Circuit Optimization

Overview

This paper is meant to optimize the voltage and current measurement interface of the : Isolated 3-Phase SPI Power Meter using the ADE9078 IC chipset. The optimization of the circuit takes the following into consideration: measuring AC voltage ranging from 208 to 480V and measuring AC current ranging from

Voltage Measurement Interface

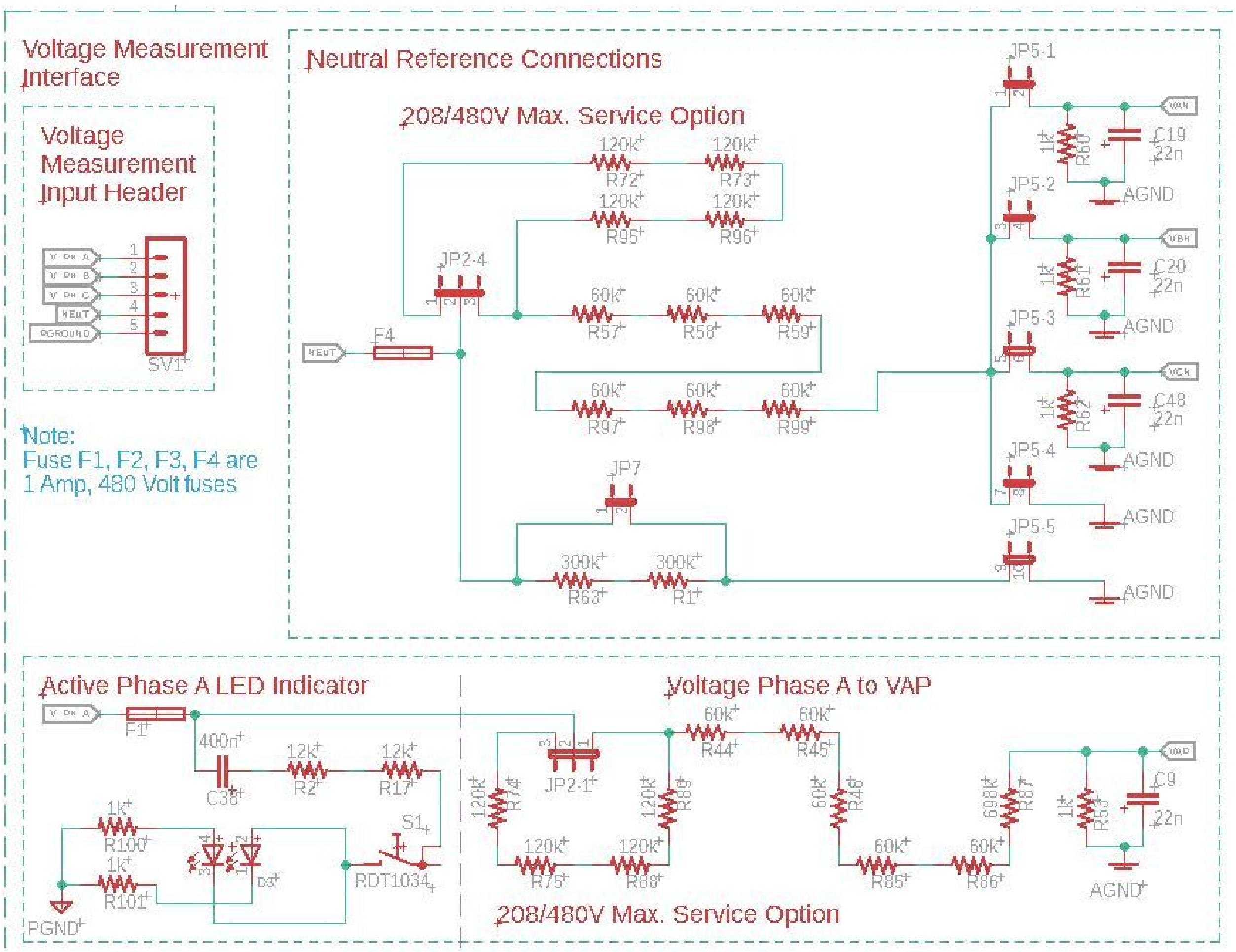


Figure 1. Eagle Schematic Revision 1.7 of Voltage Measurement Interface

*Phase B and C are omitted in Fig.1 because they are identical to the circuit of Phase A

In pages 5 of the ADE9078 datasheet, the max operating voltages on the analog input pins (VxP, VxN, IxP, and IxN) is between [-0.6 V peak , 0.6 V peak] and the differential input voltage range (VxP - VxN, IxP - IxN) is between [(-1/GAIN) , (1/GAIN)], where GAIN is the PGA Gain Settings with the following values: 1, 2, and 4. With the goal of measuring voltages up to 480 AC voltage with roughly +20% over max in case of overvoltage events, we expect the voltage measurement interface to support up to 576 AC volts (480AC * 120% = 576 AC volts).

In page 22 of the ADE9078 datasheet, with a GAIN set to 1, the differential input range is ±1 V peak (0.707 V rms). Since we have already considered a 20% overvoltage, we can expect the differential input to be +1 V peak when measuring an AC voltage of 576 VAC.

