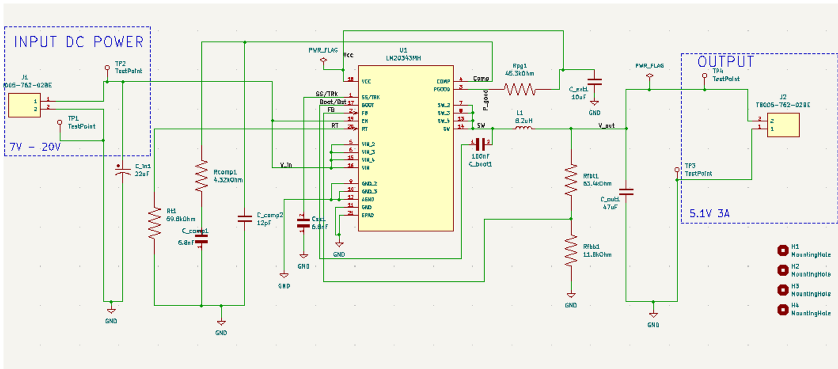
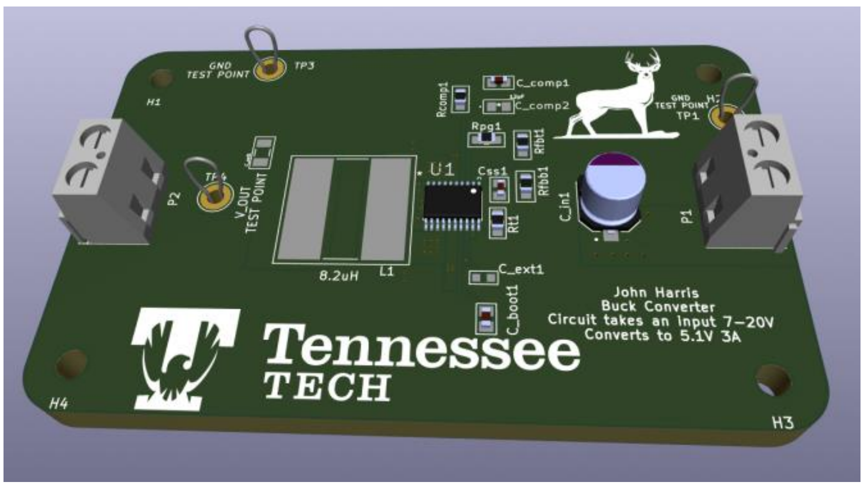
Signoff Request - 9/14

Sunday, September 4, 2022 6:34 PM

What it is Doing

The Buck converter module safely steps down the 12V battery voltage to 5.1V for the Raspberry Pi, Arduino Nano, and the network Router.





The calculation of component values were carried out by Texas Instruments We Bench Power Designer. To assist with buildability, a link to the design may be found here

The resistor, capacitor, and inductor values can be calculated from the datasheet beginning on page 12 as follows:

The Duty cycle (D) is $\frac{Vout}{Vin} = \frac{5.1}{18.5} = 27.5\%$ Here a value of 18.5V was chosen for the input voltage

The operating frequency (f) is selected at 625 kHz.

The resistor Rt controls the operating frequency is selected as $R_T = \frac{78000}{f} - 55$ Rt = 69.8kohm

The inductor ripple(Δi) is selected based on the peak output current as 3 * 30% ≈ 800mA

The minimum inductor size is selected as $\frac{(Vin-Vout)*D}{(\Delta i * f)}$ = 7.37μH

The peak to peak voltage(V_{pk-pk}) output ripple is selected to be 10 mV

The output Capacitor(Cout) is calculated as $\frac{V_{pk-pk}}{\Delta i} = R_{ESR} + \frac{1}{8 * f * Cout} = \frac{0.01}{0.8} = R_{ESR} + \frac{1}{5000000 * Cout}$ here an output capacitor must be selected with an electrical series resistance(R_{ESR}) that satisfies this requirement and one is found with C = 47 uF and $R_{ESR} = 3.79 mohms$

A non-ceramic input capacitor is selected based on RMS current rating calculated as $I_{RMS} = I_{out}\sqrt{D(1-D)}$ = 1.33A

The feedback resistors are calculated as $\frac{R_{FB1}}{R_{FB2}} = \frac{V_{out}}{0.8} - 1$ and R_FB1 = 63.4kohm R_FB2 = 11.8kohm

Rc and Cc are selected based on table 2 of the LM20343 datasheet Rc = 4.32kohms and Cc = 6.8 nF

The boot capacitor is selected as recommended 100 nF from the datasheet.

