used to configure the operating conditions to be to what I expect while also learning of where to find the data sheets to find the experimental maximums.