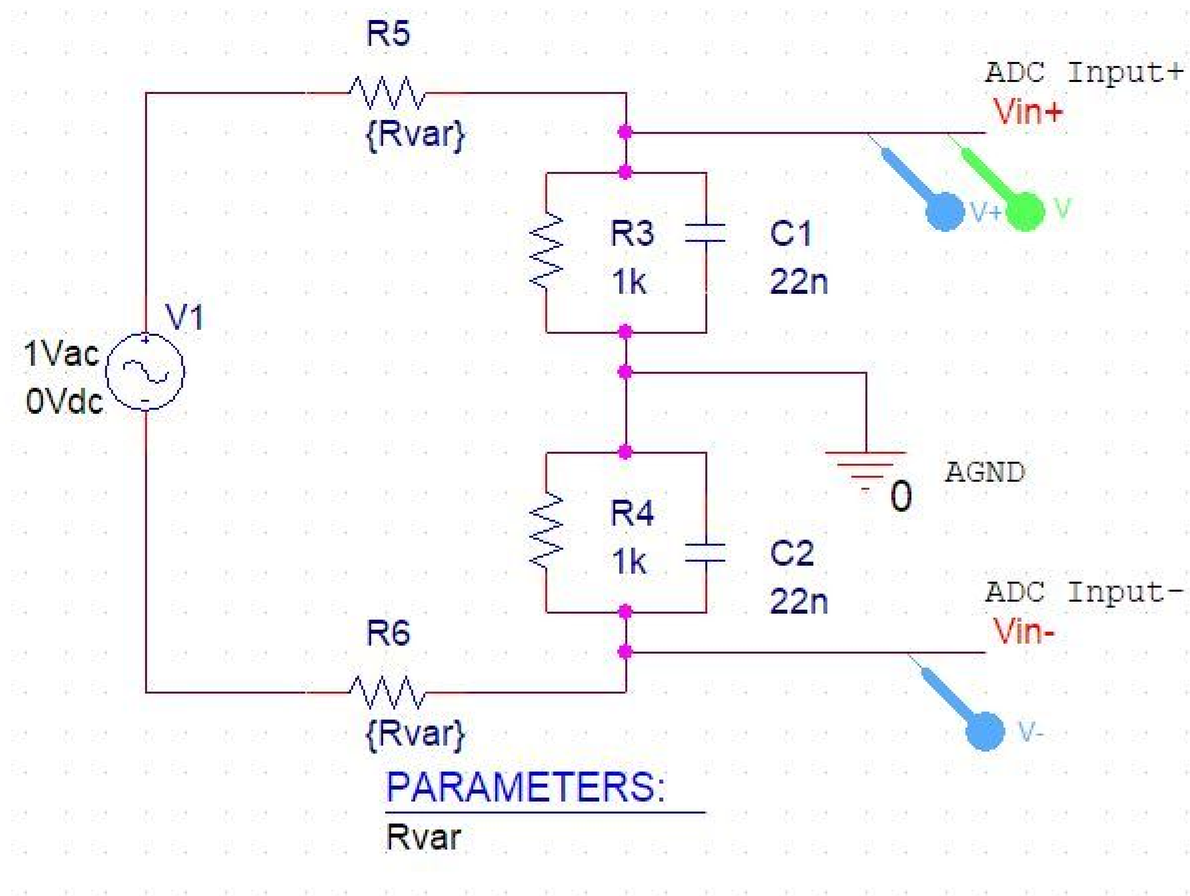
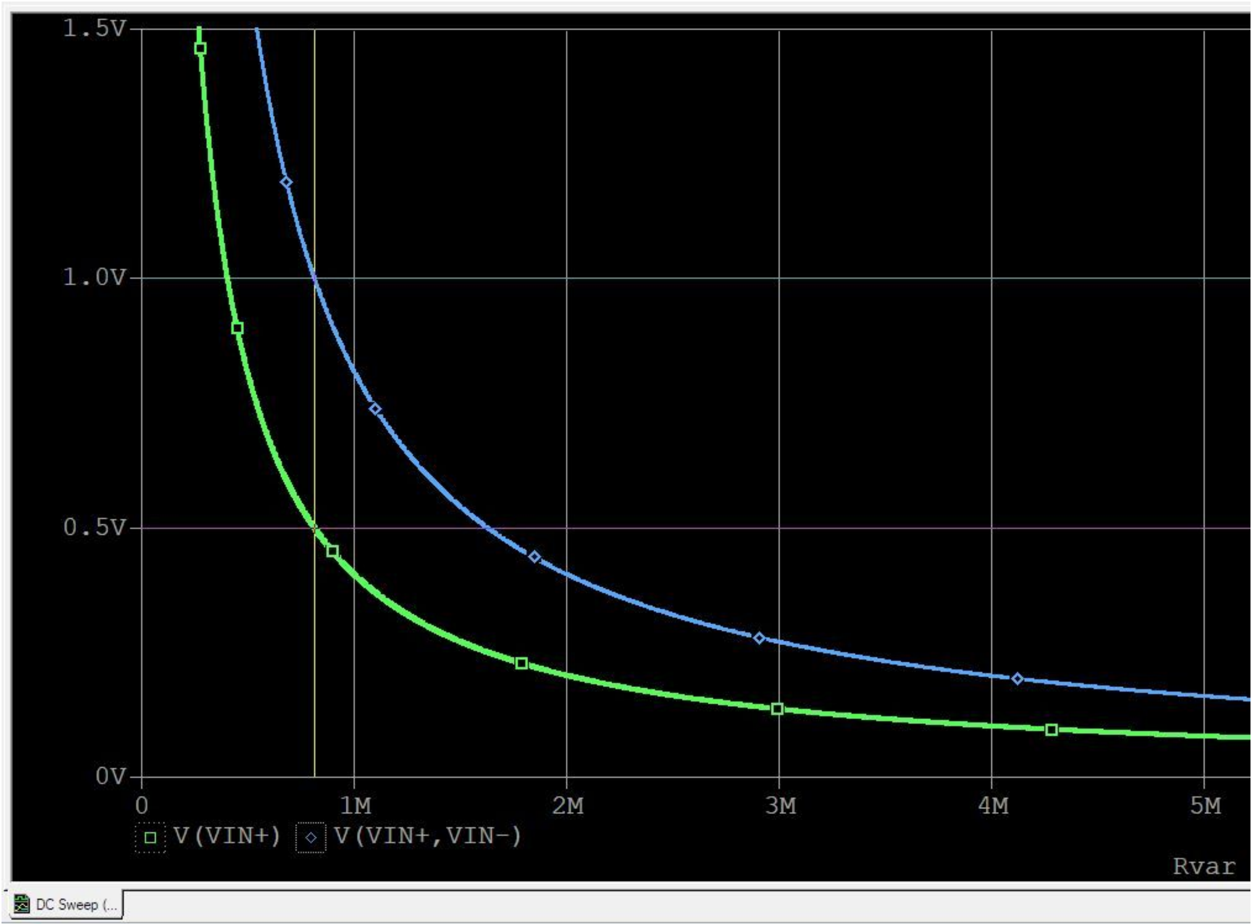