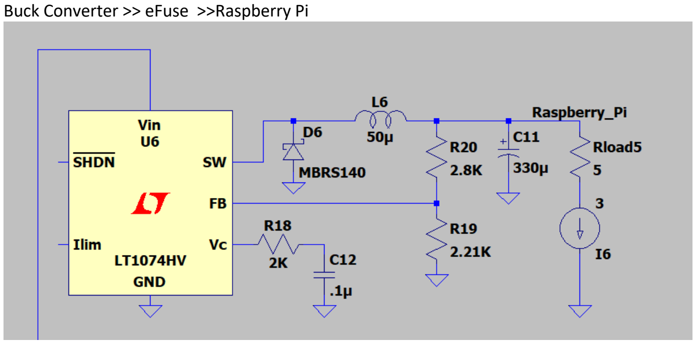
The capacitor Cs controls the soft start is selected from Table 3 in the datasheet is selected as 6.8 nF.

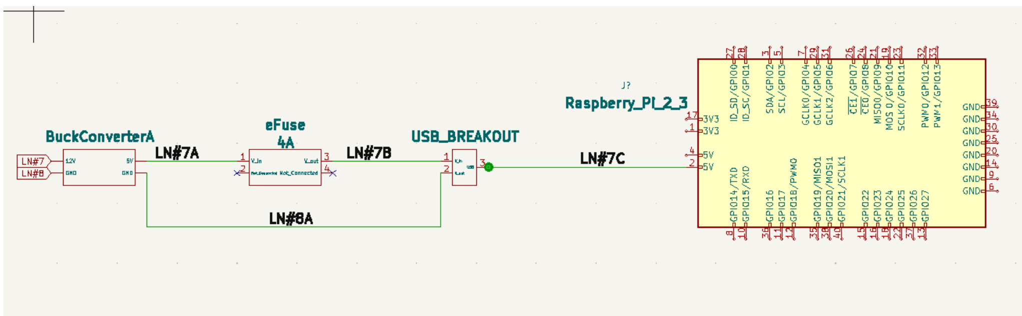
Constraints

Buck Converter A:

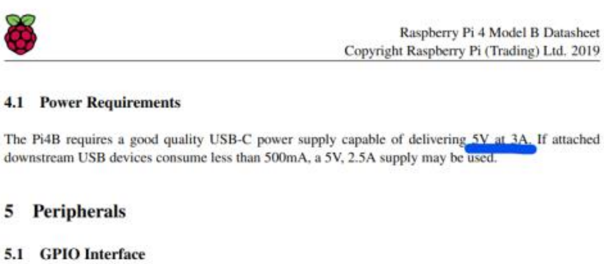
Line 7 & 8

Buck Converter >> eFuse >>Raspberry Pi





The constraints for this line comes from the datasheet for the Raspberry Pi:


Raspberry Pi 4 Model B Datasheet
Copyright Raspberry Pi (Trading) Ltd. 2019

4.1 Power Requirements

The Pi4B requires a good quality USB-C power supply capable of delivering 5V at 3A. If attached downstream USB devices consume less than 500mA, a 5V, 2.5A supply may be used.