Figure 2. Simplified Schematic of Fig. 1

Using PSPICE to simulate various amount of resistors, we assume a DC sweep of the AC voltage of 480 VAC and 208 VAC because AC voltage is assumed to be an ideal sine wave that periodic. Since AC voltage refers to its V_{RMS} value, we convert V_{RMS} to V_{PEAK} using a Peak Voltage Calculator (https://www.allaboutcircuits.com/tools/peak-voltage-calculator/)

480 VAC + 20% overvoltage = 576 VAC (also V_{RMS}) = 815 V_{PEAK}
From Fig. 2, we treat the V1 as a constant V_{PEAK} of 815 Vdc and sweep R5 and R6 from 1 to 5MEG to find when the max operating voltages on the analog input pin (ADC Input+) is less

than or equal to 0.6 V peak and the max differential input voltage [(ADC Input+) - (ADC Input-)] is less than or equal to 1V.

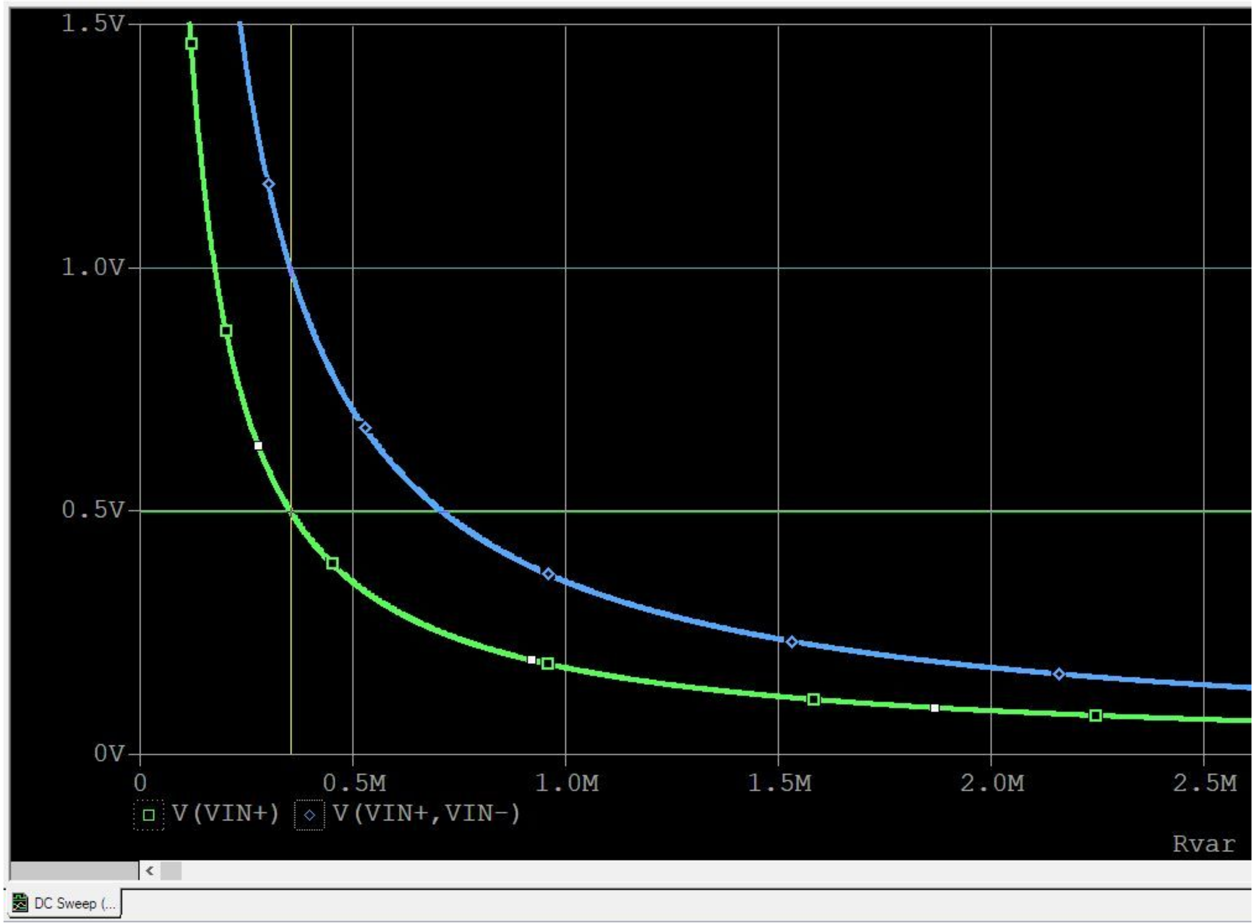


Trace Color	Trace Name	Y1	Y2	Y1 - Y2		Y1(Cursor1) - Y2(Cursor2)		500.823m		
	X Values	814.001K	815.341K	-1.3400K		Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
CURSOR 2	V(VIN+)	499.176m	499.176m	0.000		-500.823m	0.000	499.176m	499.176m	499.176m
CURSOR 1	V(VIN+,VIN-)	1.0000	1.0000	0.000		0.000	500.823m	1.0000	1.0000	1.0000

Figure 3. Finding resistance value for 480 Vac service option

At 815kΩ, the ADC Input+ (represented by the green trace) is 0.5 V peak which satisfy the condition of being less than 0.6 V peak while the differential input (represented by the blue trace) is 1 V peak which satify being at the 1 V peak operating voltage when GAIN = 1.

For the 208 AC voltage option with 20% overvoltage, V1 was set to 355 Vdc (208Vac * 120% = 250 Vac (V rms) = 355 V peak) and R5 and R6 were sweep from 1 to 5MEG to find when the max operating voltages on the analog input pin (ADC Input+) is less than or equal to 0.6 V peak and the max differential input voltage [(ADC Input+) - (ADC Input-)] is less than or equal to 1V.