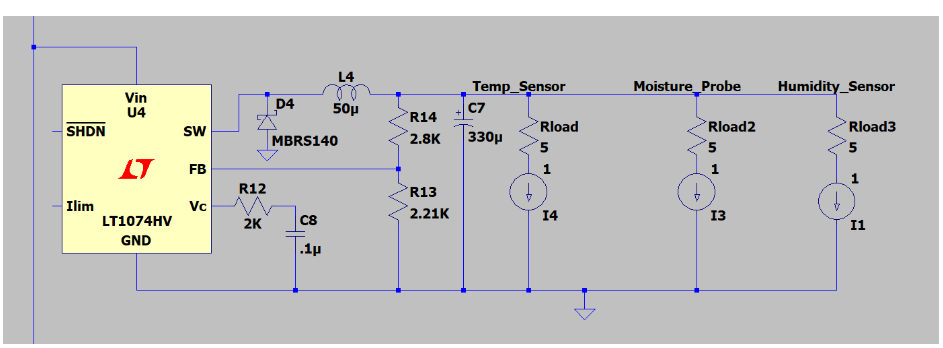
5 Peripherals

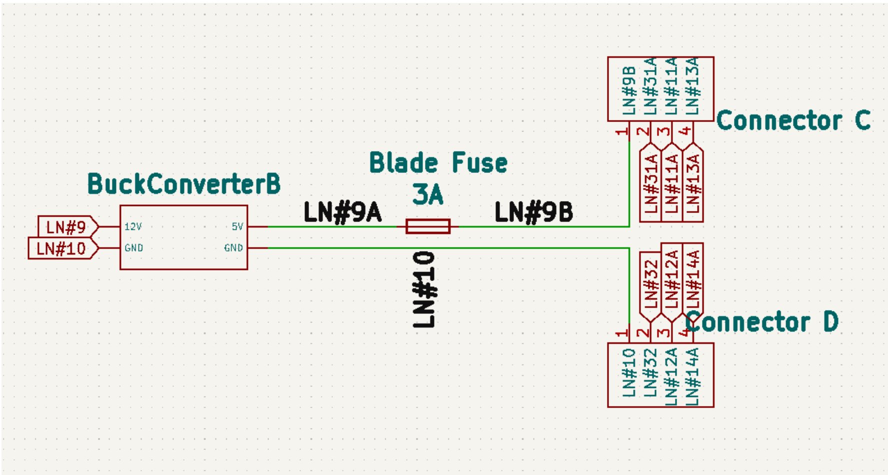
5.1 GPIO Interface

1. **5V** with **3A**

Buck Converter B

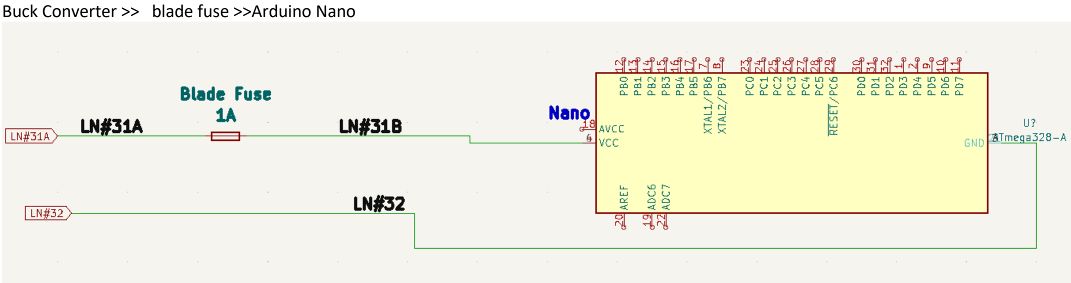
This Buck Converter will provide parallel power for three Environmental Sensors(Please see Power System signoff request for reasons). The constraints for Line Numbers 31A & 32 will first be formulated then Line Numbers 11A & 12A then Line Numbers 13A & 14A. The total constraints will be added to formulate the constraints for Line Numbers 9A & 10.





Line 31A & 32:

Buck Converter >> blade fuse >>Arduino Nano

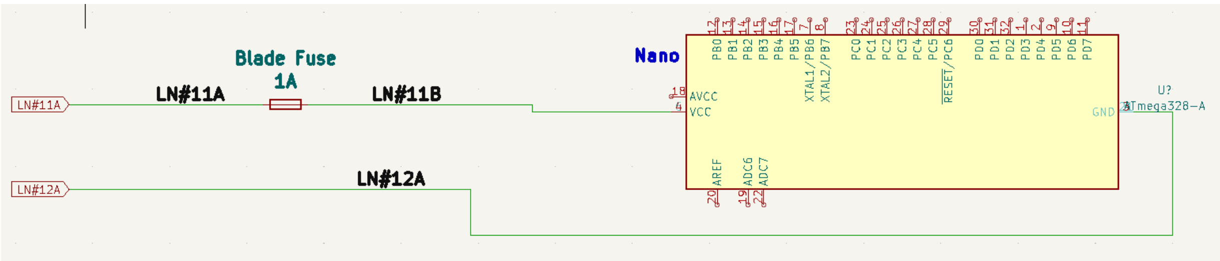


Board	Name	Arduino® Nano
	SKU	A000005
Microcontroller	ATmega328	
USB connector	Mini-B USB	
Pins	Built-in LED Pin	13
	Digital I/O Pins	14
	Analog input pins	8
	PWM pins	6
Communication	UART	RX/TX
	I2C	A4 (SDA), A5 (SCL)
	SPI	D11 (COPI), D12 (CIPO), D13 (SCK). Use any GPIO for Chip Select (CS).
Power	I/O Voltage	5V
	Input voltage (nominal)	7-12V
	DC Current per I/O Pin	20 mA
Clock speed	Processor	ATmega328 16 MHz
Memory	ATmega328P	2KB SRAM, 32KB flash 1KB EEPROM
Dimensions	Weight	5gr
	Width	18 mm
	Length	45 mm

1. **5V** and if we need all 20 pins to be at max current 0.02*20 = **0.4 A**

Line 11A & 12A:

Buck Converter >> blade fuse >>Arduino Nano



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	I2C	A4 (SDA), A5 (SCL)
	SPI	D11 (COPI), D12 (CIPO), D13 (SCK). Use any GPIO for Chip Select (CS).
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	Input voltage (nominal)	7-12V
	DC Current per I/O Pin	20 mA
Clock speed	Processor	ATmega328 16 MHz
Memory	ATmega328P	2KB SRAM, 32KB flash 1KB EEPROM
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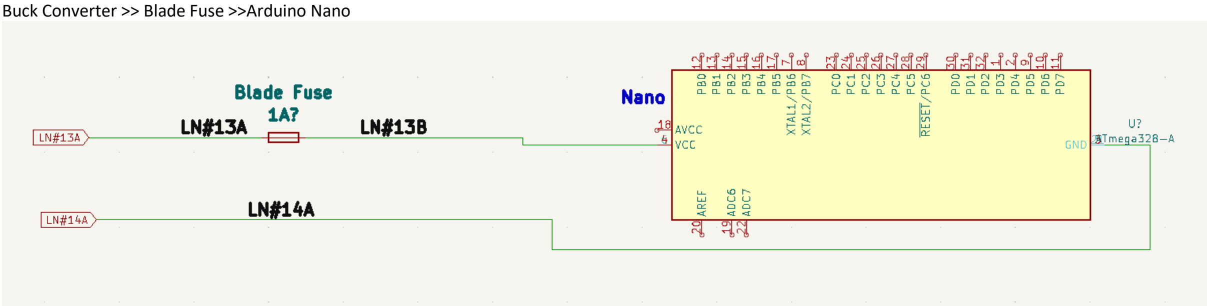
	Width	18 mm
	Length	45 mm

From <https://docs.arduino.cc/hardware/nano>

1. **5V** and if we need all 20 pins to be at max current 0.02*20 = **0.4 A**

Line 13A & 14A:

Buck Converter >> Blade Fuse >>Arduino Nano



Board	Name	Arduino® Nano
	SKU	A000005
Microcontroller	ATmega328	
USB connector	Mini-B USB	
Pins	Built-in LED Pin	13
	Digital I/O Pins	14
	Analog input pins	8
	PWM pins	6
Communication	UART	RX/TX
	I2C	A4 (SDA), A5 (SCL)
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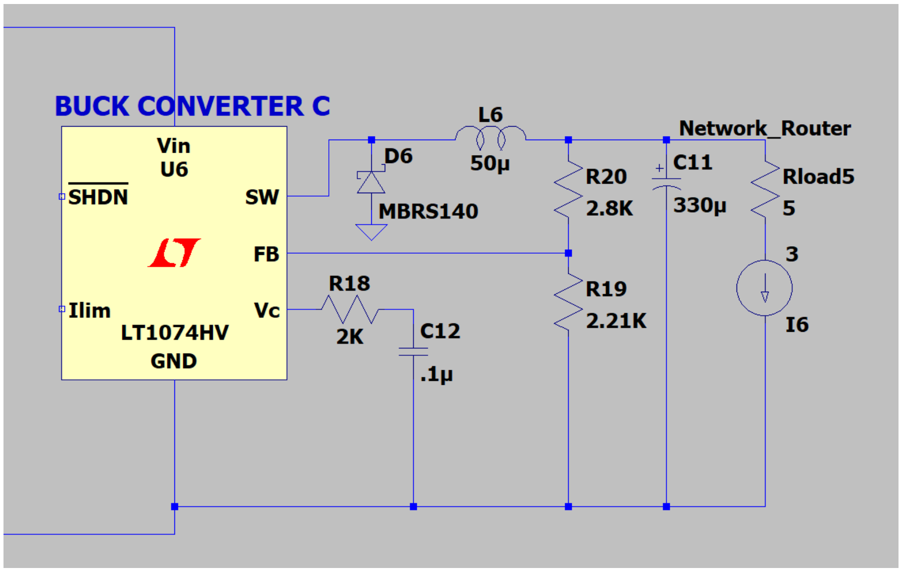
Clock speed	Processor	ATmega328 16 MHz
Memory	ATmega328P	2KB SRAM, 32KB flash 1KB EEPROM
Dimensions	Weight	5gr
	Width	18 mm

	Length	45 mm

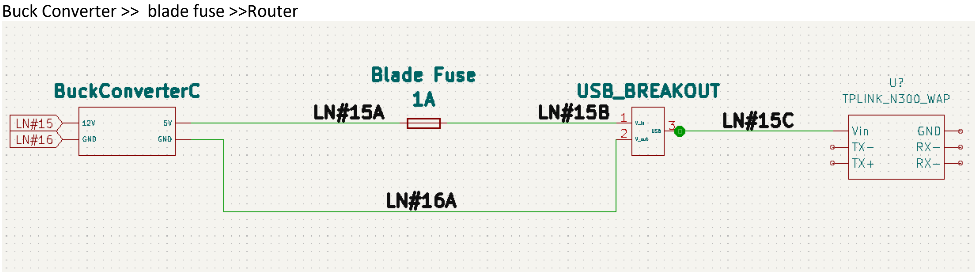
1. **5V** and if we need all 20 pins to be at max current 0.02*20 = **0.4 A**

Buck Converter C

This buck Converter will provide power for the network router.



Line 15 & 16:
Buck Converter >> blade fuse >>Router

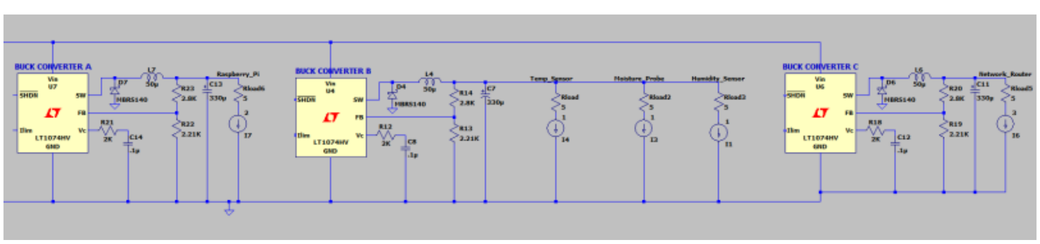


"The nano router requires a constant voltage of 5 Volts and a constant current of 1 Amp for operation [3]. Over one hour, the N300 router would use approximately 1 Amp Hours (AH) and 5 Watt Hours (WH)."
This is quoted from: -ORIGINAL_OLD - Signoff Request - August 11th, 2022 - Navigation (Wireless Access Point) Signoff that was approved.