Trace Color	Trace Name	Y1	Y2	Y1 - Y2		Y1(Cursor1) - Y2(Cursor2)		500.848m		
	X Values	354.302K	355.207K	-905.090		Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
CURSOR 2	V(VIN+)	498.305m	498.305m	0.000		-500.848m	0.000	498.305m	498.305m	498.305m
CURSOR 1	V(VIN+,VIN-)	0.9992	0.9992	0.000		0.000	500.848m	0.9992	0.9992	0.9992

Figure 4. Finding resistance value for 208 Vac service option

At 355kΩ, the ADC Input+ (represented by the green trace) is 0.5 V peak which satisfy the condition of being less than 0.6 V peak while the differential input (represented by the blue trace) is 1 V peak which satify being at the 1 V peak operating voltage when GAIN = 1.

Summary:

For the 480 Vac option, the sum of the resistors must be 815 kΩ while the 208 Vac option needs the sum of the resistors to be 355 kΩ which is shown in Fig. 1.

A potential add-on to the 480 Vac option is to use the GAIN setting of 2 and 4 to measure for 240 Vac and 120 Vac, respectively. In page 22 of the ADE9078 datasheet, the GAIN can be set higher to restrict the max differential input to 0.353 V rms (0.5 V peak) when GAIN is set to 2 or 0.1765 V rms (0.25 V peak) when GAIN is set to 4. So if we want to measure for 240 Vac, then we can use the 480 Vac service option in Fig. 1 with a GAIN of 2 in the firmware side to measure for 240 Vac with 20% overvoltage head room. The same can be said about 120 Vac as well with a GAIN of 4. This potential add-on needs to be further studied with the datasheet to see if the GAIN setting affects accuracy or would cause an issue.

Active LED values:

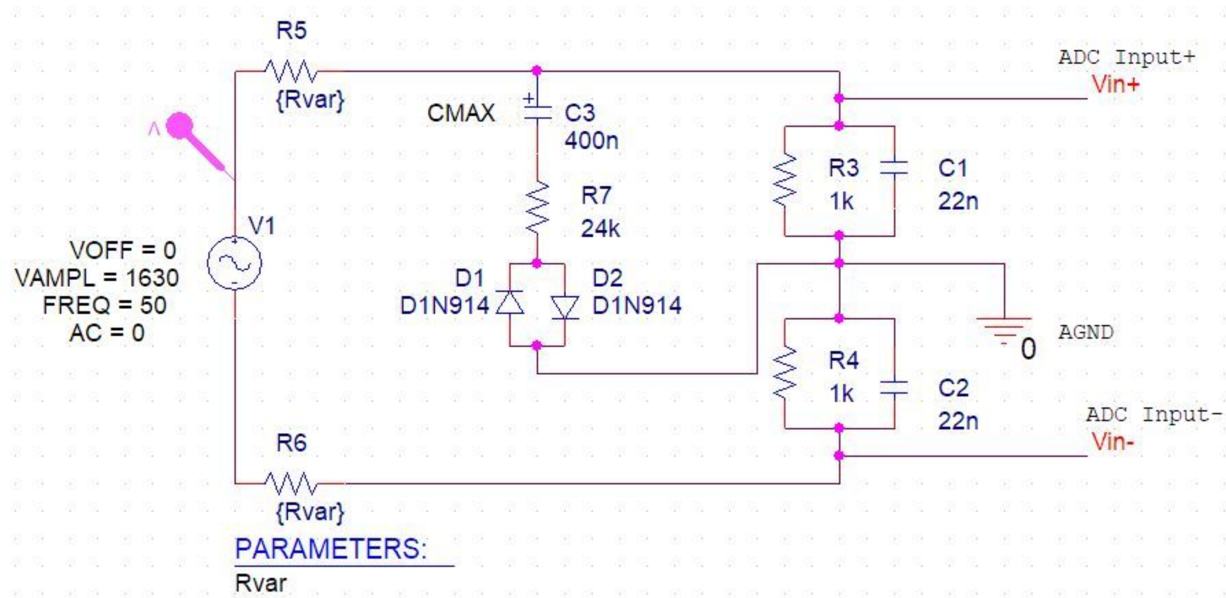
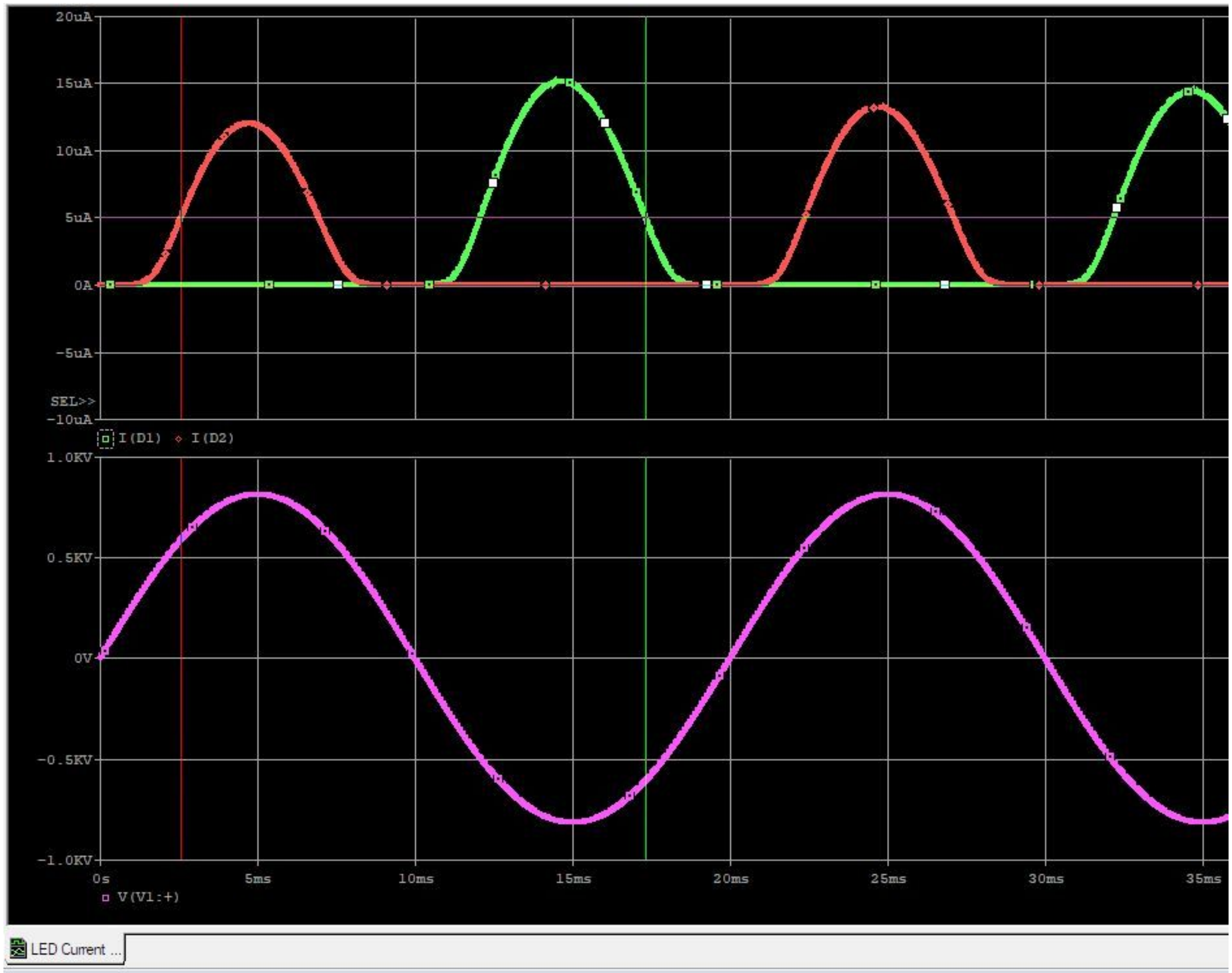