1. **5V 1A**

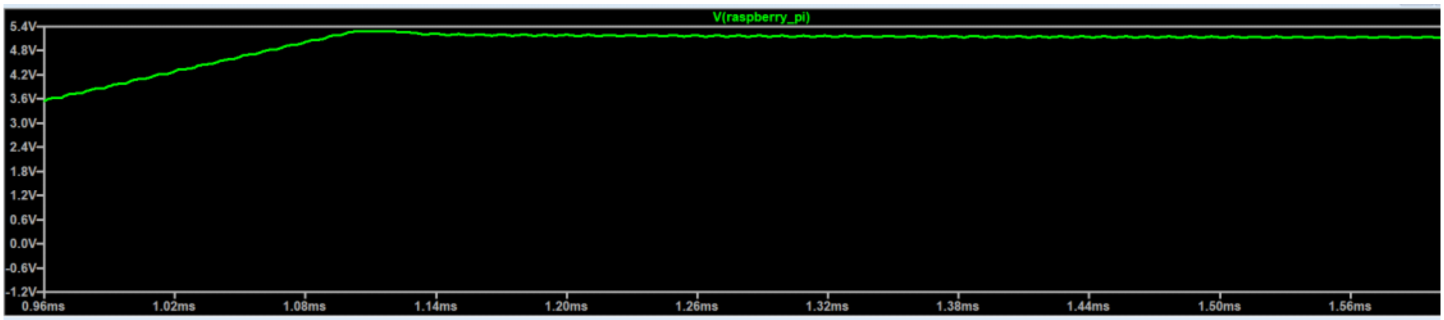
Analysis

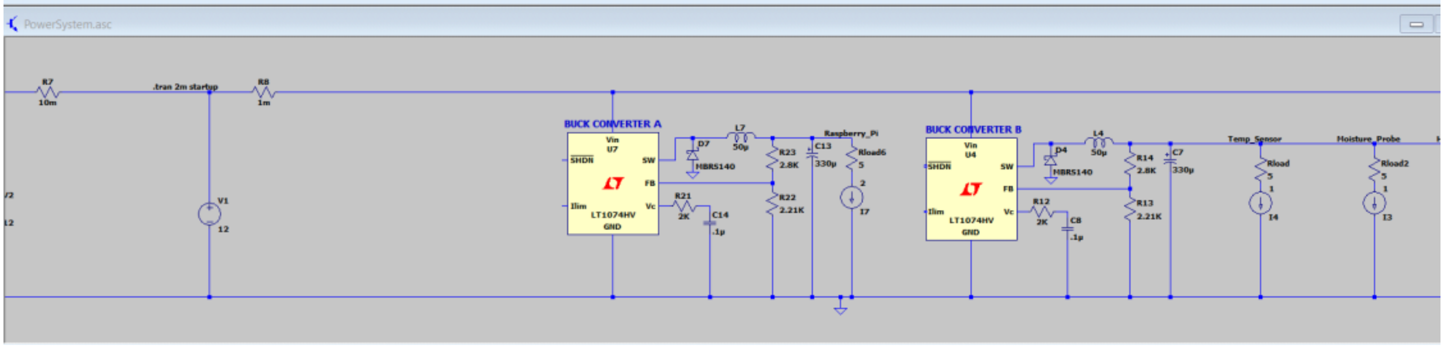
Buck Converters are a power electronics device capable of changing a DC voltage to a lower one. The following Spice Model shows the set up:



Buck Converter A

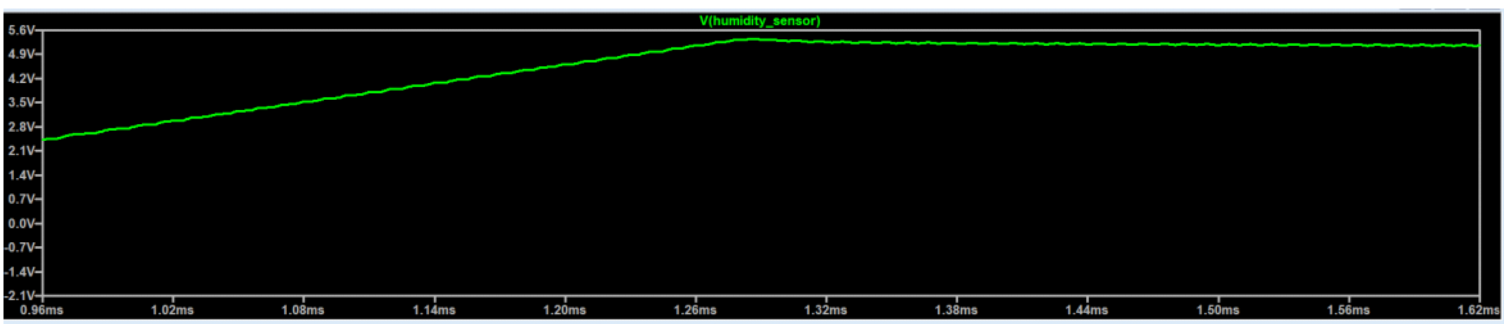
Here, a Spice model has been created with the Raspberry Pi modeled as a current source who's magnitude is equal to the worst case current laid out in the Power System Signoff. The Voltage is seen here to reach 5V.