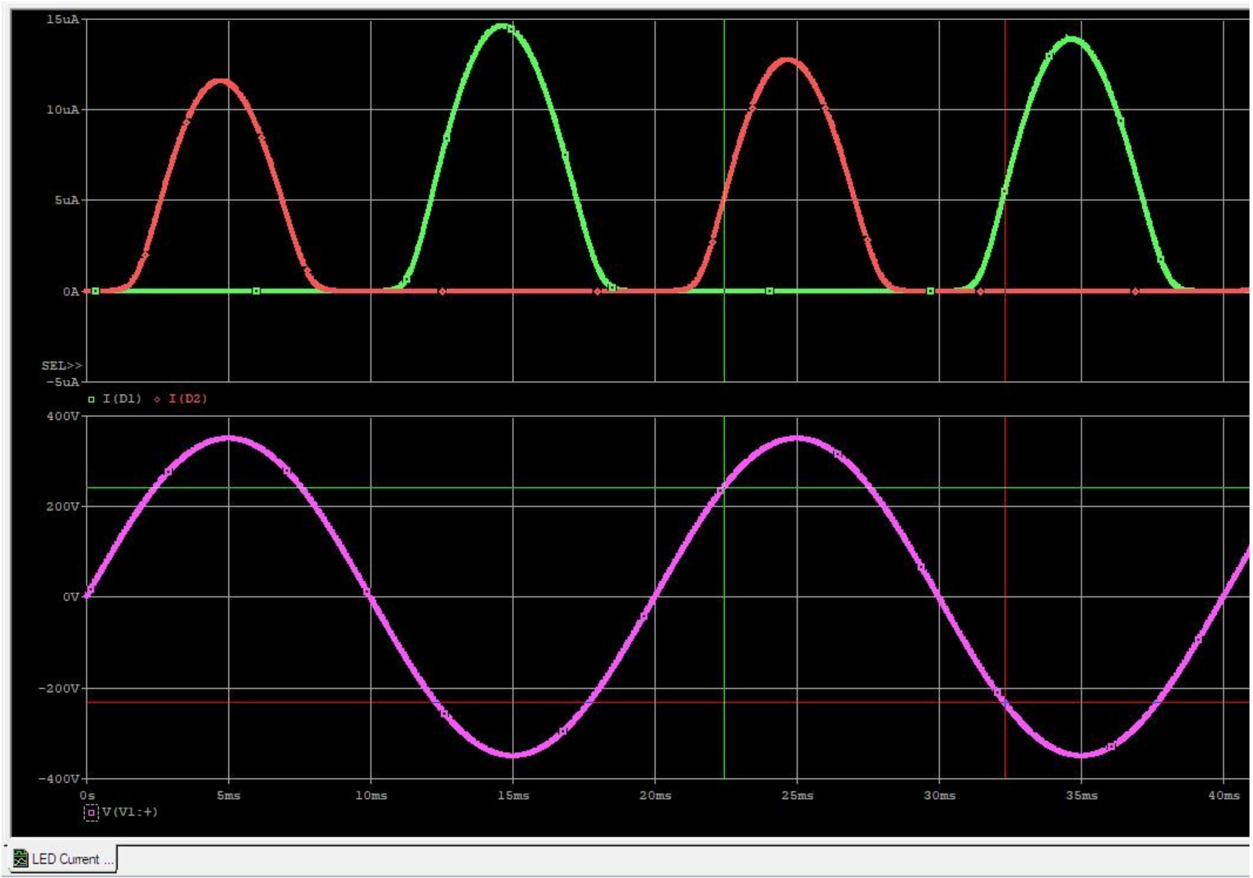
Figure 5. LED Schematic



Trace Color	Trace Name	Y1	Y2	Y1 - Y2		Y1(Cursor1) - Y2(Cursor2)		-5.0539u		
	X Values	2.5687m	17.310m	-14.741m		Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(V1:+)	586.813	-609.715	1.1965K		586.813	-609.715	586.813	-609.715	-11.451
CURSOR 1,2	I(D1)	-335.964p	5.0535u	-5.0539u		0.000	0.000	5.0535u	-335.964p	2.5266u
	I(D2)	4.9494u	104.661p	4.9493u		4.9498u	-5.0534u	4.9494u	104.661p	2.4748u

Figure 6. LED indicator for 480 Vac option (R = 815kΩ)

For the Active LED Indicator for the 480 Vac, the 480 Vac with 20% overvoltage was simulated with as Vpeak of 815V with a 50Hz (60Hz is also an option, but seeing the max and min line up at every 10ms is easier for observations). In order to aim the max of 15 uA, the capacitor was set to 400n and resistor is set to 24kΩ for the LED to turn on around 600 V peak which is 420 Vac.

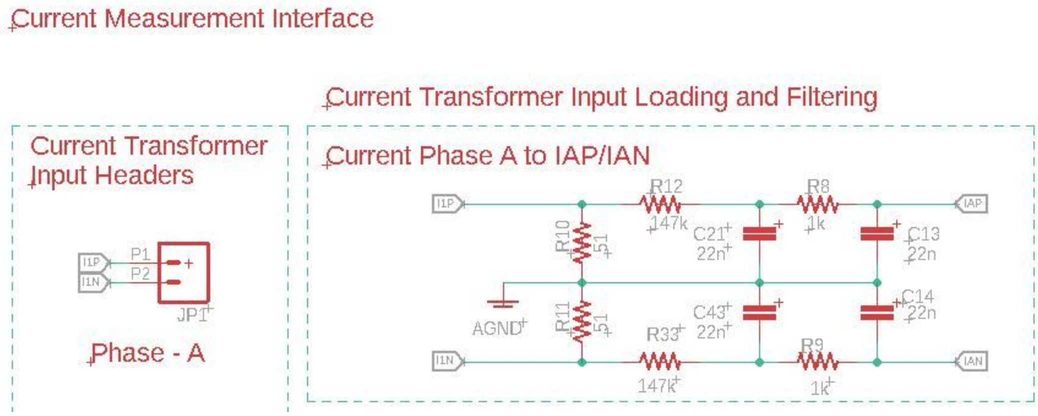


Trace Color	Trace Name	Y1	Y2	Y1 - Y2		Y1(Cursor1) - Y2(Cursor2)		-475.232		
	X Values	32.314m	22.438m	9.876m		Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
CURSOR 1,2	V(V1:+)	-232.613	242.619	-475.232		0.000	0.000	242.619	-232.613	5.0030
	I(D1)	5.4578u	-338.182p	5.4581u		232.613	-242.619	5.4578u	-338.182p	2.7287u
	I(D2)	-335.405p	5.0971u	-5.0974u		232.613	-242.619	5.0971u	-335.405p	2.5484u

Figure 7. LED indicator for 208 Vac option (R = 355kΩ)

For the Active LED Indicator for the 208 Vac, the 208 Vac with 20% overvoltage was simulated with as Vpeak of 350 V with a 50Hz. In order to aim the max of 15 uA, the capacitor was set to 400n and resistor is set to 24kΩ for the LED to turn on around 235 V peak which is 167 Vac.

Current Measurement Interface



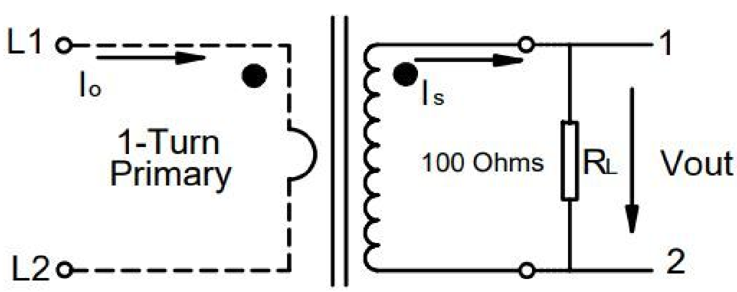
Assume that we are using the 20A Current Transformer with 1000:1 turns

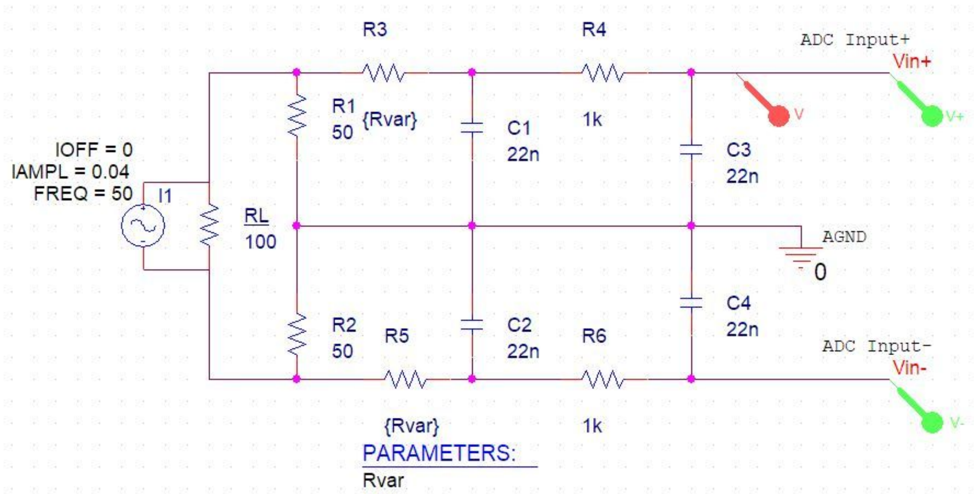
Same guideline / restrictions here:

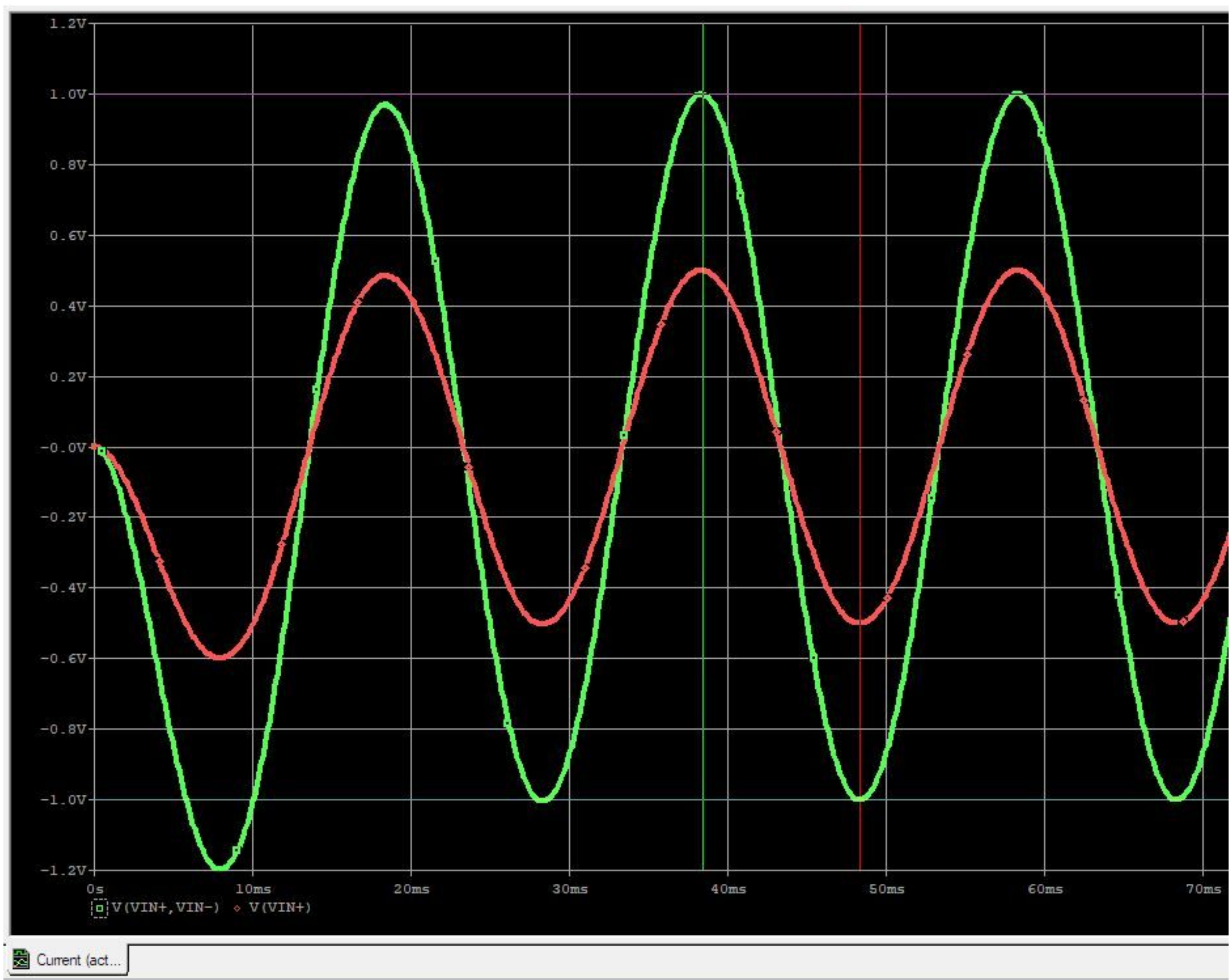
IAP, IAN, IBP, IBN, ICP, ICN, VAP, VAN, VBP, VBN, VCP, and VCN| ≤ 0.6 V peak relative to AGND
|IxP − IxN| ≤ 1 V peak, |VxP − VxN| ≤ 1 V peak

This time, we need to see (Vin+) - (Vin-) < 1 Vpeak
Add to graph to verify this because the picture for current only has Vin+ < 0.6

Need to read on datasheet of CT that we are using however to see some changes onto the voltage sweep.
https://www.alliedelec.com/triad-magnetics-cst-1020/70218007/
Up to 20A can be used for the primary current which steps down by 1000:1 so highest amps would be 20 mA
CT has a burden resistance of 100 Ohm







Trace Color	Trace Name	Y1	Y2	Y1 - Y2		Y1(Cursor1) - Y2(Cursor2)		-1.9991		
	X Values	48.334m	38.430m	9.905m		Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
CURSOR 1,2	V(VIN+,VIN-)	-1.0002	0.9989	-1.9991		0.000	0.000	0.9989	-1.0002	-663.547u
	V(VIN+)	-500.111m	499.447m	-0.9996		500.111m	-499.447m	499.447m	-500.111m	-331.774u

I am not sure if the first 10ms would affect the ADC range with 147 kΩ, but this would be the best way to have the largest ADC differential input of 1 V peak with 20A max.