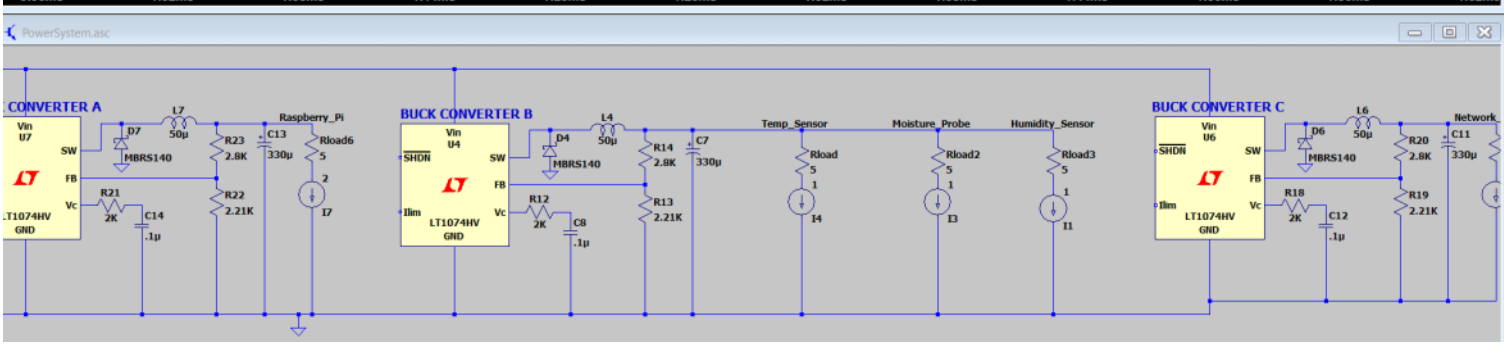




Buck Converter B

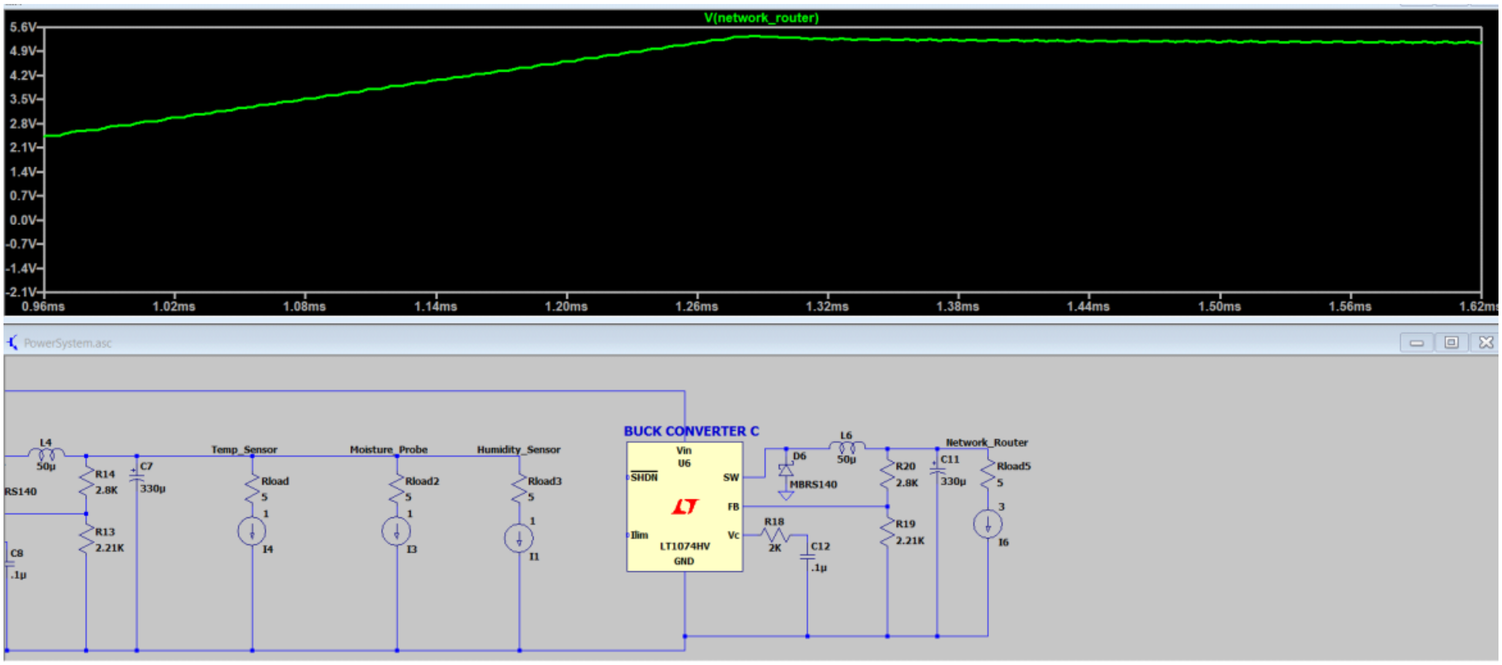
Here, a Spice model has been created with the Sensors modeled as current sources who's magnitude is equal to the worst case current laid out in the Power System Signoff. The Voltage is seen here to reach 5V.





Buck Converter C

Here, a Spice model has been created with the Router modeled as a current source who's magnitude is equal to the worst case current laid out in the Power System Signoff. The Voltage is seen here to reach 5V.



The design is also analyzed after construction to ensure that it can reliably produce a 5V output from an input voltage of 12V. An oscilloscope was used to inspect the output voltage for correctness in **Figure 1** and the output ripple is shown in **Figure 2**. The output ripple is of particular importance because the Raspberry Pi and Arduinos require a regulated input voltage to operate at.

Figure 1 Output Verification

The redline here marks the zero voltage level and the vertical divisions are set at 1V per division. The peak to peak given on this oscilloscope was 116mV, but when I scoped the output of a bench DC power supple the peak to peak ripple was also 116mV which indicates this number is probably not correct.

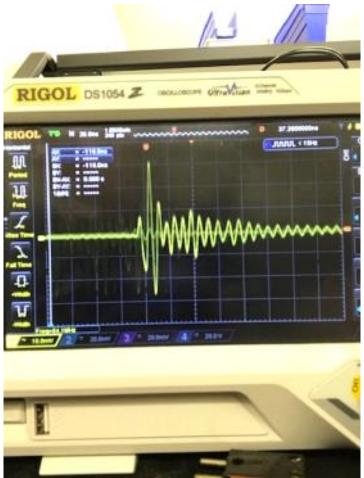


Figure 2 Output Voltage Ripple

Special thanks to Mr. Murray for help obtaining this figure. The horizontal divisions here are 10mV which gives the output ripple a peak to peak value of about 60mV pk-pk.

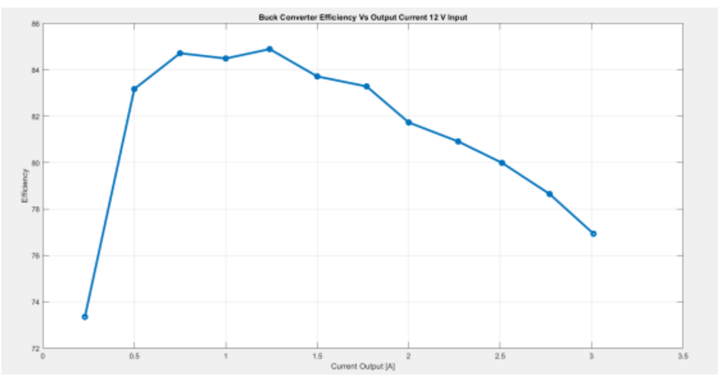


Figure 3 Efficiency Calculations

This figure was made by plotting the efficiency vs output current using an electronic load and lab test equipment. The efficiency of the converter is measured at various loads across the operating region here.

Average Efficiency @12V: 81.39 %